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June 1991

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FILING INSTRUCTIONS

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VOLUME:	Newsletters
TAB:	European Newsletters
FILING INSTRUCTIONS:	File this newsletter behind the European Newsletters tab in reverse chronological order.

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FILING INSTRUCTIONS

TITLE:	Dataquest's Outlook For 1990 and 1991: Slowing But Positive Growth
AUTHOR:	Nancy Stewart Gene Norrett
VOLUME:	Newsletters
TAB:	Other Newsletters
PAGES:	5
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September 1990

TECHNOLOGY INFORMATION DIVISION
FILING INSTRUCTIONS

TITLE:	Technology Stocks Fall To Bargain Basement Levels--So What?
AUTHOR:	Bernadette Cesena Frederick Zieber Ralph Finley
VOLUME:	Newsletters
TAB:	Other Newsletters
PAGES:	5
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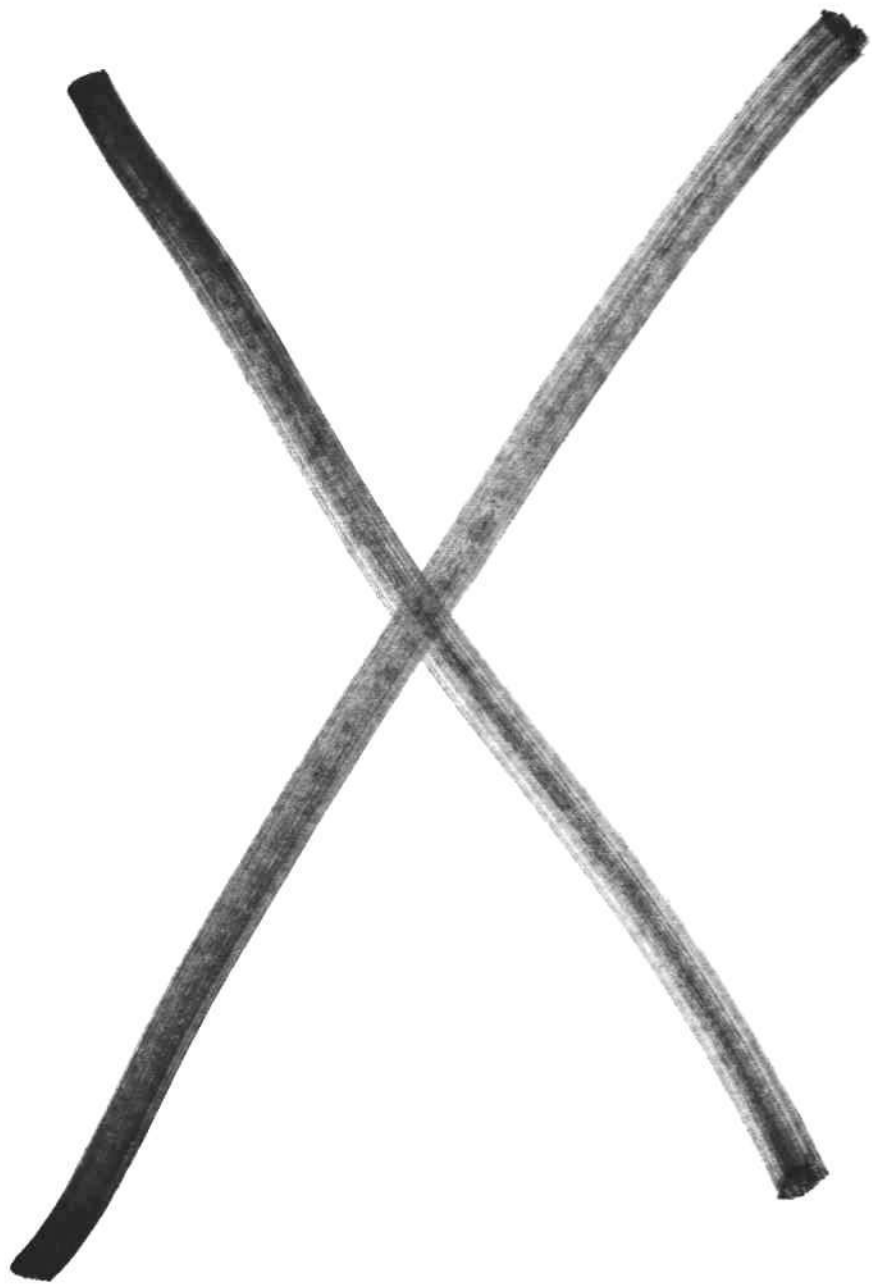
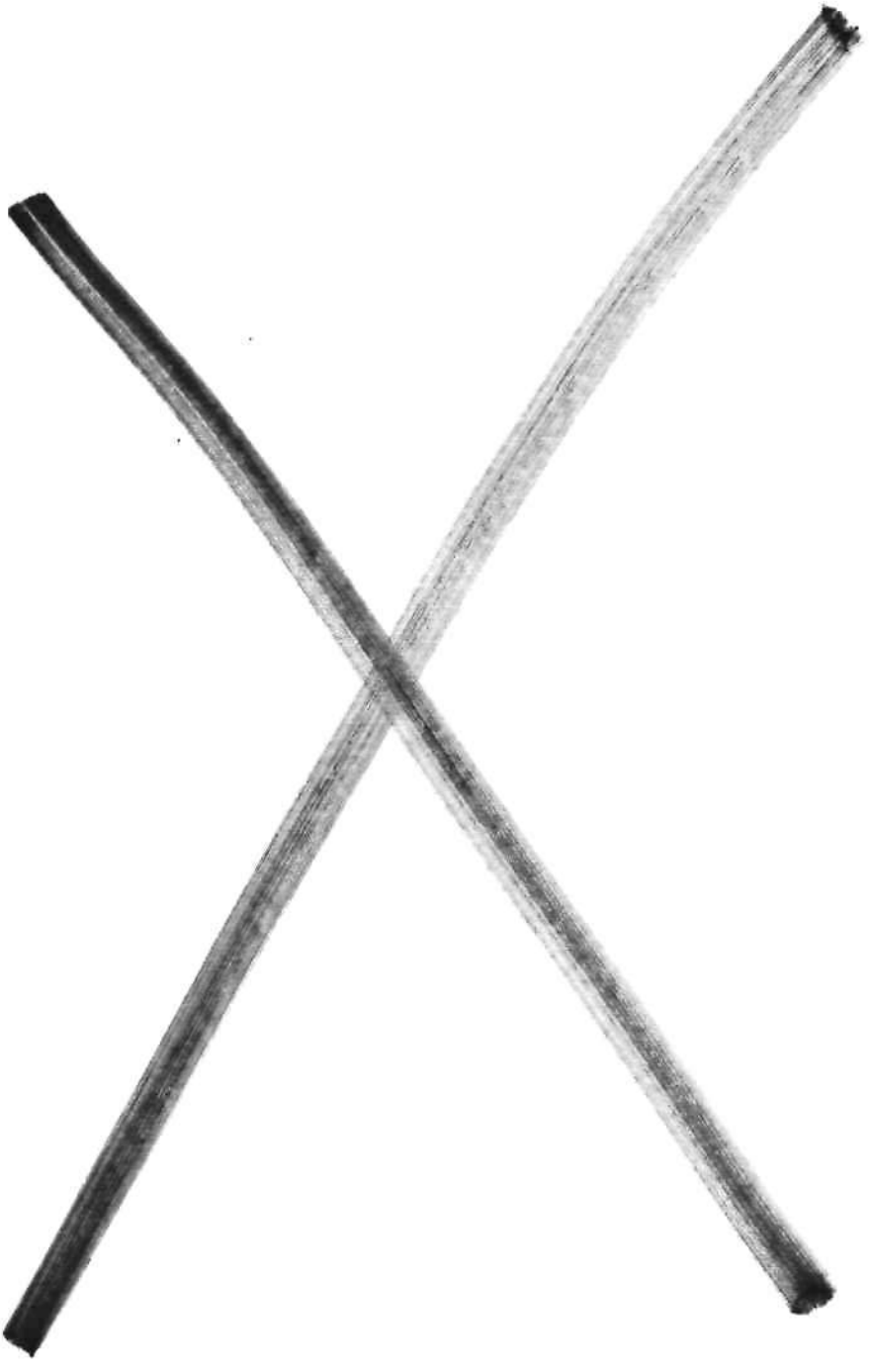
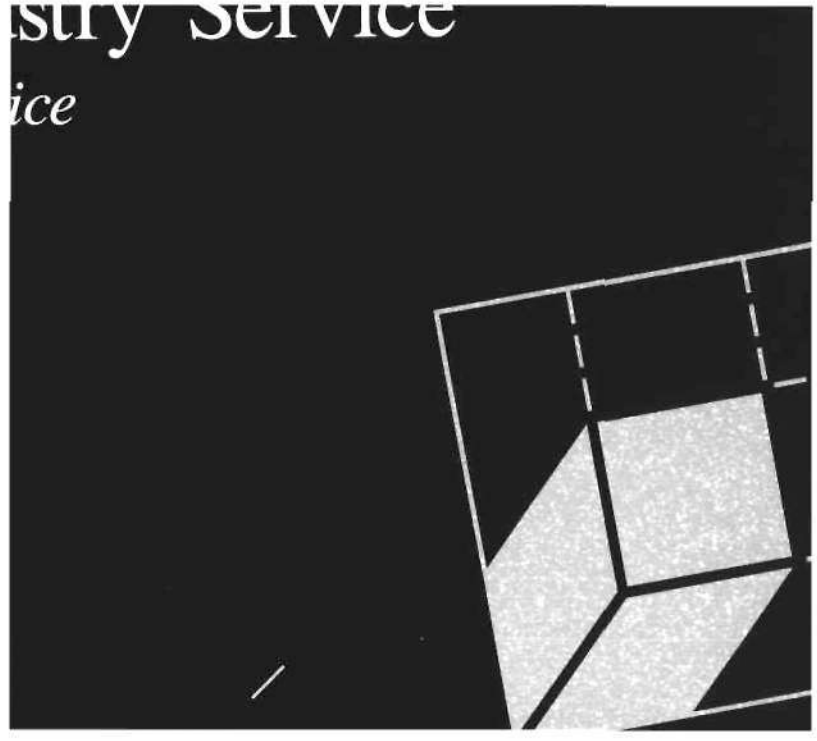
NEWSLETTER TITLE & NUMBER	GENERAL	MECHANICAL	EDA	FD & M
1988				
Facilities				
1 Geographic Information Systems....				X
2 A/E/C Systems '88: PC CAD Takes On Volcanic				X
General				
1 Japanese Technical Workstation Market	X			
2 CAD/CAM Monthly Events - December	X			
3 Object-Oriented Data Bases:	X			
4 CAD/CAM 1987--No Major Surprises	X			
5 CAD/CAM Monthly Events - January	X			
6 Prime Buys Computervision...	X			
7 Navy CAD/CAM II Acquisition Update	X			
8 "Interoperability" In The CAD Environment	X			
9 Apollo Joins The Fray Ushering In The Graphics	X			
10 CAD/CAM Monthly Events - February	X			
11 CAD/CAM Monthly Events - March	X			
12 A Command Performance: AUTOCAD On The MAC	X			
13 1987 CAD/CAM Vendor Survey: Revenue Growth...	X			
14 CAD/CAM Monthly Events - April	X			
15 Apollo On Fire Rides Into Third Quarter's...	X			
16 Monthly Events - May	X			
17 Monthly Events - June	X			
Electronic				
1 Gate Arrays: Intense Battleground			X	
2 Logic Design Automation: The Next Generation			X	
1987-				
37 CAD/CAM Monthly Events - November	X			
36 Autofact 1987		X		
35 AI-Based Input Devices Lead The Way...		X		
34 Perspectives On M&A In EDA:...			X	
33 CAD/CAM Index--September Quarter	X			
32 CAD/CAM Monthly Events - Oct.	X			
31 Navy Update: Don't Give Up The Ship	X			
30 The Far East CAD/CAM Market 3rd Quarter	X			
29 CIM Takes A Step Closer To Realization...		X		
28 Sun and Cadnetix Sign On The Line			X	
27 CAD/CAM Monthly Events	X			
26 European Trade Shows--Confusion or Consensus?	X			
25 1987 Mechanical CAD/CAM System Manager Survey		X		
24 Uncle Sam: The Major Major Account	X			
23 CAD/CAM Monthly Events	X			
22 3-D Graphics: Shifting Into High Gear	X			
21 Design Verification			X	
20 Design Environments & Integration			X	
19 CAD/CAM Index--June Quarter	X			
18 Business As Usual At The 1987 DAC: ...(EDA)			X	
17 IBM Personal System/2: ...	X			
16 PCs & Workstations Battle For The ...	X			
15 Gate Array Suppliers Position For The Future			X	
14 1986 Japan CAD/CAM User Survey	X			
13 Silicon Compiler Companies Merge ...			X	
12 CAD or GIS For Mapping: URISA Conference				X
11 1987 CAD/CAM User Survey Results	X			
10 The Navy is Cutting Bait ...	X			

09	The Missing Link: Instant 3D Hard Copy		X	
08	Valid Targets PCB Market—Acquires Telesis			X
07	Electronic CAD/CAM End-User Survey:			X
06	Surface Mount Technology: The Opportunity			X
05	Technical Workstations—Explosive Mrkt Growth	X		
04	Dataquest's EDA Focus Conference:			X
03	The 1986 Dataquest Semiconductor Industry Conf.			X
02	Customer Service—The Key to Corporate Commit.	X		
01	Reality Versus Hype: The Impact of the Intel	X		



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CAD/CAM Industry Service

Introduction to the Service

Dataquest

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Introduction to the CAD/CAM Industry Service

Welcome to the CAD/CAM Industry Service

As the CAD/CAM industry matures, with the compound annual growth rate (CAGR) slowing to the 8 percent range as we enter the nineties, the decision-making process is becoming increasingly more complex for CAD/CAM professionals.

Significant mergers and acquisitions and general market attrition have dramatically changed the competitive nature of the CAD/CAM industry over the past two years. Now more than ever a need persists for information on a global scale. A resource that can offer comprehensive worldwide research and analysis of the markets, products, trends, technologies, and participants in the CAD/CAM industry is an essential ingredient to the development of sound product and marketing strategies in the wake of this industry shakeout.

Dataquest's CAD/CAM Industry Service (CCIS) is that resource.

CCIS provides clients with qualitative insight into integral issues and trends that develop in the CAD/CAM industry. Qualitative analysis is supported by extensive quantitative data on shipments, installed base, forecasts, history, market shares, market segmentation, and company performance. Exhaustive research provides all levels of personnel at our client companies with the information and analysis they require to make informed, timely business decisions.

For example, CCIS provides tools to help you do the following:

- Identify effectively the most appropriate target markets
- Gain a realistic understanding of end-user requirements
- Analyze the effect of contributing technology trends on your future product plans
- Evaluate competitors' marketing strategies and product offerings
- Position your products properly in relation to your competitors

CCIS has a highly professional research staff with an in-depth background in the CAD/CAM industry and research techniques. Augmenting the skills of the CCIS staff are the resources of other Dataquest syndicated services. Worldwide dedicated research in more than 25 technology areas enables Dataquest to provide an unparalleled picture of the total electronics industry. In addition, Dataquest brings to bear the vast resources of its parent company, information industry giant Dun & Bradstreet. Through its

relationship with D&B, Dataquest is uniquely positioned to assess the impact of external influences such as economic, political, and monetary trends that may effect the electronics industry.

Service Structure

Dataquest's CAD/CAM Industry Service has two major components: the core (or general) service and the application-specific segments. The service has been structured in this manner to provide clients with both a comprehensive overview of the CAD/CAM industry and an in-depth vertically focused view of the primary application markets.

Core Service

The core service represents a macro view of the entire CAD/CAM market, with information and analyses relevant to all CAD/CAM industry participants. Core service is rendered by a staff of industry and research experts. The core service is provided to all CCIS clients. It consists of the following elements:

- **Industry overview data base notebook.** This notebook contains analyses of the macro industry parameters, including summaries of the major CAD/CAM market segments. (Forecast data bases are also available to clients in electronic format upon request.)
- **Research Studies.** Research studies are event-driven publications that provide a continual flow of timely information and analyses on major industry events and issues.
- **Inquiry privilege.** This feature is designed to meet the unique information needs of each client, enabling the client to communicate directly with the CCIS research staff. Through this vehicle, questions concerning information in the data base notebooks, the impact of new product announcements, technical trends, and issues that will affect the general business environment, are addressed on a timely basis. Inquiries can be made in person or via telephone, fax, or telex.
- **Industry conference.** An annual conference brings together industry decision makers to review the state of the CAD/CAM industry and to discuss major issues in an open forum. Clients are entitled to one free conference seat, and seats must be reserved in advance.
- **Research libraries.** Clients have access to Dataquest's extensive libraries offering a broad range of reference materials in our San Jose, Boston, London, Paris, Munich, and Tokyo offices.
- **CAD/CAM industry directory.** Clients receive one free copy of the annually updated directory containing pertinent information on more than 600 CAD/CAM suppliers and their products.
- **Demographics and economic reports.** These reports present in-depth analyses of external influences on the electronics industry.

- **International support.** International support is provided through access to the Dataquest research staffs in our London, Paris, Munich, and Tokyo offices.

Application-Specific Segments

The application-specific segments are available to CCIS clients who need detailed information on a specific CAD/CAM application market. The following application segments are available:

- Mechanical CAD/CAM (MCAD)
- Electronics Design Automation (EDA)
- Facilities Design and Mapping (FD&M)

Each segment contains information and analyses particular to the specific application, including research studies and other event-driven publications, market overview, detailed market segmentation, forecasts, market shares, both vendor and end-user surveys, and specialized research reports. Each application segment is supported by a staff of CCIS analysts with experience in the specific application.

Detailed analyses and data are provided down to the design phase within each application specific segment. The following design phases are covered within the respective segments:

- **Mechanical CAD/CAM (MCAD)**
  - MCAE
  - Drafting
  - Design
  - FEM/FEA
  - Numerical control
  - Solid modeling
  - Process simulation
- **Electronic Design Automation (EDA)**
  - ECAE
  - IC
  - PCB
  - Compilation
  - Test
  - Logic design automation
  - Simulation

- **Facilities Design and Mapping (FD&M)**
  - Architectural
  - Facilities management
  - Process design
  - Mapping
  - Geographic information systems
  - Structural
  - HVAC and piping

CCIS also provides three additional information segments:

- **European Markets.** The European Markets segment provides the country-by-country data and analyses required to effectively penetrate the markets of Europe. European Markets offers insight into the market-specific parameters, coupled with an in-depth review of the government, trade, and economic forces that shape the European marketplace. Detailed information and analyses are available for the following regions:
  - United Kingdom
  - France
  - Italy
  - German region
  - Scandinavia
  - Benelux
  - Rest of Europe
  - Total Europe
- **Asian Markets.** The Asian Markets segment offers comprehensive coverage of the fastest-growing, yet most complicated, marketplace in the world. Similar to the European Market segment (and its coverage of the markets of Europe), the Asian Markets segment provides in-depth coverage of the dynamics of the individual markets that make up Asia. Detailed information and analyses are available of the following regions:
  - Japan
  - Taiwan
  - Korea
  - Singapore

- — Hong Kong
- — China
- — Rest of Asia
- — Total Asia

- **Personal CAD: Markets at the Low End.** With the dramatic decline in CAD/CAM workstation selling prices, the continued blurring of the distinction between a personal computer and a technical workstation, and the realization by traditional turnkey vendors of the necessity of offering a scalable solution, the market for low-end CAD/CAM solutions (under $15,000) has experienced explosive growth.

  As the price of low-end turnkey systems drops below the $15,000 mark, it will become increasingly difficult to profitably sell low-end solutions utilizing traditional sales channels. This is a challenge that all turnkey vendors currently are, or soon will be, facing. It is imperative that all vendors understand the complexities and competitive nature of the new low-end markets and delivery mechanisms. The Personal CAD segment will help you to confront the distribution challenges of the low end and to understand thoroughly the competitive pressures being exerted by PC-based solutions that offer competitive performance capabilities.

Figure 1 shows the total CAD/CAM Industry Service segmentation.

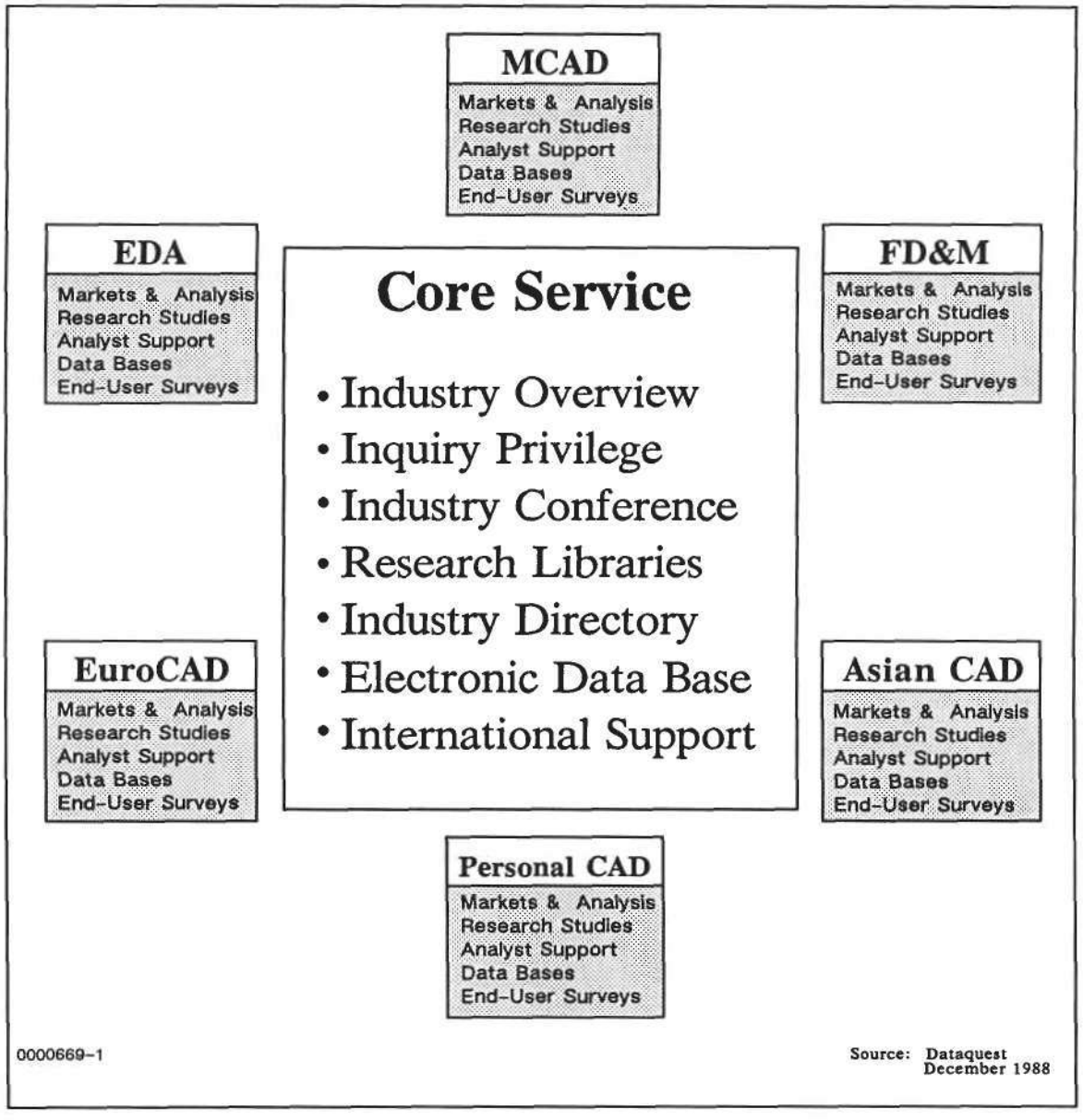

Figure 1. Total CAD/CAM Industry Service segmentation

Information Structure

The information available to CAD/CAM Industry Service clients is structured to provide data and analyses that are easily accessible and clearly defined. Figure 2 illustrates the CCIS information model. The components of the information model are defined on a macro level in the Industry Overview Data Base Binder and on an application-specific basis in each of the respective application segments.

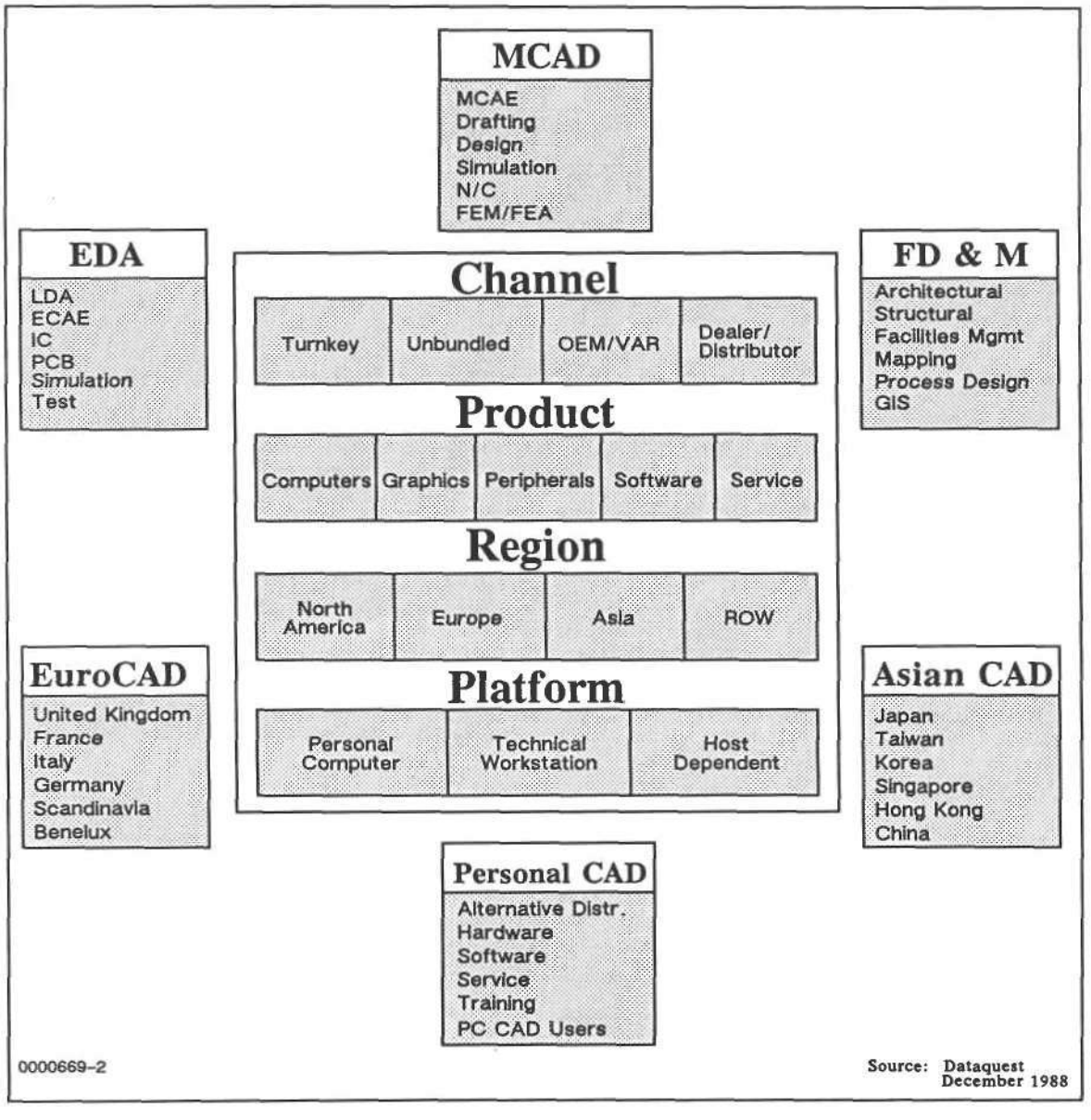

Figure 2. CCIS information model

Channel

Channel, the first of the data base models, identifies how CAD/CAM systems ultimately reach the end user. This tier will help you distinguish the various distribution channels and marketing arrangements used to bring products to market. These include the following:

- **Turnkey.** The turnkey channel encompasses the sale of complete CAD/CAM systems. A complete system is defined as CPU, graphics device, operating system, application software, and basic peripherals.

Turnkey vendors also typically offer complete service, training, and maintenance programs for the systems they sell.

- **Unbundled.** The unbundled channel comprises the sale of CAD/CAM system components, such as application software or hardware, sold independently of one another. Unbundled components may be sold by either a company that specializes in that particular component, such as a software-only company or a computer manufacturer, or by a turnkey vendor selling its software independent of the system.
- **OEM/VAR.** The original equipment manufacturer (OEM) and the value-added reseller (VAR) channel consist of companies that sell their products to other companies for resale. Resale may be to another tier in the distribution channel or to the ultimate end user. An example of companies in this tier are the computer manufacturers that sell their systems to turnkey vendors, who then bundle the hardware with applications software and resell the computers to end users.
- **Dealer/Distributor.** This growing channel is made up of a group of companies that resell products developed by other companies. Although not limited to personal computers, the majority of CAD/CAM products moving through this channel reside on this platform.

Product

The product tier tracks the dollar volume of sales from major subsystems of a turnkey CAD/CAM system. Subsystems covered include the following:

- Computers
- Graphics terminals
- Peripherals (such as plotters and printers used in CAD/CAM applications)
- Application software
- Service

In addition to dollar volume, unit volume is also identified for the computer and graphics terminal segments.

Region

The regional segment of the CAD/CAM Industry Service data base defines four regions into which CAD/CAM systems are sold. This segmentation will aid in your understanding of the geographic characteristics of the global CAD/CAM industry. The following geographic regions and regional segmentation are covered:

- North America
  - United States

  - Canada
  - Mexico
- **Europe**
  - United Kingdom
  - France
  - German region
  - Italy
  - Benelux
  - Scandinavia
  - Rest of Europe
- **Asia**
  - Japan
  - Taiwan
  - Korea
  - Singapore
  - Hong Kong
  - People's Republic of China (PRC)
- **Rest of World (ROW).** This segment includes the sale of CAD/CAM systems into categories not included in the North American, European, or Asian regions.

Platform

Platform segmentation identifies three major architectures being delivered into the CAD/CAM market. This segmentation will help you understand the trends related to the type of systems being purchased.

The three types of systems are personal computers, technical workstations, and host-dependent systems. The major distinction among these product types is that personal computers and technical workstations contain their own CPUs and operating systems and therefore are classified as being fully distributed systems. Host-dependent systems, however, are considered shared-logic systems because their CPUs and operating systems are used as shared resources. For counting purposes, Dataquest treats personal computers and technical workstations as both CPU units and workstation units. This approach allows comparison between total distributed versus shared-logic CPUs, along with comparison of the total number of workseats that reside in the personal computer and technical workstation class versus total seats on

host-dependent systems. Platforms are further distinguished by the following characteristics:

- **Personal computer**
  - DOS, OS/2, or OS operating system
  - Single processing capability
- **Technical workstation**
  - Resident operating system
  - Full virtual operating system, such as UNIX or VMS
  - Multitasking
  - Networked communications support
  - Integrated graphics
- **Host dependent**
  - CPU external from the workstation
  - No local operating system at the workstation level
  - Conditioned environment requirement

Forecasting Methodology

Fundamental to the way Dataquest conducts its research is an underlying philosophy that says the best data and analyses come from a wellbalanced program. This includes balance between primary and secondary collection techniques; balance between supply-side and demand-side analysis; balance between focused, industry-specific research and coordinated, "big picture" analysis aided by integration of data from the more than 25 separate high-technology industries Dataquest covers; and balance between the perspectives of experienced industry professionals and rigorous, disciplined techniques of seasoned market researchers.

The CAD/CAM industry market estimates and forecasts are derived using the following research techniques:

- **"Bottom up" aggregation.** This method involves adding all relevant vendor contributions to arrive at total market estimates for all historical data.
- **Segment forecasting.** For each application segment tracked by CCIS, individual forecasts are derived following the basic information model defined previously. Specifically, each design phase covered within each application is segmented by channel, product, region, and platform. In this way, each application segment incorporates its own set of unique assumptions.
- **Demand-based analysis.** Market growth is tracked and forecast in terms of the present and anticipated demand of current and future

users. This requires the development of a total available market (TAM) model and a satisfied available market figure to accurately assess the levels of penetration. In addition, Dataquest analysts factor in the acceptance or ability for users to consume new technology.

- **Capacity-based analysis.** This method involves identifying future shipment volume constraints. These constraints, or "ceilings," can be the result of component availability, manufacturing capacity, or distribution capacity. In any case, constraint is capable of keeping shipments below the demand level.

Dataquest's revenue and shipment estimates are based on the following sources:

- Information supplied by company management or gathered from publicly available published sources
- Large-scale end-user surveys
- Information supplied by other Dataquest industry services relating to components/ subsystems of CAD/CAM
- Information provided by OEMs or resellers of the manufacturers' products
- Senior staff estimates based on reliable historical data and in-depth understanding of a company's products and strategies

CCIS data are based on revenue and unit data of systems sold to end users. Rigorous cross-checking is undertaken to assure that no double counting exists in our unit and revenue numbers. To augment your understanding of the information structure, we offer these caveats regarding the interpretation of the data:

- Certain assumptions, definitions, or conventions implicit in our forecasts may differ from those of others. Please refer to our Industry Overview and Application notebooks for definition of forecasting terms, and analysis and interpretation of the data.
- Our shipment estimates of systems and workstations include only those delivered to paying customers, not the total that is manufactured (the backlog).
- Revenue and average selling price estimates are based on transaction prices, not on list prices.
- All data elements have been adjusted to reflect the forecast period, which is the calendar year.
- Manufacturers do not release their actual unit sales, application distribution, geographic distribution, or platform distribution. In order to provide our clients with the most accurate forecasts, we have given careful consideration to estimating these companies' data.

- Prior to 1983, Dataquest did not segment revenue geographically other than into U.S. and non-U.S. markets. To accommodate the expanded geographic segmentation, we added all non-U.S. data into the ROW segment for 1981 and 1982.
- Prior to 1983, Dataquest did not differentiate products based on hardware type. To accommodate our expanding platform segmentation, we have grouped all platforms prior to 1983 into the host-base category. Although not all systems shipped prior to 1983 were of the host-based variety, the vast majority were.

Figure 3 is a pictorial summary of the information compendium offered by the Dataquest CAD/CAM Industry Service.

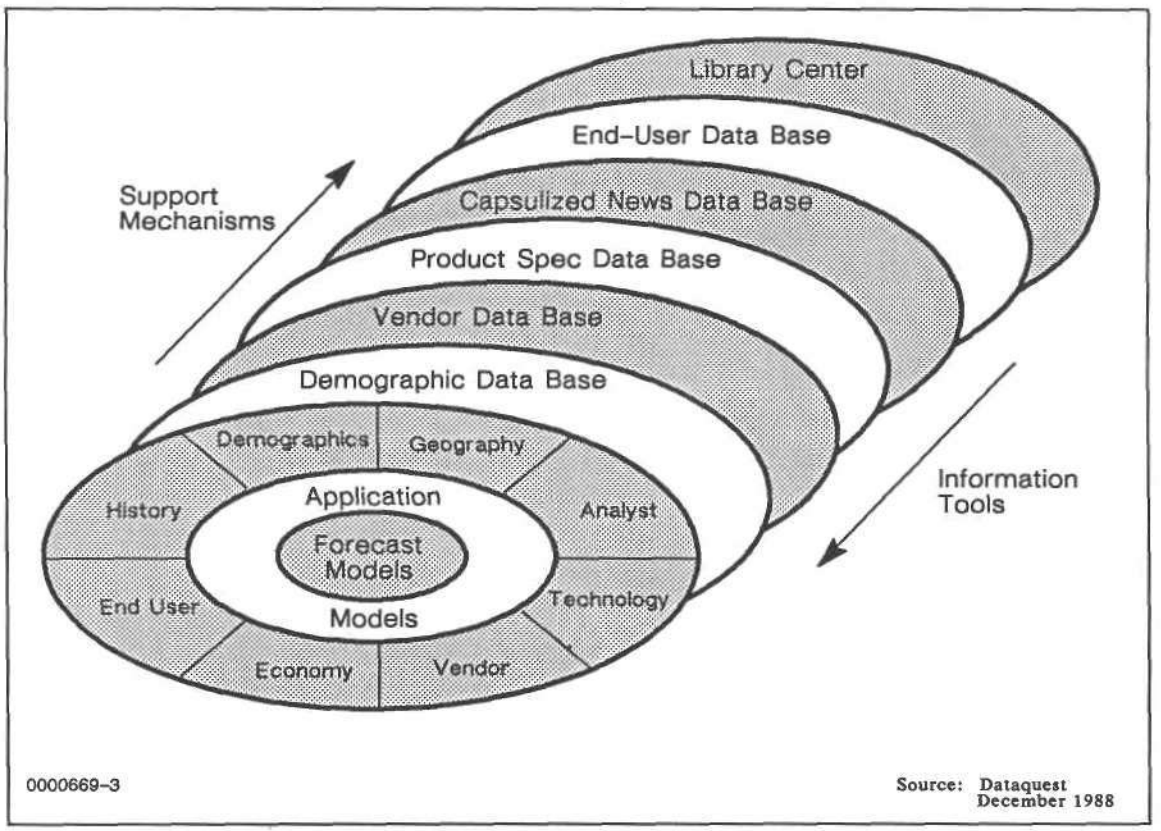

Figure 3. A pictorial summary of the information compendium offered by the Dataquest CAD/CAM Industry Service

Companies

CCIS continues to expand the number of companies included in our forecast model. The model consists of two groups of companies: those listed individually, or "main companies," and those consolidated into the "other" category. A company is listed individually only if its total CAD/CAM end-user revenue is $15 million or more. Conversely, a company is in the "other" category if its total CAD/CAM end-user revenue is less than $15 million.

Main Companies

- Apollo Computer
- Apple Computer
- Asahi Optical
- Autodesk
- Auto-Trol
- C. Itoh Techno-Science
- CADAM
- CISIGRAPH
- Cadnetix
- Calay Systems
- Calma
- Cimlinc
- Compaq Computer
- Computervision
- Control Data
- Daisy Systems
- Dassault Systems
- Digital Equipment
- ECAD
- ESRI
- Exapt
- Ferranti Infographics
- Fujitsu
- Futurenet
- Gerber Systems
- Hewlett-Packard
- Hitachi
- Hitachi Zosen
- Holguin
- IBM
- ICL
- ISICad
- Info. Services Int'l. Dentsu
- Intergraph
- ItalCAD
- MacNeal-Schwendler
- Matra Datavision
- McDonnell Douglas
- Mentor Graphics
- Mitsubishi Electric
- Mutoh Industries
- NEC
- Nippon Univac Kaisha
- Norsk Technovision
- Olivetti
- PAFEC
- PDA Engineering
- Personal CAD Systems
- Prime Computer
- Racal-Redac
- Robo Systems
- SDA

- SDRC
- Schlumberger (Applicon)
- Scientific Calculations
- Seiko Instruments
- Sharp System Products
- Siemens
- Silicon Compiler Systems
- Silicon Graphics
- Silvar-Lisco
- Sun Microsystems
- Swanson Analysis Systems
- Synercom Technology
- Syscan
- Technodia
- Tektronix
- Tokyo Electron
- Toshiba
- Unisys
- Valid Logic Systems
- ViewLogic Systems
- Zenith
- Zuken
- Zycad

Other Companies

- A/SA Software
- ACDS
- Accel Technologies
- Accugraph
- Advanced Geographics Systems
- Aida Engineering
- Albert Nestler
- Algor Interactive Systems
- Altera
- American Int'l Systems
- American Small Business Computers
- Analog Design Tools
- Andor
- Aptos Systems
- Aries Technology
- Asahi Giken
- Assigraph
- Autokon CIM Systems
- Automated Systems
- Automated Technology Products
- BV Engineering
- BYG
- Bentley
- Bishop Graphics CAD Systems
- CAD Centre

- CAD Lab
- CAD Software
- CADKEY
- CPU
- Cade
- Caeco
- Cambridge Interactive Systems
- Cascade Graphics Development
- Case Technology
- Century Research Center
- Challenger Software
- Cognition
- Cubicomp
- DFI
- Datagraph
- Dennis Klein & Associates
- Design Automation
- ECAD
- ECS
- EESOF
- EIE
- ERDAS
- ESRI
- Engineered Software
- European Silicon Structures
- Evans & Sutherland Computer
- Evolution Computing
- Exapt
- Foresight Resources
- Gateway Design Automation
- Generic Software
- Genrad
- Geobased Systems
- Geographic Data Technologies
- Geomath
- Geovision
- Gerber Scientific
- Graphtec Engineering
- HHB Systems
- HOK/CSC
- Hakuto
- Harris Computer
- Hitachi Seiko
- ICAD
- ISYKON Software
- Ikos Systems
- Infinite Graphics
- Info. Services Int'l Dentsu
- Innovative Data Design
- Integrated Information Systems
- ItalCAD
- Ithaca Software
- Kanematsu Semiconductor
- Kork Systems

- LSI Logic
- Logic Automation
- MAGI
- MARC
- MATC CAD
- MDSI
- MPSI Systems
- Manufacturing Consulting Services, Inc.
- Mapinfo
- Maptech
- Marconi CAE Systems
- Marubeni Hytech
- Mechanical Dynamics
- Mega CADD
- Meta-software
- Micro CAD/CAM
- Microsim
- Mitsui Engineering
- Olivetti
- Omation
- Orcad Systems
- Pafec
- Point Line Company
- Quadtree
- Quantic Laboratories
- Quwat (Shukosha)
- Rikei
- Robocom
- SDA
- Seattle Silicon Technology
- Secagraphics
- Secmai
- Shape Data
- Sigma Design
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- Skok Systems
- Sony
- Strategic Locations Planning
- Sukosha
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- Sumitomo Electric Industries
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- The Great Softwestern Co.
- Thom 6
- Tokyo Keiki
- Toyo Information Systems
- Toyoelectric Manufacturing

- Transformer CAD
- Uchida Yoko
- Unicad
- Univac Information Systems
- Ustation
- VLSI Technology
- Vamp
- Versacad
- Via Systems
- ViewLogic Systems
- Visionics
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- Japanese Semiconductors
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- Semiconductor Equipment and Materials
- Semiconductor User Information
- Semiconductor Application Markets
- European Semiconductor Application Markets
- Japanese Semiconductor Application Markets
- MilAero Technology
- Personal Computers
- European Personal Computers
- Technical Computer Systems
  - Minisupercomputers
  - Technical Workstations
- Business Computer Systems
- European Computers
- Superperformance Computing
- Office Systems

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- Software
- CIO Advisor
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  - Rigid
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  - Optical
  - Subsystems
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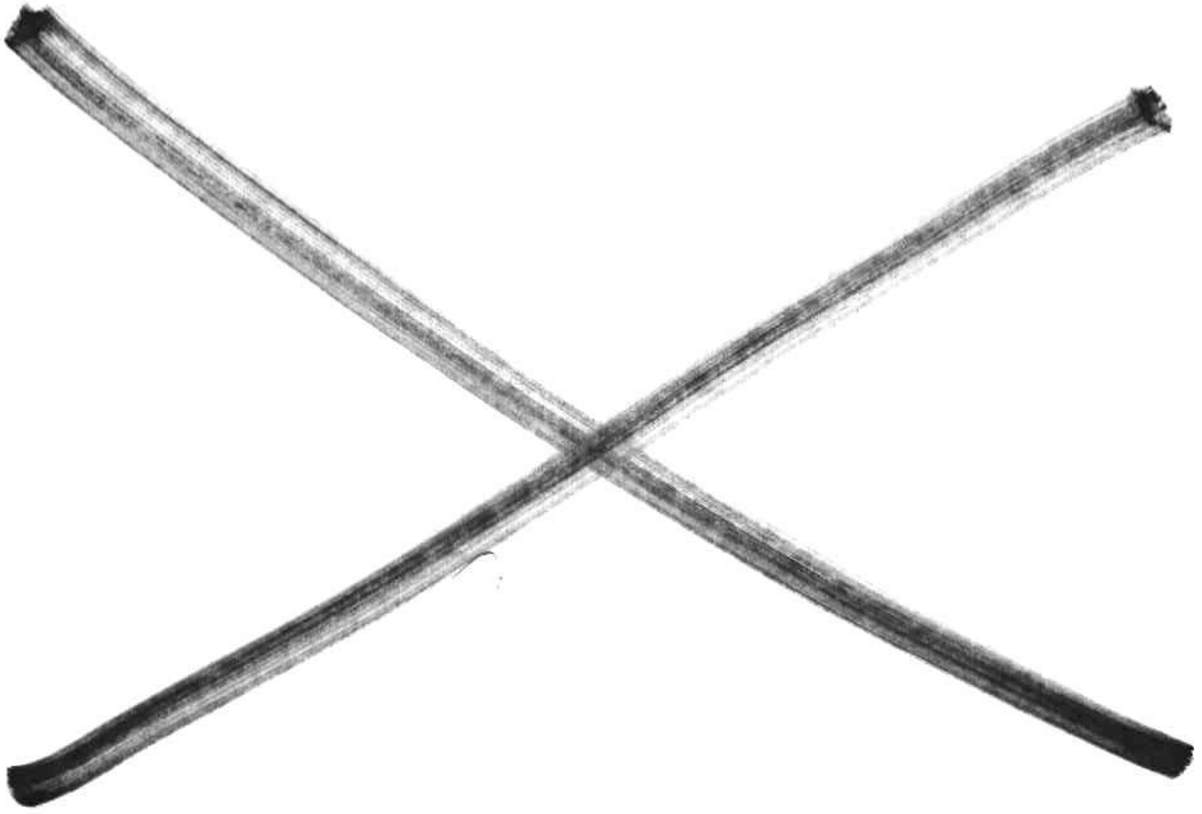

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Research Newsletter

CAD/CAM/CAE NEWS AND VIEWS

AEC AND GIS

Knowledge-Based Engineering Comes to A/E/C

Accugraph Corporation of El Paso, Texas, showed the most intriguing new product at A/E/C Systems '91, an expert system feature to be added to the company's MountainTop CAD product that runs on both the Hewlett-Packard Company (HP) and IBM workstations. Delivery is scheduled in about 18 months. The new feature will be the first commercial implementation of the Intelligent Computer-Aided Design System (ICADS) developed by the CAD Research Unit at California Polytechnic State University in San Luis Obispo, California, under the direction of Dr. Jens Pohl. This ambitious undertaking brings elements of both concurrent engineering and knowledge-based engineering (KBE) into conceptual architectural design.

ICADS, which is based on CLIPS public domain expert system development software, has been funded primarily by IBM and the U.S. Department of Energy and secondarily by Accugraph and the U.S. Navy. The ICADS model has three conceptual elements, as follows:

- A CAD DBMS, which includes both "experience" in the form of nongraphic standard query language (SQL) databases and a Geometry Interpreter to extract geometry (from MountainTop) as the user enters design elements
- Multiple "experts," each formed from a unique set of rules, all overseen by the superexpert known as the "blackboard," which serves as the oversight icon
- The user interface, which places the designer in control of both geometry development and the blackboard

Databases may incorporate multiple design considerations. For example, a Building Type database contains typical building type information for high-rise apartments only. A Site database might contain information directly applicable to the given site. Reference databases might contain data on material properties or manufacturers' products.

Each expert (representing different design professions, such as cost estimating, light, thermal, and structural) is represented by icons in a column down the screen. As the design progresses, the experts continually evaluate the design, reporting back unresolvable conflicts to the blackboard, which is an expert conflict resolver. When suggestions coming from the experts create conflict, the blackboard creates a counterproposal. The experts look at the counterproposal, assess the impact, and create new proposals. The process iterates to resolution, displayed intriguingly with an array of blinking lights, which illustrate active "conversations" among the experts. As the designer enters design elements on the CAD system, the experts run as separate processes in a multitasking environment, providing the architect with interactive evaluation from a set of experts. Veto power is held by the architect/designer. This complex array of computing can slow down even the screamingly fast HP Apollo 9000 Series 400 and 700 workstations, and provides a useful demonstration of what to do with all those mips.

ICADS is currently based on a two-dimensional model using MountainTop. The CAD Research Unit has signed an agreement with IBM to develop a three-dimensional implementation on Catia, as the enterprise moves from architecture into mechanical design and manufacturing. Dr. Pohl believes that the 3-D product can be implemented using only Catia's Graphics Interactive Interface toolkit/program for application development, which will not require specific

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support from Catia's owner, Dassaut Systemes of France.

ICADS is also supported by the AEDOT project emanating from the U.S. Department of Energy's (DOE) Pacific Northwest Laboratory in Richland, Washington, which is run by Battelle Memorial Institute. Considerable government investment has been made in simulation software for energy conservation, which has lain fallow for lack of accessibility to the average architect. Recognizing the potential for commercial implementation of this DOE investment, Battelle has invested in the 2-D ICADS program, with a prototype due in April 1992.

The CAD Research Unit is looking for more industry partners. Dr. Pohl believes that his multiexpert system can be incorporated either into traditional CAD vendors products or into existing KBE vendors' products as a mechanism of providing the blackboard's management functions among a collection of resident expert systems.

Dataquest Perspective

The ICADS project illustrates the major trend at the high end of the AEC CAD industry—the flow of ideas and implementation from mechanical design to architectural design. In contrast to some of the initial success stories in mechanical KBE (see the CCIS Mechanical newsletter number 1990-1, "Knowledge-Based Engineering: A New Weapon in the MCAD Arsenal"), no buildings have been designed using the ICADS product. But the concepts are compelling.

The ICADS model, although complex to implement, offers the potential for developing a wide array of "expert professionals" to assist the architect. Considerable opportunity exists for vendors, for consultants, and even for individual engineers who may someday be able to market their accumulated knowledge as a module that works with the blackboard. This technology needs to be carefully explored by all AEC vendors.

PERSONAL CAD

CalComp Buys CAD Clout

Computer graphics manufacturer CalComp Incorporated of Anaheim, California, previously an investor in Access Graphics Technology Inc., of Boulder, Colorado, has acquired the national distributor of computer graphics products peripherals and workstations. CalComp, which has held a minority stake in Access Graphics since the privately held company was formed in 1989, will add about $120 million in sales from the Access acquisition to the company's current annual revenue of about $400 million. Terms of the agreement, under which CalComp agreed to purchase the remaining 75 percent of Access Graphics shares that it did not already own, were not disclosed.

Dataquest Perspective

CalComp has acquired quite a plum—Access is the most successful CAD hardware distributor, with annualized sales of $120 million, which consist mainly of graphics peripherals and UNIX workstations, to VARs throughout the United States. This is only the second significant investment in the CAD reseller channel, the first being two rounds of venture funding in CAD Solutions, of San Jose, California. Beyond that, the financially strapped CAD reseller channel is self-funded.

Access is an important distributor for such vendors as Sun Microsystems Inc., of Mountain View, California, and several other hardware vendors would like to move their product through Access. CalComp now is in a good position to influence the sales of many kinds of hardware, and to more aggressively pursue its interests through the CAD reseller channel.

Most CAD vendors have rather passively watched the reseller channel develop while making a minimal financial investment into the channel. Now a peripherals manufacturer has jumped in and taken control. We expect CalComp management to have a lot of dinner invitations from other hardware suppliers.

Windows-Based CAD Packages Promised

Personal computer CAD vendors continue to add to the burgeoning Windows product count. Major CAD players Autodesk Inc., ISICAD Inc., Sigma Design Inc., CADkey Inc., and Alias Research Inc. all announced or displayed new CAD products under Windows at the A/E/C/Systems '91 show in Washington D.C.

Autodesk displayed an early version of Autocad with Windows, with delivery promised mid-1991. Autocad's Windows kit will give its current and future Release 11 DOS customers the option to run Autocad on DOS, under Windows, or in both environments interchangeably.

Among other CAD vendors' Windows entries, ISICAD's CADVANCE 5.0 Windows-based package also was demonstrated at A/E/C, and the company is planning shipments for first quarter 1992. Likewise, Sigma Design announced that it has ported its ARRIS software from the UNIX operating system to Windows 3.0, although it promised volume shipments of ARRIS for Windows by this fall. In addition, other demonstrations of CAD/Windows included CADkey's Windows CAD, which is planned for end-user shipments in early 1992, and Alias Research's Alias Upfront 3-D drawing package, which ships this month.

Dataquest Perspective

These announcements, combined with existing Windows products—such as Computervision's DesignView, the newly acquired Premise product, Ashlar's Vellum, and Drafix Windows CAD—mean that users can now pick from quite a collection of announced CAD Windows products, although not all are currently shipping and performance definitely will be an issue. For example, Autodesk promises that Autocad on Windows will be "significantly slower" than Autocad 386.

Demand for Windows products will increase strongly over the next five years. Dataquest's forecast on the Windows/DOS market is for overall Windows-based DOS shipments in all applications to steadily increase from about 2 million units in 1990 to more than 8 million by mid-1993, the point at which Windows-based DOS shipments will begin to equal shipments of character-based DOS systems. Existing DOS-based PC CAD users can be expected to show a general tendency to cross over to Windows; new Intel-based users can be expected to actively seek out Windows-based solutions.

Apple's QuickTime Brings Movies to the Desktop

Apple Computer Inc. has released the first extension to its recently announced System 7 operating system with a so-called "dynamic media" system software architecture, called QuickTime, that will allow third-party software developers to add multimedia attributes such as sound, video, and animation in a seamless, consistent fashion across applications.

QuickTime, which Apple announced June 3 at the Seybold Digital Media Conference, consists of system software, file formats, compression schemes, and interface standards. The components form a software architecture that Apple claims is extensible and open, offering cross-platform standards for dynamic data exchange. With QuickTime, Apple is hoping to raise the least common denominator of applications capabilities to include support for dynamic data, with future Macintosh applications not only supporting graphics but also such dynamic data.

Apple's QuickTime includes a Movie Toolbox in which the term "movie" denotes dynamic data with sound, video, and animation. The Movie Toolbox provides features that will enable software developers to easily add support for movies into their new applications. With QuickTime, Apple uses an Image Compression Manager (ICM) to shield the applications from the difficulties of data compression and decompression. The ICM also allows developers to take advantage of several existing data compression schemes, such as fax and Moving Pictures Experts Group (MPEG), in their applications without modifications.

In addition to managing compression, the Apple software includes a Component Manager so that external system resources, such as digitizer cards, VCRs, and system software extensions, can register their capabilities with the Macintosh system software to allow any application to access those capabilities. QuickTime also features a new file format that Apple calls "Movie," referring to dynamic data such as a presentation slide show or a dynamic graph of lab data, for which Apple plans to publish full specifications and thus provide developers with standards for exchanging dynamic data.

To actually make a movie with QuickTime, however, some third-party products, such as SuperMac's VideoSpigot system, are required. A user can just plug VideoSpigot in and make movies. In fact, Apple has lined up third-party software support, such as WordPerfect for the Mac and Aldus Persuasion, with those applications expected to be ready to go with shipment of QuickTime. Apple's first extension to System 7.0, QuickTime is expected to ship by the end of 1991, probably priced on the order of media and distribution cost.

Dataquest Perspective

Once again, Apple is on the cutting edge—as the company was with the ground-breaking graphical user interface of the Macintosh at its 1984 introduction. Nobody else has done anything quite like this. After a dry spell of several years, the

QuickTime announcement dramatically demonstrates that there is a place in the competitive market for proprietary systems such as Apple's where the company has complete control of the environment. Apple can much more quickly integrate additional data types, such as sound, video, and animation incorporated into the basic operating system. Even better, Apple promises that the second release of QuickTime will also deliver 32-bit QuickDraw to the older 68000-based Macintosh machines, allowing the entire installed base to view movies.

With QuickTime and the "movie" metaphor, Apple is hoping to do to home-made movies what desktop publishing did to the publishing world. In a nutshell, where desktop publishing inspired an avalanche of poorly conceived newsletters, QuickTime could do the same for video production on a computer, because this system is going to be as easy to learn and master as desktop publishing was in its early days. Now professionals in the movie world are going to be holding their noses, and consulting their copyright lawyers, as they watch the rest of us make movies. But after the initial rush of tasteless and incomprehensible creations, useful animations eventually will hit the desktop.

Just as not everybody jumped onto the desktop-publishing bandwagon, not everyone is going to want to go out and make movies. Many people will just want to receive final products. But what brought desktop publishing to nonprofessionals was similar to what this will do for nonprofessional movie makers.

For the CAD/CAM/CAE world, there is considerable applications potential. Just as users have begun to seek out strong graphical user interfaces, we believe that users in coming years will begin to expect more of their vendors in terms of vendor documentation and training. Integrated text, audio, video, and animation, probably delivered on a CD-ROM, will become a differentiating feature in CAD documentation and training products. In addition, CAD users are likely to integrate engineering data into more meaningful technical manuals using these newer data types.

One inhibitor to QuickTime growth in the CAD and documentation markets will come from the U.S. Department of Defense-based CALS initiative, the recognized authority on evolving industry data types. Soon, a technician in a submarine should be able to invoke, within a CD-ROM field service manual, a short video demonstrating removal and replacement of a key component, thereby avoiding potentially disastrous misinterpretation of technical documentation. But right now, the military could not accept the feature as a formal part of documentation, because the myriad of industry-standard data types that are included in Apple's QuickTime technology are not currently accepted under CALS regulations.

EUROPEAN MARKET

HP GmbH Buys ABB Cade's Electromechanical Subsidiaries

Hewlett-Packard GmbH, the German subsidiary of Hewlett-Packard Company (HP), last month signed an agreement under which the company will acquire two electromechanical software subsidiaries of ABB Corporation, of Switzerland, giving HP GmbH a foothold in the growing European electromechanical applications market.

HP GmbH's Mechanical Design Division (MDD), based in Böblingen, Germany, agreed to acquire the two ABB subsidiaries, ABB CADE International GmbH in Laichingen, Germany, and ABB CADE AG in Baden, Switzerland, as part of the division's long-term strategy to expand into the electromechanical arena. Financial terms of the agreement were not disclosed.

The acquisition of ABB's subsidiaries will become final after gaining approval by the German Federal Cartel Office in Berlin. HP now will expand its range of CAD offerings beyond the company's current lineup of mechanical engineering and database management software in the European market. ABB CADE's products include DDS-C, an electrical wiring design system; KEN (Knowledge ENvironment), a knowledge-based engineering shell; and DMS, a document management system.

Dataquest Perspective

This acquisition by HP GmbH will introduce German electrical engineering technology through HP's worldwide sales network. ABB CADE mainly sold its products through the ABB network, which is not the ideal distribution channel for CAD products. Because of this, ABB CADE lost market share in 1990. Last year, ABB had CAD sales of about $13 million, of which about $9 million was electromechanical. ABB CADE did not have a good year in 1990 while the competition did, and that is the main reason ABB sold the subsidiaries.

Through HP's direct sales force, the electromechanical product now will be introduced to a much larger community.

Electrical engineering CAD's main users are electrical engineering companies such as ABB and Siemens, along with manufacturers of construction and machine tools, specialty machinery, electrical power utilities, mining, and automotive industries. Led by German vendors, a consortium called VNS has been formed that has developed a data exchange standard for electrical engineering CAD systems. VNS is supported by DIN, the German standards organization, creating potential for worldwide influence in the standards arena.

Dataquest estimates that the electrical engineering CAD market in Europe was $200 million in 1990. Unlike all the other CAD market segments, which are dominated by U.S. vendors, the electrical engineering market is dominated by German vendors. Dataquest estimates that approximately 80 percent of the European electrical engineering market is sold by German vendors. Dataquest expects these European vendors to increasingly expand their overseas operations over the next five years to become more globally competitive. Leading vendors in this market segment are taking steps to introduce their technology in the United States and in Japan.

Kathryn Hale
Petra Gartzen

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Research Newsletter

CAD/CAM/CAE NEWS AND VIEWS

This newsletter is a summary of significant news events happening in the CAD/CAM/CAE industry over the past month. Dataquest will publish this "News and Views" feature along with topical feature articles on markets, technology, and company profiles every month beginning in July, when the CAD/CAM/CAE industry service begins production of its client newsletters under the new *Dataquest Perspective* format.

INTERGRAPH WINS LARGEST MECHANICAL CAD CONTRACT

Last month, Intergraph Corporation won the largest single mechanical CAD/CAM/CAE contract ever awarded—a $362.4 million deal to supply the U.S. Navy with computer-aided design and manufacturing (CAD/CAM) computer systems, software, and services.

Outbidding several competitors, Intergraph was awarded the indefinite-delivery-requirements contract that is projected to generate between $40 million and $65 million in additional revenue through 1992 for the CAD/CAM vendor based in Huntsville, Alabama.

The contract—which is part of the navy's approximately $2 billion CAD-2 program for the acquisition of state-of-the-art CAD/CAM systems based on off-the-shelf, commercially available equipment—was awarded by the U.S. Navy's Information Technology Acquisition Center (ITAC) in support of the Naval Sea Systems Command (NAVSEA). NAVSEA provides technical and logistical support for ships, craft, shipboard weapons systems, guided missiles, mines, and torpedoes through the life of these systems.

NAVSEA will order Intergraph hardware and software components during the first eight years of the contract and technical and software support services for an additional four years. Intergraph will provide NAVSEA with a total CAD/CAM systems solution, including hardware, software, maintenance, and training and technical support services to support the design, construction, maintenance, overhaul, alteration, and repair of navy ships and shipboard systems.

Among other specifics, the contract calls for 2,820 workstations, 450 servers, and 11,000 mass-storage devices. Intergraph also will provide 500,000 work hours of support services. Intergraph's team includes CASDE Corporation, The Jonathan Corporation, Martin Marietta's Information Systems Group, and 3Com Corporation.

Dataquest Perspective

Persistence is a virtue, as attested to by Intergraph's recent win of the largest mechanical CAD/CAM/CAE order on record. The contract is expected to contribute approximately $10 million to $15 million in sales during 1991 and approximately $30 million to $50 million in 1992. The remainder of the $362 million contract will be delivered over the following six years.

The original technical specification for this contract was distributed in early 1987. Hundreds, perhaps thousands, of work weeks of effort went into sales negotiations and benchmark activity by dozens of vendors hoping for a piece of this U.S. Navy business. It came down to Computervision and Intergraph in a duel to the finish. Computervision had an inside track, having won the first navy CAD contract in 1980; but Intergraph demonstrated a full range of applications supported by a strong networked computing environment.

The subsequent protest filed by Computervision and its systems integrator, PRC Inc., came as no surprise, because Computervision suggested that Intergraph failed to meet some of the contract

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specifications. However, the protest was later withdrawn without prejudice, precluding any further appeals.

Dataquest believes that several very positive results are evolving from this contract activity. Certainly, one of the principal gains is the navy vote of confidence, confirming Intergraph as a world-class supplier of mechanical CAD/CAM/CAE products. In landing the contract, Intergraph also enhanced its role as a systems integrator, overseeing a large project that will require the coordinated efforts of Intergraph, Martin Marietta, The Jonathan Corporation, CASDE Corporation, and NAVSEA.

Another winner in the bidding process was McDonnell Douglas Systems Integration Company; not because it won the contract, but rather because the company realized the business potential of the team approach in bidding on contracts for large, sophisticated users. McDonnell Douglas formalized this team approach by pulling together what is now called "The All Star Team," comprised of McDonnell Douglas and CAD vendors such as CGTech, ICAD, PDA Engineering, and Valisys.

In fact, the bidding on this navy contract has done more to increase needed synergistic relationships between vendors than any single influence in the U.S. market, and we expect the benefits of these relationships and the resulting team approach to be applied to large projects in France, Germany, Japan, and other overseas markets.

MECHANICAL CAD/CAM/CAE COMPANIES SHOW STRONG GROWTH

Gains by several mechanical CAD/CAM/CAE vendors during the first quarter of the calendar year bolstered optimism that this segment of the industry will experience healthy growth through the remainder of the year, as forecast.

Leading the way on the fast-growth path was Parametric Technology Corporation, which reported revenue of $10.34 million, a jump of 76 percent over the same period a year ago. The small Waltham, Massachusetts-based CAD firm reported that net income increased 76 percent to $2.4 million, or $0.26 per share, for the quarter ended March 30, 1991, compared with $1.3 million, or $0.15 per share, for the three months ended March 31, 1990.

"Strong domestic and international sales through both the direct and value-added-reseller channels contributed to our success this quarter," stated Steven C. Walske, president and chief executive officer. During the quarter, Parametric Technology also welcomed Cimplex and Spatial Technologies to its cooperative marketing program. These software vendors have chosen Parametric's Pro/ENGINEER software as the front-end design tool for their manufacturing products.

PDA Engineering reported record quarter revenue and earnings. Net earnings increased 25 percent to $759,000 for the quarter ending March 31. On a per-share basis, earnings were 16 cents per share on 10 percent more shares outstanding, compared with 14 cents per share last year. Total revenue was $8.7 million, an increase of 3 percent over the $8.5 million for the same quarter of the previous year.

Software product revenue was at record levels for PDA during the quarter at $7.16 million, up 16 percent from last year. Louis A. Delmonico, PDA president and chief executive officer, said, "The financial focus for PDA Engineering has been for consistent growth, based upon the careful execution of business planning and controls. We are unable to control the procurement delays in the defense industry that resulted from budgetary problems last fall or the impact that the Mideast war has had on government R&D programs. We are pleased that even at current lower revenue, this segment is profitable."

Intergraph Corporation reported operating results for the first quarter of 1991, with net income up 33 percent to $19.9 million, compared with $15 million the previous year. Net income per share increased 37 percent to 41 cents, up from 30 cents a year ago. Revenue was $287 million for the quarter, compared with $230 million for the same period of the prior year, an increase of 25 percent. New systems orders rose by 14 percent to $200 million during the first quarter.

Intergraph stated that demand for its products remained firm despite the current economic conditions in the United States and Europe. Although the company is feeling some effect of the economic downturn, especially in Europe, it continues to plan for growth estimated in excess of 20 percent for the year.

Structural Dynamics Research Corporation (SDRC) reported record earnings and revenue for the first quarter ended March 31, 1991. Net earnings for the first quarter of 1991 increased 39 percent to $3.3 million compared to $2.4 million for 1990's first quarter. Revenue rose 27 percent to $31.9 million compared with $25.2 million for the same period last year. Earnings per share

were 24 cents, compared with 18 cents per share for the same period in 1990.

Ronald J. Friedsam, SDRC chairman and chief executive officer, said, "Earnings have now increased in each of the last 19 consecutive quarters when compared to each of the prior years' quarters. Revenue from our software products division grew significantly, increasing by 33 percent over the first quarter of last year."

Table 1 shows the performance of several vendors in the mechanical CAD/CAM/CAE arena.

Dataquest Perspective

The companies mentioned earlier represent a healthy cross section of the leading vendors in the mechanical CAD/CAM/CAE business. Our forecast of average expected growth for the industry is in the 10 to 20 percent range for this year, depending on the mix of hardware and software. Almost all of the above companies are on or above our forecast target, indicating a continued healthy buying demand in the end-user markets.

In general, the increasing level of indispensability for mechanical CAD/CAM/CAE applications is fueling this market growth. The issue of indispensability stems from a combination of need for integrated systems and vertical market applications, a need to become more competitive, and a basic demand of engineers and designers to have access to the technology.

Many large strategic system purchases have been made in the last few months. General Dynamics Corporation, The General Electric Company, Northrop Corporation, and the U.S. Navy have recently made large orders for integrated systems.

TABLE 1
Mechanical CAD/CAM/CAE Vendor Performance

Company	Revenue (U.S.$M)	Growth (%)
Parametric Technology	10.34	76*
SDRC	31.86	27*
Intergraph	286.64	25*
PDA Engineering (software only)	7.16	16*
MacNeal-Schwendler	56.6	26**
Swanson Analysis	24.6	18**

*First quarter 1990 to first quarter 1991
**Annual
Source: Dataquest (May 1991)

Competitive pressures on these companies are forcing improved profitability through productivity enhancements. These enhancements are being achieved through the development and implementation of concurrent engineering, multilevel engineering data management, and powerful end-user development tools. Vertical markets are experiencing a maturing process as users demand tighter integration in related applications. A good example would be those combining sophisticated analysis functions, such as computational fluid dynamics and acoustical and structural analysis. The basic demands for general applications as well as experts' tools are driving the steady increase in the number of engineers, designers, and technicians who are now using CAD/CAM/CAE technology.

Dataquest expects the mechanical CAD/CAM/CAE market to continue to experience healthy growth well into the next century. Evolving user expectations for high-performance integrated applications with new user interfaces will force the development required to make such growth happen.

EDA MARKET LEADERS SUFFER SOFT QUARTER

With few exceptions, the market share leaders in the electronic design automation (EDA) market faced relatively flat growth in sales and profitability during the first quarter, if in fact any gains were made at all. Among the EDA industry's bigger players—Cadence Design Systems Inc., Mentor Graphics Corporation, and Valid Logic Systems Inc.—only one, Valid Logic, recorded a good jump in profitability.

The industry slowdown perhaps hit Mentor Graphics the hardest among major EDA vendors. Mentor reported first-quarter revenue of $103.71 million, down from $116.747 million for the same period a year ago. The company posted a loss of $3.99 million, or 9 cents per share, versus net income of $11.56 million, or 26 cents per share, for the first quarter of 1990. Mentor's loss was the first quarterly loss ever in the firm's seven-year history as a public company.

Cadence Design's revenue increased to $59.4 million, up from $50.2 million in sales during the first quarter of 1990; but the company's net income slipped 22 percent in dropping to $6.5 million from the $8.4 million earned during the first quarter of 1990.

Although Valid Logic reported almost $1 million in profits, the company's sales actually dropped to $34.74 million, down from the $35.02 million in revenue in the first quarter of

1990. Valid's profits jumped to $900,000, or 2 cents per share, from the net loss of $6.73 million, or 21 cents per share, suffered in the first quarter of 1990.

Among the EDA market's smaller publicly held players, Zycad Corporation and IKOS Systems Inc. reported modest gains in profitability. Although Zycad's revenue fell to $8.36 million for the first quarter of 1991 compared with $9.23 million in first-quarter 1990 sales, the company managed a net profit of $521,000, or 3 cents per share, compared with a net loss of $1.34 million, or 9 cents a share, for the first quarter of 1990.

Dataquest Perspective

The semiconductor industry's first-quarter book-to-bill ratio, which is a ratio showing the number of products shipped or billed to the amount of new orders, is indicative of the market for EDA tools: fair. During the first quarter, the semiconductor industry's book-to-bill ratio showed steady increases with March bookings jumping 7.2 percent to $1,362.9 million from February's tally of $1,271.9 million. The first-quarter 1991 book-to-bill ratio represented modest gains by chipmakers.

Clearly, for the EDA market-share leaders, the quarter was difficult. One of the major problems for the bigger players was the Gulf War and the continued economic malaise. Currently, there is an undercurrent of conservation, given both the general state of the economy and the turmoil in the EDA industry itself.

The issue is that almost all of these companies had bad quarters. In Mentor's case, the reason for the first-quarter stumble can be traced to the fact that the company is late with its new product, Concurrent Design Environment Release 8.0, resulting in a continued sales slump as the company ramps up shipments of the latest release. Because it is difficult for Mentor to sell last-generation products to new customers, the company is caught in a classic product transition situation. Although Mentor started shipping Release 8.0 by the end of the first quarter, only the first piece was ready for shipping. The remainder will begin shipping throughout the year.

In Cadence's case, the company's limited presence in the systems design market has begun to impact the company. The company has tremendous market share in the IC-layout market, but the big challenge for Cadence is to successfully expand in the systems market. Although Cadence currently has several thousand Verilog-simulation seats installed in the systems market, the company does not have full account control at these sites because nearly all Verilog-simulation users interface to the simulator through third-party CAE front ends, such as those from Valid Logic and Mentor Graphics. Those companies, the ones that control the front end of the design system and provide the EDA foundation, have account control.

In addition, there is a particularly difficult challenge ahead for Cadence's management to remain focused on product development and sales in the face of the shareholder lawsuit that was recently filed against the company.

At Valid Logic, the company changed its business model late last year, moving from shipping both hardware and software to a software-only operation. This change has had an impact on the company's stability, but Dataquest believes that Valid will be able to adjust to the new business model. The real challenge for Valid is to provide a top-down design environment. The company is lacking several key components in this area, such as logic synthesis technology.

Viewlogic Systems Inc. had a fairly strong quarter. Dataquest's research shows that an increasing number of Viewlogic users are beginning to rely on the Viewlogic Sim S/D product. This focus is helping to boost the company's market position and strengthen its account control.

In regard to the DAZIX subsidiary portion of Intergraph, Dataquest believes that DAZIX had a soft quarter, as expected. The reason is that DAZIX currently is in the midst of integrating the product lines, distribution channels, organizations, and corporate cultures, as a result of the merger consummated between Intergraph and DAZIX in the last days of 1990. Dataquest's research shows, however, that there is a fair amount of demand for DAZIX software within the company's installed base of approximately 12,000 seats.

Dataquest believes that, for most EDA companies, the second quarter will look quite similar to the first quarter. It will be difficult for most companies to make significant strides forward, as we expect that the upcoming Design Automation Conference (DAC) will be the primary focus of companies throughout the quarter. In addition, many buyers will likely delay buying decisions until they see what is on the show floor at DAC. With the DAC show coming in the mid-June time frame, the trade show may actually work to help companies improve their second-quarter performance.

Many EDA smaller players had a strong quarter, indicating that market demand for EDA

products remains high. Dataquest expects the niche suppliers to enjoy a strong market, whereas performance of the larger players will remain relatively flat. Our research shows that market demand for merchant EDA tools remains high, even though an undercurrent of caution appears to be pervasive throughout all segments of the electronics industry.

EDA COMPANIES TEAM UP

In a pair of EDA partnering relationships, Intergraph Corporation last month bought an approximate 18 percent equity stake in Silvar-Lisco (Menlo Park, California) and Zycad Corporation acquired the RTrace software product line from Transform Logic (Phoenix, Arizona).

Intergraph paid approximately $1.1 million for the Silvar-Lisco common shares in a deal that includes a warrant for Intergraph to buy up to an additional 300,000 shares of common stock for a total exercisable price of $186,000, payable in cash. The warrant is exercisable in whole or over a five-year period. The deal actually will supply Silvar-Lisco with a total of $1.8 million in cash, including the $1.1 million current equity investment, over the next three quarters, which the company plans to use for working capital.

In addition, Intergraph and Silvar-Lisco signed an OEM agreement under which Intergraph will distribute worldwide Silvar-Lisco's place and route tools embedded into Intergraph's design flow. The companies also signed a joint technology agreement allowing each to begin work on integrating Silvar-Lisco's SL-Cell and SL-Array products into Intergraph's computer-aided engineering (CAE) product offering.

Zycad's purchase of RTrace from Transform Logic will give the firm a software tool designed to reduce development costs and improve design productivity. RTrace enables the user to analyze specification requirements, manage traceability reporting, define allocation structures, and establish and report requirement allocations. Originally developed in 1985 as a custom product for RCA Corporation, RTrace was first sold commercially in 1988 and currently has approximately 200 users in 30 companies.

Dataquest Perspective

The agreement between Intergraph and Silvar-Lisco makes sense for both parties. Silvar-Lisco gets the worldwide distribution and marketing muscle of Intergraph, while Intergraph rounds out its product line in an area that Dataquest defines as of strategic importance. In short, Dataquest believes that it is essential for an EDA supplier to possess sound understanding of the IC design marketplace because today's system is tomorrow's applications-specific integrated circuit (ASIC). Forging a partnership with Silvar-Lisco will provide Intergraph with a more in-depth understanding of the IC design automation market. The relationship is also further evidence that Silvar-Lisco's strategy of focusing on development of the tools for the market it understands best, IC layout, is paying off.

Zycad's purchase of RTrace is an indication of its attempt to reposition itself in the marketplace. Zycad is moving toward the high-level systems design marketplace in order to complement its hardware accelerator-based systems verification business. Dataquest believes that this area is an emerging market that holds great promise for EDA companies throughout the coming decade.

EUROPEAN GIS SHOW SHORT ON BUYERS

About 1,000 vendors, users, and assorted academics gathered early last month in Brussels, Belgium, for the EGIS '91 Second European Conference on Geographical Information Systems (GIS).

Dataquest Perspective

Attendance at the show generally appeared to disappoint vendors faced with an unhealthy mix of bureaucrats and academics. An oversupply of such attendees seeking EC funding was counterbalanced only by the large student population; hence, prospective buyers were scarce. The paucity of potential buyers gives further credence to the unfortunate notion that, at least for the foreseeable future, vendors will continue to be forced to fund separate GIS shows in each country. Prospects do not look bright for a pan-European GIS show.

COMPAQ CUTS PRICES TO COMBAT CLONES

Compaq Computer Corporation last month slashed prices, with across-the-board price cuts

ranging from 8 to 34 percent on its personal computers, in an effort to regain the market share lost in recent years to an onslaught of PC clones. In addition, Houston-based Compaq revamped its Authorized Dealer pricing structure, reducing the amount of dealer discounts allotted to its retailers.

Dataquest Perspective

Until now, Compaq has maintained its leadership position as the top choice among CAD dealers in North America. Lately, however, the competition has been intensifying. Compaq's price cuts, combined with reducing the dealer discounts, will bring Compaq products' street and list prices much closer together.

In the past, Compaq offered high discounts to dealers, which made list prices look high on paper. This strategy portends an important first step for Compaq to counter the company's high-priced image problem, which was partially a market perception problem and partially an actual problem. This move will serve to counteract Compaq's actual price problem in the marketplace. Ross Cooley, Compaq's vice-president of North America, stated that the company's goal was to reduce the premium a user pays for a Compaq system versus the street price of a system of an established clone-maker, such as those from Dell Computer Corporation or Everex System Inc. Compaq believes that users will pay a premium of 15 to 20 percent.

Dataquest believes that 15 to 20 percent is just about the right premium to demand for Compaq's brand name and system quality. Compaq has been losing some ground among CAD dealers not only to lower-priced PC clone-makers but also to Sun Microsystems Inc.—which offers comparably priced products, with the added cachet of UNIX. Dataquest believes that Compaq is right on target here. The next step is to address the "high-priced" image problem through a more effective advertising campaign.

IBM TRANSFERS CONTROL OF DESKTOP CAD TO CADAM

Less than two years after buying CADAM Inc., IBM has decided to transfer responsibility for the management, marketing, and development of IBM CAD and the extended version of IBM CAD/Plus to its Burbank, California-based, wholly owned subsidiary CADAM.

Dataquest Perspective

Because CADAM has relatively little inherent interest in supporting an additional DOS-based product, it appears that IBM is backing away from this fledgling attempt to sell its own low-end CAD software. A number of PC CAD software products with very low market share are struggling to survive, and this is one of them. IBM has the same problem as other niche PC CAD players—even Big Blue can't make it.

GENERIC AND SOFTDESK RELEASE NEW AEC LINE

Generic Software Inc. and Softdesk Inc., formerly DCA Software, announced a new line of AEC software products, called GenCADD, for a variety of AEC-specific applications. The new GenCADD line, which runs within Generic Software's low-cost Generic CADD software, offers PC users low-cost 2-D drafting programs for the AEC environment. Under the joint development, both companies will market and sell the GenCADD application software product line, which will include the Generic CADD 5.0 engine and will retail for under $1,000.

Dataquest Perspective

With this joint offering, both Softdesk, a leading supplier of AutoCAD add-on software products, and Generic Software, a wholly owned subsidiary of AutoDesk Inc., are carefully tending their major growth opportunities, a key one of which is nibbling away at the low end of potential AutoCAD buyers. The partnership allows Generic to raise its prices closer to the more lucrative $1,000 (list) price point. The move also benefits Softdesk by opening a new market opportunity to sell add-on products to the most price-sensitive architectural users.

This is a smart move for both companies because it opens up an opportunity to reach the most price-sensitive prospects in the AutoCAD market.

ISICAD'S CADVANCE CERTIFIED FOR NOVELL LANS

PC CAD vendor ISICAD Inc. announced that its CADVANCE software passed the NetWare (from Novell Inc.) certification program, making

the ISICAD CADVANCE software the first CAD software to be certified by the Novell Labs. The ISICAD software package has specific built-in network functionality.

Dataquest Perspective

Novell is far and away the dominant network sold by CAD dealers, and ISICAD's effort to become the first CAD package certified for Novell networks is proof that the company is on the ball in this fast-growing area. Although ISICAD is a small player in the CAD market, the company has been making good progress in creating networked DOS-based CAD applications, and competitors should watch the company's strategy to see if it sells.

Michael Seely
Ron Collett
Kathryn Hale

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Research Newsletter

THE CAD/CAM/CAE MARKET FORECAST: 1991-1995

INTRODUCTION

In a year when many high-technology markets had difficulty maintaining their current position, the CAD/CAM/CAE market grew steadily, and this growth pattern is projected to continue. The CAD/CAM/CAE market grew 14 percent to $14 billion in 1990 and is forecast to grow at a compound annual growth rate (CAGR) of 12.9 percent through 1995. (The current forecast is based on the CAD/CAM/CAE industry service's preliminary market information and will be updated again in October.) The following newsletter compares the CAD/CAM/CAE industry service's current forecast with last year's and also highlights the key factors that will drive the CAD/CAM/CAE market over the next five years.

FORECAST ACCURACY AND COMPARISON

Overall, the CAD/CAM/CAE market forecast appears to be right on target with some variance among regions (see Table 1). European growth in 1990 was slightly less than expected because of slower growth in some application areas. The current North American forecast for 1991 has been lowered because of current U.S. economic conditions.

TABLE 1
CAD/CAM/CAE Forecast Comparison (Billions of Dollars)

	1990	1991	CAGR (%) 1990-1995*
Worldwide			
Last Year's Forecast	14.2	16.2	13
Current Year's Forecast	14.0	15.9	13
Difference (%)	-1	-2	
North America			
Last Year's Forecast	5.0	5.6	12
Current Year's Forecast	5.0	5.4	11
Difference (%)	0	-4	
Europe			
Last Year's Forecast	5.0	5.7	14
Current Year's Forecast	4.9	5.6	14
Difference (%)	-2	-2	
Asia			
Last Year's Forecast	3.8	4.4	14
Current Year's Forecast	3.8	4.6	14
Difference (%)	0	4	

*Percentages have been rounded to the nearest whole number.
Source: Dataquest (May 1991)

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WORLDWIDE FORECAST DRIVERS

The worldwide CAD/CAM/CAE market will maintain consistent, steady growth over the next five years (see Table 2). The following are the main forces driving the CAD/CAM/CAE worldwide forecast:

- CAD/CAM/CAE systems will continue to give buyers a competitive edge; CAD "works"—As time-to-market requirements shrink, demand for design automation tools will increase.
- Market demand will be limited by vendors' inability to fully meet demand for integrated systems—No vendor will completely solve the systems integration puzzle; the proliferation of the hardware junkyard will continue. Successful vendors will invest in systems integration to ensure that hardware and software work together.
- Incremental progress in delivering open systems and standards to market will constrain market demand—When and how successfully more open systems arrive on the market will show the value of CAD tools to many users. The move toward standards also will spur growth; but, standards must emerge to spawn third-party software suppliers.
- The "late majority" buyers for CAD/CAM/CAE will be coming to market over the next five years, driving additional growth—However, conservative buyers will favor market leaders. These conservative buyers are the "late majority" buyers who do not buy until the weight of the majority seems to legitimize the product. Therefore, for vendors, the value of having high market share as well as financial clout will increase.

NORTH AMERICAN FORECAST DRIVERS

The North American market grew 9 percent in 1990 to $5 billion and is forecast to have a CAGR for revenue of 10.6 percent through 1995. Some of the main issues driving the North American forecast are the following:

- Growth will be limited until 1992 because of the slower economy and the recession—Many U.S. businesses have cut spending and are waiting out the recession before resuming purchases.
- Growth will be lower because of decreasing average selling prices (ASPs)—The North American market will shift to more of a replacement market. Unit shipments will continue to grow significantly, while revenue will grow at a slower rate because of strong price competition. See Figure 1, which shows the continued growth of North American shipments ahead of European and Asian shipments.
- Growth will be limited because of lower defense spending—The fiscal 1992 and 1993 defense budgets submitted to the U.S. Congress in February contain a wide range of weapon platform upgrades; many are in lieu of new program starts. However, plans for upgrades do not necessarily guarantee program funding. The difficult budgetary situation will continue to enforce tough decisions. CAD companies that are heavily dependent on government defense spending contracts will increasingly have limited growth opportunities.

EUROPEAN FORECAST DRIVERS

The European market is forecast to overtake the North American market in terms of revenue in 1991 and will reach $9.2 billion by 1995 (see Figure 2).

The European market grew 15 percent in 1990 to $4.8 billion and is forecast to have a CAGR for revenue of 13.5 percent through 1995. Some of the main issues driving the European forecast include the following:

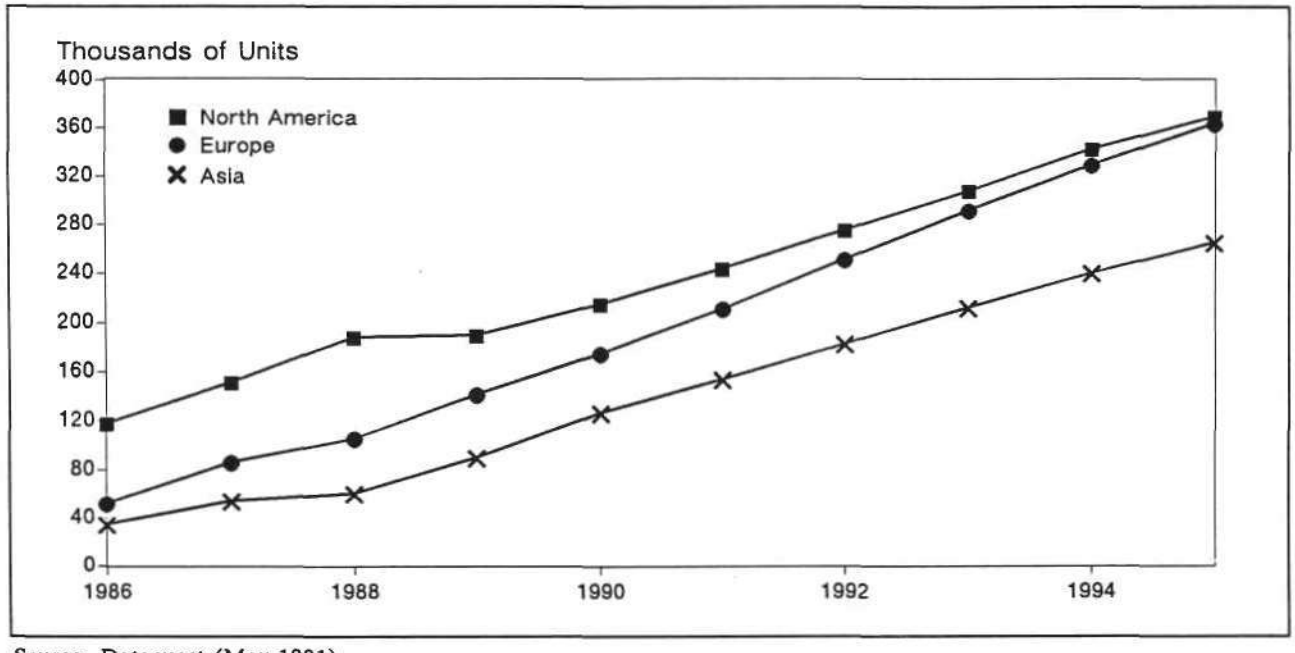
- Growth will be strong in Eastern Europe—Central and Eastern Europe continue to attempt the transformation to world economies. Output declined in all these countries in 1990 and is likely, at best, to stabilize in 1991, while inflation and the lack of hard currency in many countries remains a widespread problem. The slowdown in the world economy and the rise of interest rates have made it a difficult environment in which to pursue the sort of restructuring that is needed. Significant investments in infrastructure, specifically telecommunications and buildings, are still needed. The markets for CAD and Geographic Information Systems (GIS) products selling into these industries (telecommunications and construction) will continue to grow. The manufacturing industry also will have an increased need for CAD as it gears up to compete with Western economies. The Eastern European market will begin to affect the overall European market in the 1994 to 1995 time frame.

TABLE 2
CAD/CAM/CAE Worldwide Forecast by Region

	1990	1991	1992	1993	1994	1995	CAGR (%) 1990-1995
Worldwide							
Revenue (U.S. $M)	14,031	15,943	18,130	20,395	22,924	25,692	12.9
Systems	494,994	593,980	703,450	814,760	926,070	1,023,290	15.6
Workstations	529,058	624,970	731,300	838,680	946,840	1,040,970	14.5
North America							
Revenue (U.S. $M)	5,003	5,378	6,024	6,713	7,478	8,276	10.6
Systems	202,636	233,310	266,150	299,990	335,620	363,760	12.4
Workstations	215,648	244,110	275,600	308,100	342,840	369,930	11.4
Europe							
Revenue (U.S. $M)	4,893	5,616	6,345	7,147	8,095	9,199	13.5
Systems	164,750	201,730	243,140	283,820	323,620	358,990	16.9
Workstations	175,254	211,460	251,770	291,010	329,790	364,410	15.8
Asia							
Revenue (U.S. $M)	3,845	4,576	5,264	5,926	6,634	7,372	13.9
Systems	117,500	144,830	174,340	205,250	234,450	260,340	17.2
Workstations	126,832	153,920	182,660	212,420	240,450	265,190	15.9
Rest of World							
Revenue (U.S. $M)	291	373	498	609	716	844	23.7
Systems	10,109	14,110	19,830	25,690	32,380	40,210	31.8
Workstations	11,324	15,480	21,280	27,140	33,760	41,430	29.6

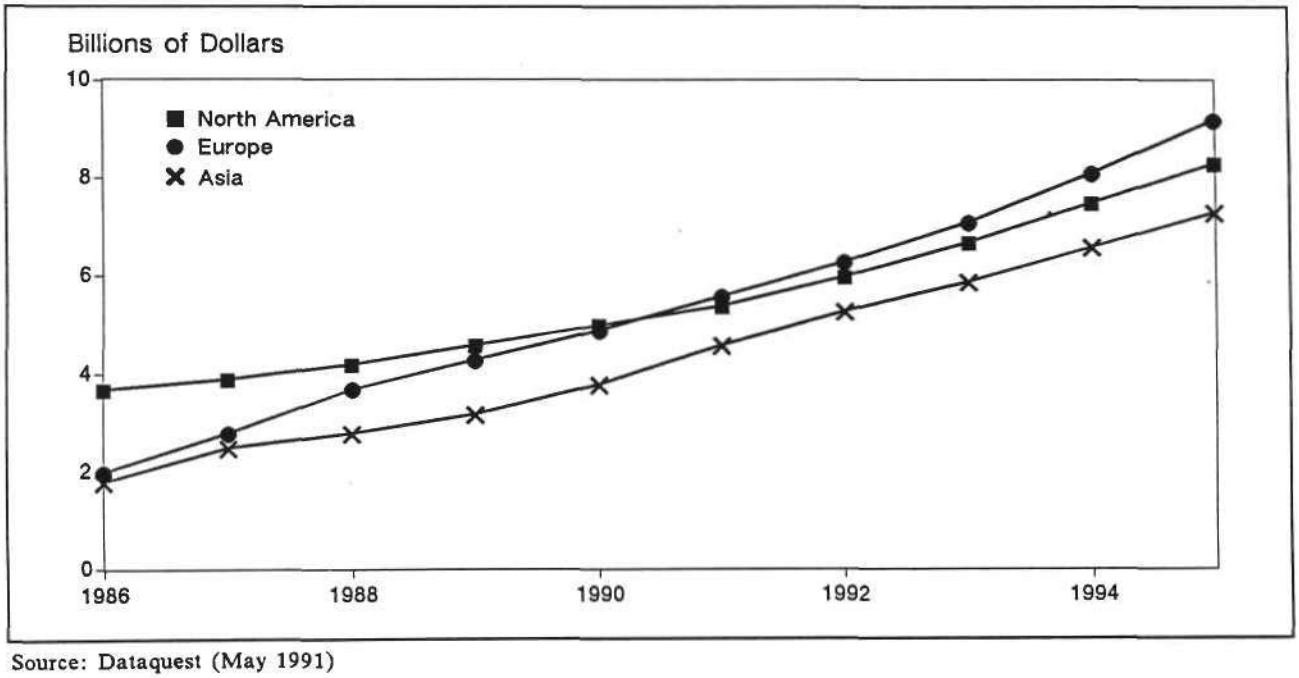
Source: Dataquest (May 1991)

FIGURE 1
CAD/CAM/CAE Shipment Forecast by Region



Source: Dataquest (May 1991)

FIGURE 2
CAD/CAM/CAE Total Revenue Forecast by Region



Source: Dataquest (May 1991)

- Growth will be moderate up to 1992 (EC)—With the advent of 1992, European markets continue to offer strong growth opportunity. However, the effects of 1992 will be evolutionary, not revolutionary, and will be felt over time. Merger and acquisition activity of large end users preparing for the open competition that will occur in 1992 is expected to continue and should spur CAD/CAM/CAE growth over time. Japanese and U.S. companies will increasingly invest in European business.
- Growth is expected for European vendors in non-European markets—To date, most European vendors have not competed on a global basis. Over the next forecast period, European vendors will increasingly expand their overseas operations to become more globally competitive. For example, CAD tool vendors for electrical engineering are taking more and more steps to introduce their technology in the United States and Japan.
- Growth will be slower because of the economy and budget cuts—The severe economic problems in the United Kingdom are currently affecting U.K. businesses overall but should ease up toward 1993. Cuts in defense budgets have slowed growth in countries—such as France, the United Kingdom, and Italy—that rely heavily on the defense industry.

ASIAN FORECAST DRIVERS

The Asian market grew 20 percent in 1990 to $3.8 billion and its forecast CAGR for revenue is 13.9 percent through 1995. Some of the main issues driving the Asian forecast are as follows:

- Shifting labor costs will affect growth among countries—Labor costs in Japan, Korea, Taiwan, and Hong Kong will continue to increase, which will result in growing demand for productivity tools including CAD/CAM/CAE. Industries with blue-collar workers will transfer operations to Indonesia, Malaysia, the Philippines, Thailand, and the Republic of China; Japan, Korea, Taiwan, and Hong Kong will grow based on the work of the white-collar workers. Remote design and manufacturing sites also will encourage the growth of electronic data sharing and thus CAD/CAM across Asia.
- Growth is less likely in some Asian countries because of stringent intellectual property rights—Most Asian countries, with the exception of Japan, have few laws governing intellectual property rights. Many companies will be hesitant to invest or set up operations in a region where they will receive no design protection.
- Growth will be strong in EDA—Demands for EDA tools supporting the design of ASICs, MCMs, and ASSPs (application-specific standard products) will expand; the development of in-house electronic products will continue to decline. Over the next few years, the EDA industry will move toward an oligopoly of vendors providing a full line of tools encapsulated within an open framework and niche vendors providing point-solution tools.
- Mechanical growth will be strong because of the need for concurrent engineering—In the mechanical CAD/CAM/CAE area, the need for concurrent engineering will increase. Point-solution tools associated with parametric and variational design, manufacturability, and testability will be required. Major vendors will add these tools through OEMs, merger and acquisitions, or in-house development in order to defend their installed base.

CAD/CAM/CAE industry service staff

Dataquest
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Research Newsletter

THE BIGGER THEY ARE, THE HARDER THEY FALL—IS THE IBM MAINFRAME BUSINESS IN TRANSITION OR DECLINE?

INTRODUCTION

On March 28, IBM announced another reduction in force of some 14,000 people. On March 19, IBM disclosed to security analysts that it expected its first quarter earnings to be approximately half of what it had previously projected, with flat or slightly declining revenue during the remaining portion of 1991. IBM contended that this decline is due to current soft economic conditions, is industrywide, and is a temporary phenomenon. Amdahl, a mainframe vendor, is projecting that first quarter revenue will be down, particularly in the United Kingdom. Unisys expects slow mainframe results in Europe.

In view of these revelations and the critical impact of mainframe demand on industry revenue and profit, Dataquest is revising downward its mainframe projection (see Figures 1 and 2). There is a consensus that 1991 will be a sluggish year for mainframes, but a divergent body of opinion exists on what will happen with mainframes beyond 1991. The following explores different perspectives and presents the revised projection.

RECENT HISTORY AND EXPECTATIONS FOR 1991

The 1990 mainframe revenue constituted 29 percent of the total computer market, down 5 points from 34 percent in 1986 even though mainframe revenue experienced a compound annual growth rate of 7.7 percent. IBM's share of the mainframe market increased from 48 percent in 1986 to 58 percent in 1990. Over this same period, the portion of IBM revenue derived from mainframes remained constant, at approximately 56 percent of total IBM computer systems revenue.

Dataquest estimates that industrywide mainframe revenue and unit shipments will decline by 2 percent in 1991. This expected mainframe market contraction is the result of the following:

- In the current recession, businesses are holding back on large capital expenditure, such as for mainframes.
- Customers are expected to delay some mainframe purchase decisions until IBM announces further models of Summit—the result: a dip in the mainframe market. Amdahl, HDS, and IBM all introduced new mainframe products in the fall of 1990, with availabilities ranging from third-quarter 1991 through second-quarter 1992.

This is the expectation for the mainframe market in 1991, but what about the future? There are two different perspectives for the mainframe market after 1991: perspective number 1—the mainframe market will recover and grow; and perspective number 2—the unit sales and revenue of mainframes will be impacted by distributed computing solutions involving midrange systems, workstations, and PCs.

PERSPECTIVE NUMBER 1: MAINFRAMES WILL RECOVER AFTER THIS ECONOMIC DOWNTURN

Mainframe sales will surge and stabilize after the economic downturn; it's inevitable. The demand-driven market forces act like unbreakable rubber bands—they can only be stretched so long, and then they bounce back. Users' needs for mips and on-line storage will continue to exceed previously unthought-of levels.

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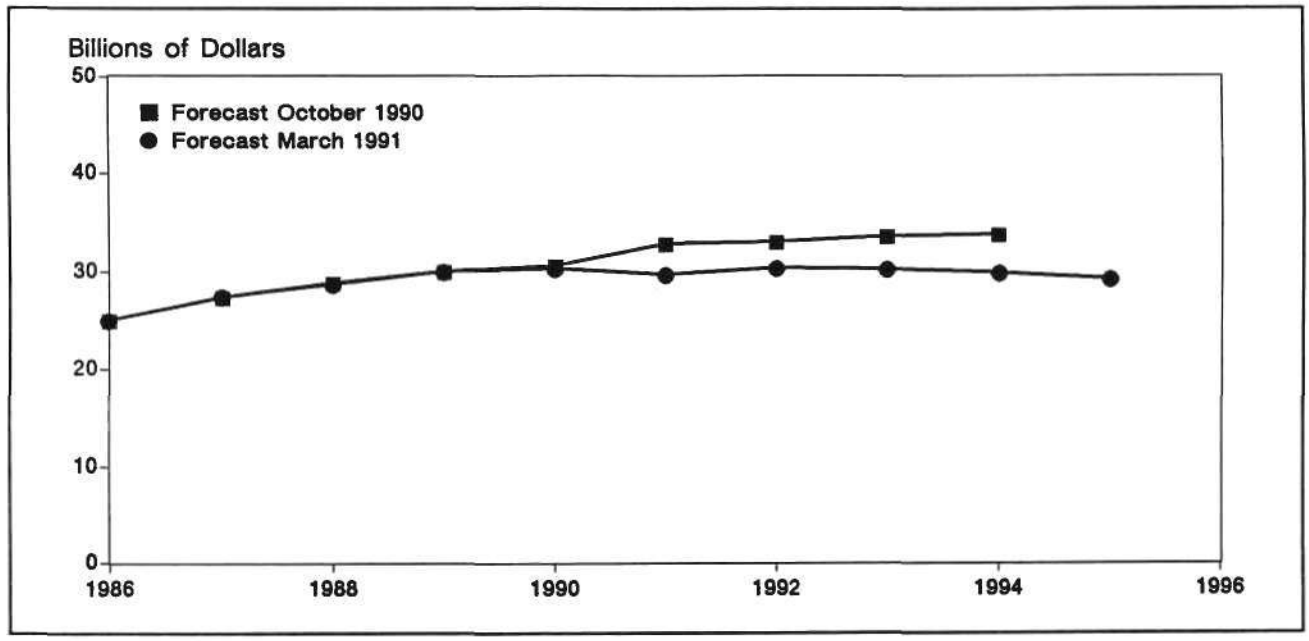
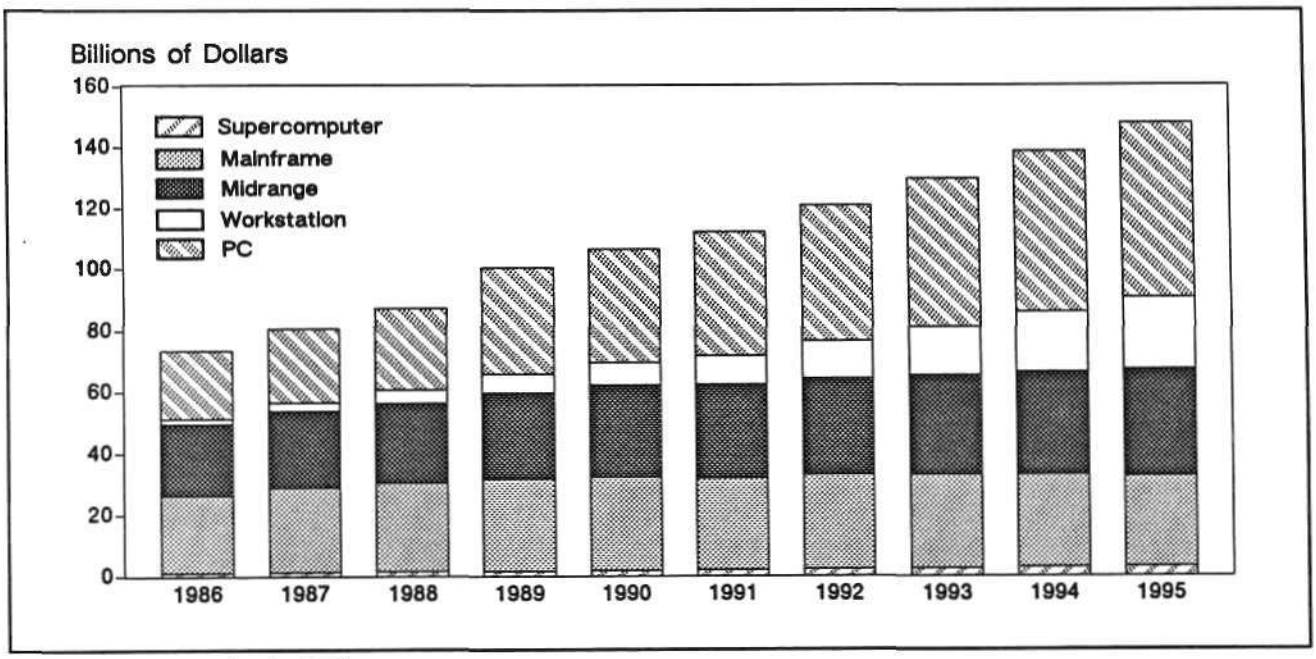
FIGURE 1
Mainframe Forecast Change



Source: Dataquest (April 1991)

FIGURE 2
Worldwide Computer Systems



Source: Dataquest (April 1991)

There is a simple reason that mainframes will always have a major presence in the marketplace; it is an issue of data. Who owns, manages, and controls the data? There can be only one traffic cop. This is the gist of 25 years of hard-learned lessons in the information systems business.

There is no question that networked PCs and workstations are rapidly gaining dominance of the desktop. And, similarly, there is no question that mainframes are rapidly evolving to accommodate these changes as the industry evolves. In the future, mainframes will control the data and serve out subsets of data to networks of midrange, desktop, and deskside machines. Those smaller machines will then do the processing locally that they do more efficiently than the mainframe.

The key word is evolve. The industry does not change by revolution. That has been demonstrated repeatedly. The 1970s were filled with dire predictions that the midrange would obviate the mainframe. It never happened and will not happen. Similarly, workstations and PCs will not obviate the mainframe either.

The following reviews some of the specific reasons that vast farms of networked PCs and workstations obviating mainframes is a myth:

- There is a vast investment in mainframe data, applications, and infrastructure, and it would not make economic or practical sense to make a replacement in the short to medium term. Large data centers requiring and utilizing terabytes of data and thousands of transactions per minute simply cannot scatter, without control, to midrange systems. When these organizations need more capacity, they will buy a larger mainframe.
- Software and data currency on a mainframe is an issue of paramount importance. Keeping a distributed farm of PCs or workstations at the same level of currency in a heterogeneous environment is a nearly impossible task, particularly if the end users are ignorant about such issues or simply do not care. Tasks such as maintenance and upgrades are routine on a mainframe but are horrendous on a farm of thousands of networked PCs or workstations.
- At some level, mainframe software actually becomes cheaper than multiple licenses of PC software. In the words of one chief information officer, ". . . until you've upgraded 4,000 copies of OS/2, you haven't lived."
- A primary reason that companies buy mainframes is for reliability. A significantly large portion of hardware on a mainframe is for reliability checking; there are checks on everything.
- Subsecond response time is an absolute requirement in today's computing systems. Identifying the nodes and managing the traffic between distributed databases of thousands of gigabytes is a complex issue, and it will take longer to service a request in that environment than in a centralized mainframe system.
- It is important to differentiate between the theoretical and practical costs of mips. Workstations claim to be cheaper than mainframes as they can be acquired at $1,000/mips. It is important to consider, though, how frequently those mips are used. Mainframes typically have full-time staffs of people who tune performance in order to keep utilization high, often 24 hours a day, 7 days a week. The majority of workstations sit idle until a user sits in front of a workstation, which generally is not the case after hours.

There is no question that the role of mainframes is changing. In fact, the evolving distributed or client/server architecture will ensure a solid position for mainframes in the future. Mainframes will manage huge data repositories in the future and act as servers to desktop machines. The mainframe will make data available for flexible application development on smaller machines.

The key problem in the industry today is not dollars/mips, which is what the workstations solve, but reducing the applications backlog. Past studies have indicated that in the federal government less than 5 percent of the applications developed are used as planned. The rest either are abandoned during development or come on-line too late to be useful.

Just as in the '60s, '70s, and '80s, all studies in the '90s indicate that the applications backlog is growing across the industry and is not being reduced in size. Mainframes will play a key role in providing the backbone for a heterogeneous, client/server computing environment that will forever be trying to keep up with insatiable user needs.

This view is not shared by all, however.

PERSPECTIVE NUMBER 2: THE DEMISE OF THE MAINFRAME

A strong case can be made that the recent IBM bombshells are not solely a case of an industrywide slowdown but, rather, are more indicative of several phenomena. The distributed computing phenomena (for example, PCs and workstations) are finally impacting IBM's hallowed mainframe and midrange business. The movement away from expensive, centralized computing that

began five years ago and negatively impacted the smaller players such as Data General, Prime, and Wang has moved precipitously into the larger vendor bases such as Digital Equipment Corporation and Unisys, and might now be finally affecting IBM.

Distributed computing solutions will cause applications (such as transaction processing and order entry) to migrate from the mainframe. Companies are beginning to consolidate their data centers, and, as a result, these data centers will be much bigger. As they do consolidate, they will use fewer numbers of mainframes.

However, this consolidation will not eliminate the need for a mainframe class of computers. As a result of this consolidation, there will be a reverse flow of data to centralized data repositories on the mainframe. Data will migrate to "data warehouses," especially as companies discover that it is now possible for them to assemble and centralize data that they could not keep in one location previously, such as centralized customer lists and credit reports. This will result in the continuation or possible proliferation of large data centers. The mainframes that these companies consolidate toward will have to be more powerful systems, but there will be a smaller number of these mainframes installed.

Other factors fueling the long-term decline of the IBM mainframe business beyond this current lull include the following:

- IBM's success with its greatly improved RS/6000 workstation almost certainly has convinced IBM's laggard technical application mainframe users (CAD/CAM and scientific applications users, for example) to begin the long-awaited move from the mainframe and down to workstations that offer much better price/performance. Indeed, IBM claims that a staggering 10,000 RS/6000s were shipped in December, which coincides with the availability of IBM's leading CAD/CAM packages (CADAM and CATIA) on the RS/6000.
- A recent Dataquest survey conducted with 300 mainframe users indicated that 74 percent are either investigating, currently migrating from, or have completely migrated from mainframes to distributed solutions.
- The rapid advances and introduction of IBM mainframe connectivity products now incorporated within PCs and workstations are giving users more cost-effective access to mainframe databases and applications without increasing mainframe cycle loading, thereby lessening the demand for additional mainframe capacity.

In the open systems market, IBM is now facing several threats to its mainframe business:

- European or U.S. government customers are now requiring open systems, not IBM proprietary hardware and software solutions.
- IBM is facing stiff competition from Fujitsu, Hitachi, ICL, and NEC in the form of better price/performance. IBM's only other serious competitor previously was Amdahl in the open systems market.

Open systems mainframes will finally pass through that magic wall where the performance and reliability are so high that users will start to be more interested in average selling prices than they are today and will buy systems based on price, not name recognition. Certainly Fujitsu, Hitachi, ICL, and NEC will be willing to produce mainframes that are less expensive than IBM's.

Given the recessionary outlook for much of the world this year, big-ticket purchases such as mainframes are certainly going to be canceled or postponed as IBM has cautioned and Dataquest has forecast. It stands to reason, therefore, that if mainframe users can live without adding mainframe capacity for a year by opting for more reduced-cost solutions such as PCs and workstations, they may choose to continue this course and never return to a meaningful level of mainframe buying activity. In any case, the real question regarding the fall of the mainframe is not a matter of if, but of when. Triggered by the recent IBM announcement, the beginning of the end for mainframes may indeed occur in 1991.

CONCLUSION: THE DATAQUEST FORECAST

Although Dataquest analysts have differing perspectives on the ultimate fate of the mainframe, all agree that the mainframe forecast should be revised downward. Figures 1 and 2 reflect this revision.

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Research Newsletter

DISTRIBUTION CHANNELS: CAD/CAM/CAE 1990

EXECUTIVE SUMMARY

Indirect channel sales grew steadily in 1990; CAD/CAM/CAE vendors continued to invest heavily in indirect distribution systems. While indirect channel sales increased as a percentage of the market, OEM channel sales decreased. For turnkey vendors, the attractiveness of OEM distribution declined. This newsletter looks at evolving distribution channels in the 1990 CAD/CAM/CAE market.

Channel Definitions

Channel definitions are as follows:

- Direct sales to end user—The sale of equipment directly to the end user by a vendor that contributes significant development or integration to the product
- Indirect sales (dealers, VARs)—Product resellers selling to end users
- OEM sales—Product resellers that integrate hardware, software, and services, add their own label to the product, and back up their warranties
- Total distribution channel sales—The sum of direct, indirect, and OEM sales. Dataquest does not report OEM revenue in its market totals to avoid double counting revenue.

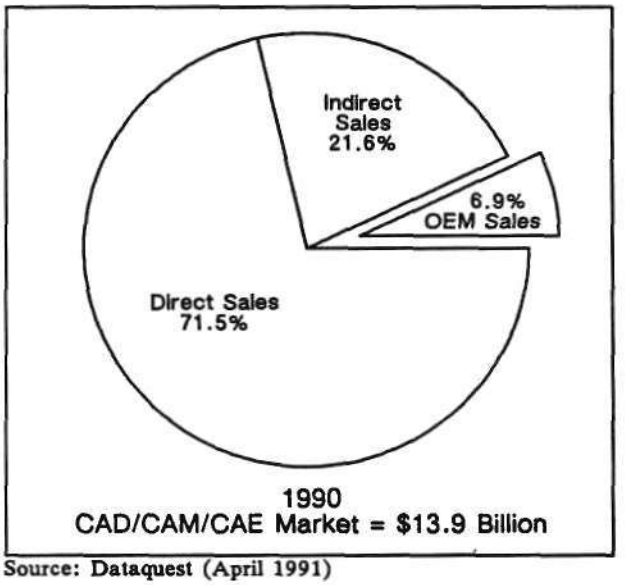
A NEW MARKET PIE

The CAD/CAM/CAE industry relies predominantly on direct sales. Indeed, direct sales to end users accounted for over 71 percent of the total market. Figure 1 depicts the CAD/CAM/CAE market *including* OEM revenue. In 1990, indirect sales (VARS and dealers) were over 21 percent of the total CAD/CAM/CAE market, and OEM sales were 6.9 percent.

Many companies looked to the indirect channels for cost-effective ways to build and streamline their distribution systems and thus allow them to focus their direct sales force on strategic or high-volume accounts. In general, companies have found it difficult to maintain a direct sales channel when the average sales price (ASP) per seat falls below $30,000. Yet most CAD VARs cost-effectively sell seats in the $17,000 to $20,000 range. Therefore, it is not surprising that as system ASPs have declined, more and more sales have fallen into the CAD VAR/dealer range, making it more practical for companies to shift their distribution to that channel. This trend will undoubtedly continue.

Even though OEM revenue is decreasing overall, those companies with OEM revenue continue to have an extended market influence. This

FIGURE 1
Total Distribution Channel Revenue



Source: Dataquest (April 1991)

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additional influence stems from the stronger competitive position a company often has because of its "hidden" OEM revenue. The OEM revenue is "hidden" in the sense that Dataquest does not report OEM revenue in its market totals in order to accurately represent the market and thus avoid double counting.

An example of a company that has a stronger competitive position because of its OEM revenue is Digital Equipment Corporation (DEC). (See Figure 2, which ranks top CAD/CAM/CAE companies by market position and segments by distribution channel. Note that data in this newsletter may vary slightly from Dataquest's previously published results. The CAD/CAM/CAE Industry Service group is currently updating its company data and will publish final market share results in June.) DEC's 1990 CAD/CAM/CAE revenue through all distribution channels including the OEM portion was $1.3 billion. However, DEC's actual market share position is based on $891 million in revenue, the company's total CAD/CAM/CAE revenue minus the OEM portion. This comparison demonstrates that DEC, with its OEM revenue included, is more strongly positioned as IBM's direct competitor. Thus, although OEM revenue cannot be considered when looking at market share position, it can be a significant factor in evaluating a company's competitive position.

THE HIDDEN OEM SLICE

DEC holds the number one position in total OEM sales with approximately $425 million in revenue. However, Sun Microsystems Inc. is gaining rapidly because of strong overall company growth (see Figure 3). Sun is the only major hardware vendor that is showing growth in OEM revenue, though as a percentage of sales, OEM revenue has been decreasing since 1988. Of the top six companies with OEM revenue, four are major hardware vendors. The other two, CADAM and SDRC, have OEM revenue because of their software sales mainly to IBM. Some of the major OEMs of these companies are as follows:

- Sun: Prime/Computervision, McDonnell Douglas, Dazix/Intergraph, Schlumberger, Matra Datavision, and Racal-Redac
- DEC: McDonnell Douglas, Intergraph, Schlumberger, and Matra Datavision
- HP/Apollo: Mentor Graphics, McDonnell Douglas, Siemens, Auto-Trol, and Racal-Redac
- SGI: Control Data Corporation and Matra Datavision
- CADAM: IBM
- SDRC: IBM and others

In 1990, many companies shifted away from the OEM business model. Companies that formerly sold only turnkey systems, the major source of OEM revenue for the hardware vendors, continued the move to software-only sales as the costs of managing large inventories of hardware and supporting multiple platforms became evident. Companies also tended to modify their OEM agreements for different types of distribution relationships. For example, in 1990, Prime/Computervision exchanged a portion of its turnkey/OEM business with Sun for a straight distributor relationship.

HOW DISTRIBUTION BY PLATFORM STACKS UP

Technical workstations, by far the largest platform, contain the most direct sales revenue. However, a higher percentage of host-based systems are sold by a direct sales force (see Figure 4). This difference makes sense when considering the higher price tags that are attached to most host systems. At the lower end of the market, PCs are largely sold through VARs or dealers. For example, many large PC hardware and software vendors such as Apple Computer, Inc., Autodesk Incorporated, and Compaq Computer Corporation sell only through indirect channels. OEM sales are an insignificant proportion of PC distribution.

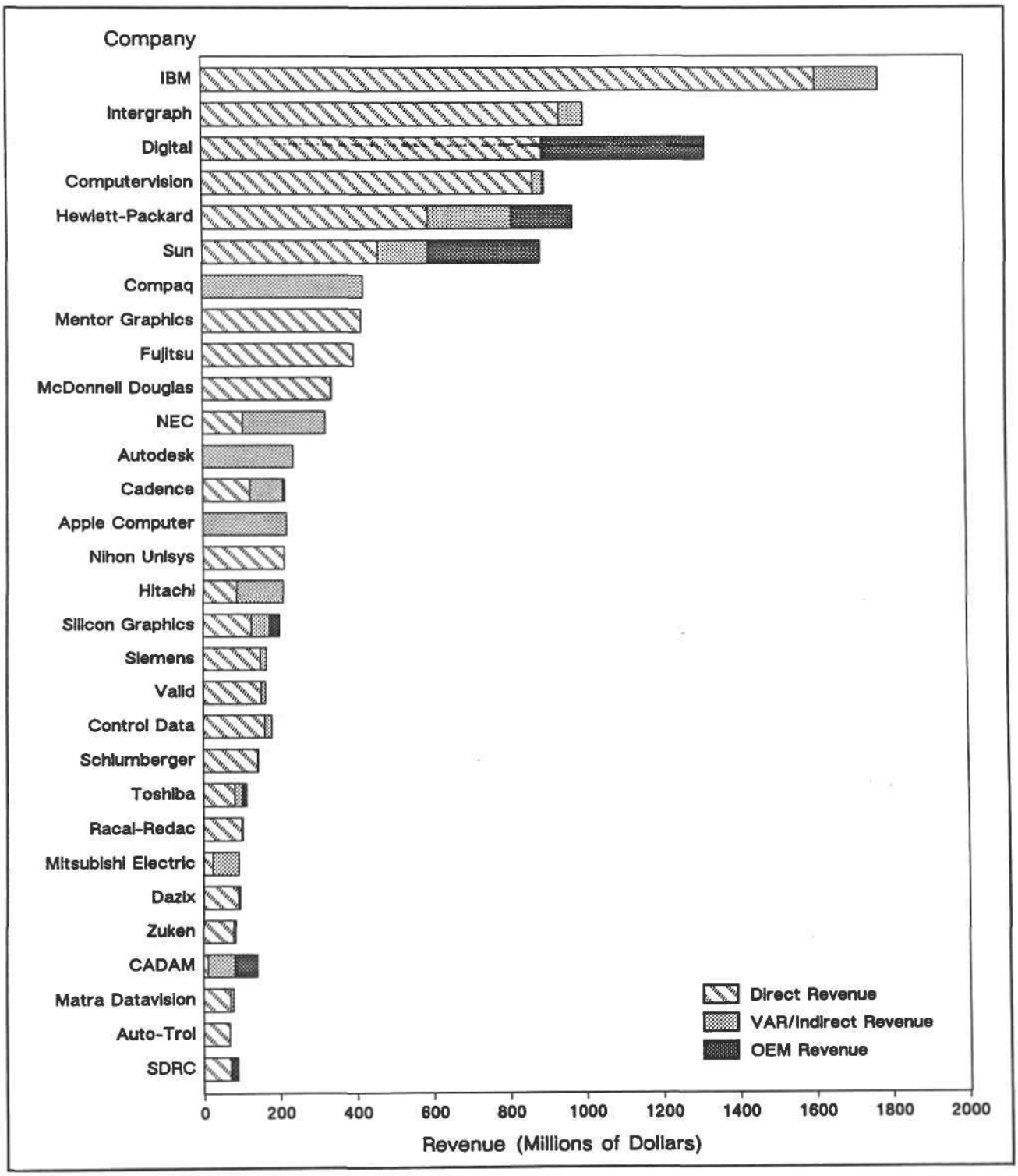
HOW DISTRIBUTION BY APPLICATION STACKS UP

Mechanical design automation, the largest CAD/CAM/CAE application area, offers the largest OEM revenue opportunity (see Figure 5). The electronic CAE application area, which has a significant percentage of OEM revenue now, should decrease its OEM portion soon as more and more EDA companies get out of the turnkey business. The AEC application area naturally has a rather high percentage of indirect channel revenue (36 percent) as it is heavily based on PCs.

HOW DISTRIBUTION BY REGION STACKS UP

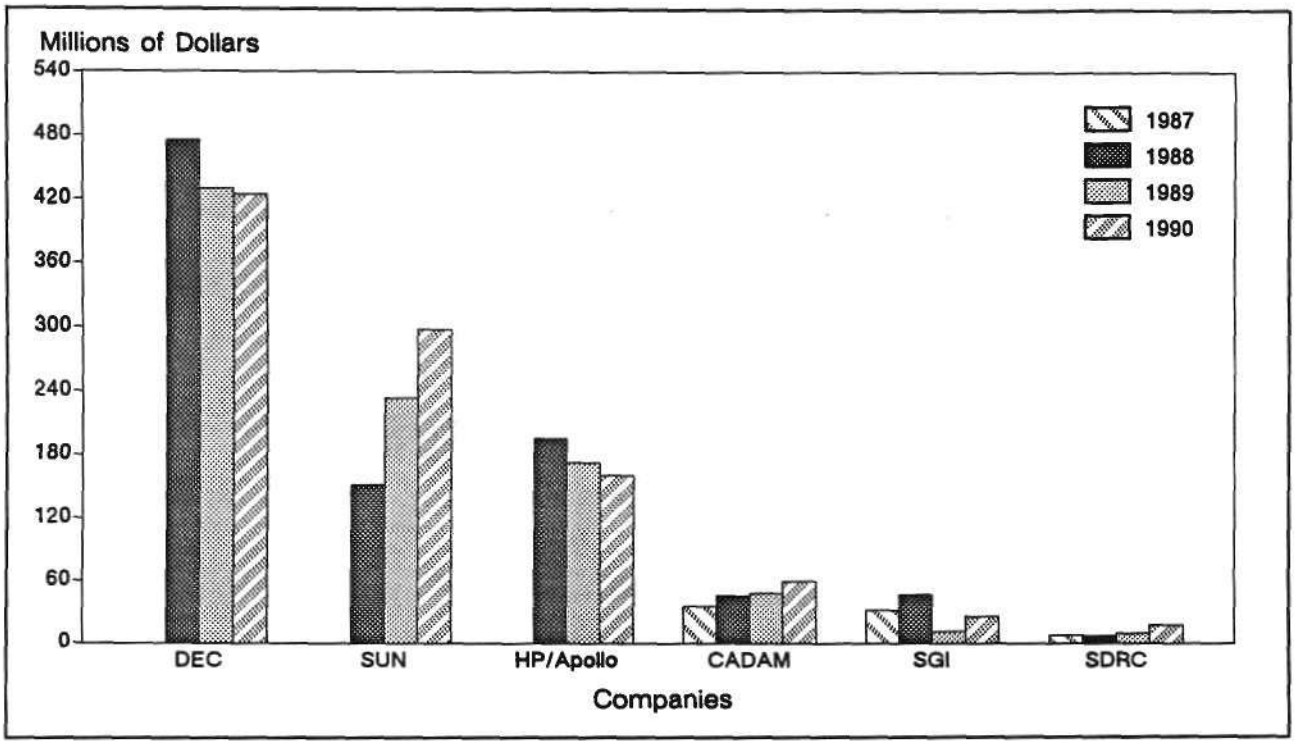
The type of distribution channel varies little by region; European and Asian companies tend to

FIGURE 2
CAD/CAM/CAE Companies Ranked by Market Position and Segmented by Distribution Channel Revenue



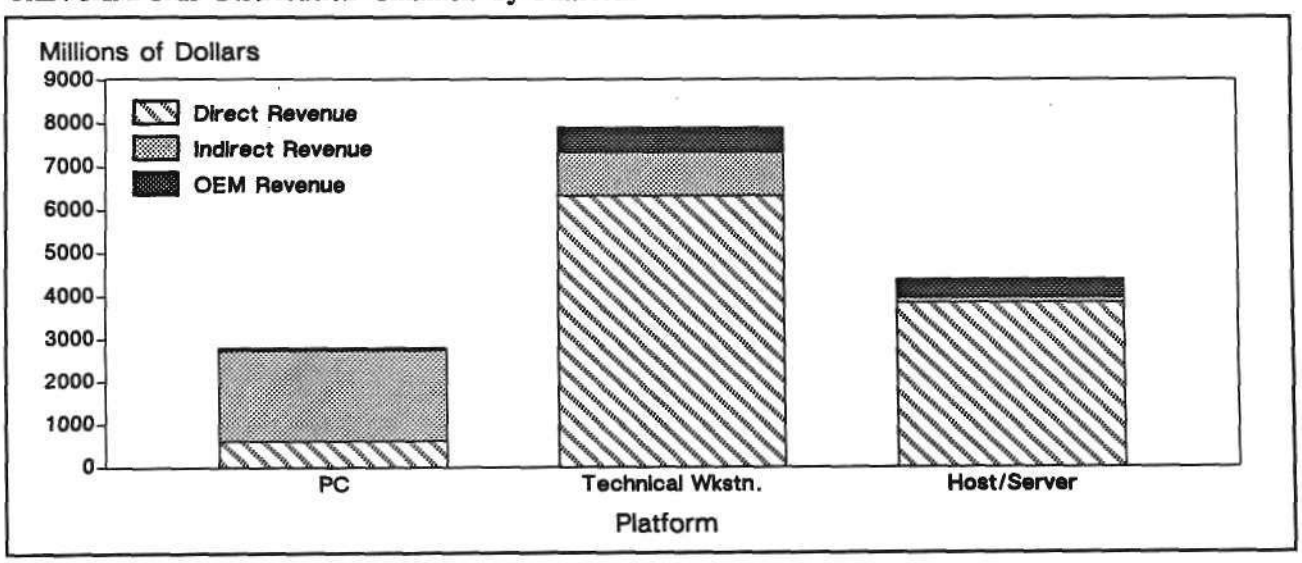
Source: Dataquest (April 1991)

FIGURE 3
Top OEM Companies in the CAD/CAM/CAE Market



Source: Dataquest (April 1991)

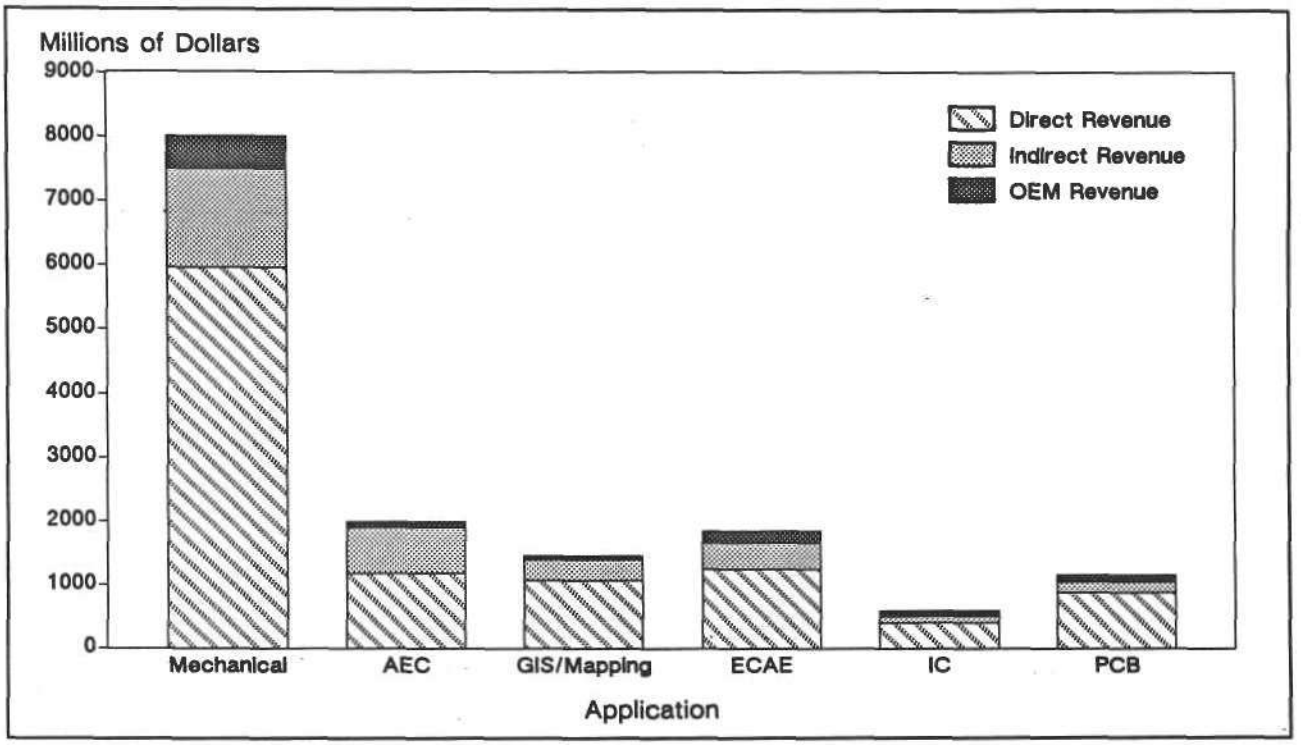
FIGURE 4
CAD/CAM/CAE Distribution Channels by Platform



Source: Dataquest (April 1991)

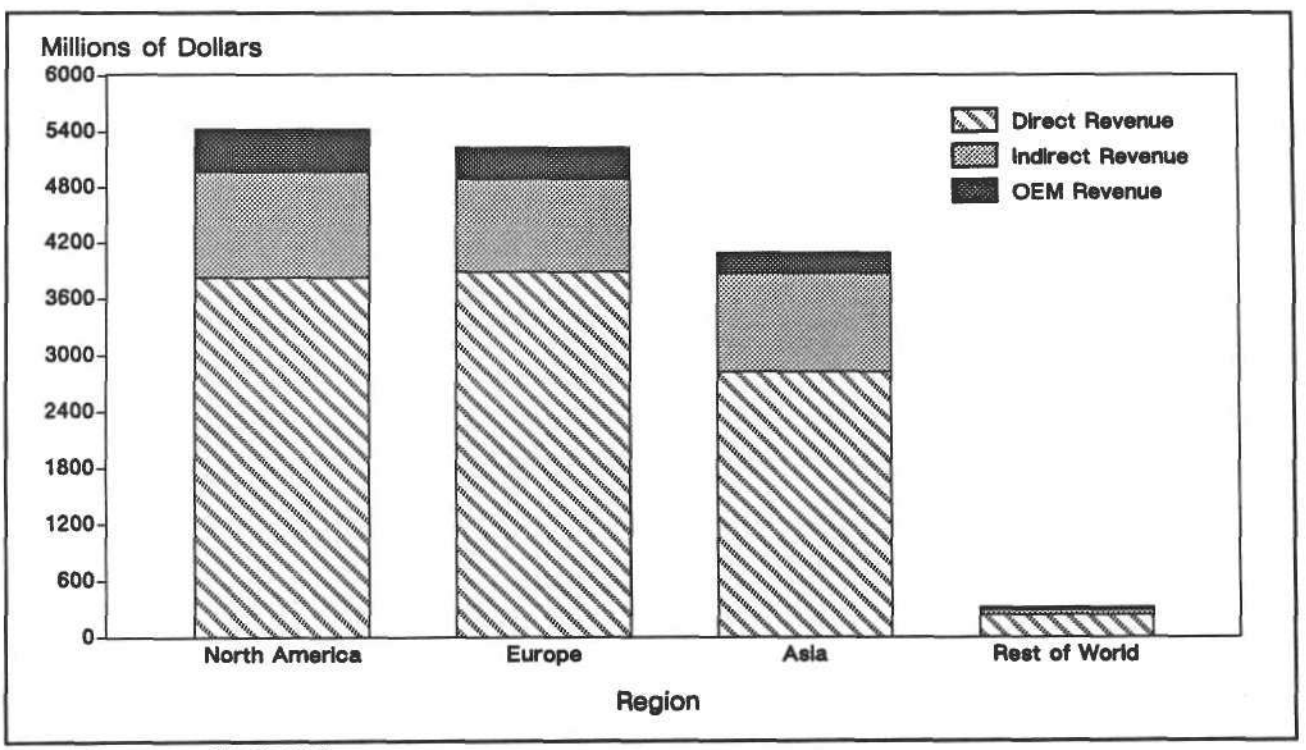
use similar methods of distribution and in the same proportion as North America-based companies when selling at home versus abroad. However, in Europe and Asia the indirect VARs often sell workstation-based products and generally sell to an exclusive territory, while U.S. VARs are more likely to sell PC-based systems without benefit of territory protection (see Figure 6).

FIGURE 5
CAD/CAM/CAE Distribution Channels by Application



Source: Dataquest (April 1991)

FIGURE 6
CAD/CAM/CAE Distribution Channels by Region



Source: Dataquest (April 1991)

DATAQUEST PERSPECTIVE

Distribution channels are the strategic weapon for the 1990s; companies that have made significant investments in their channel systems as well as refined their distribution strategies by platform, application area, and region will be well poised for future growth. Growth will largely occur in indirect channel sales. The CAD/CAM/CAE industry that previously relied on direct sales will tend to rely more and more on indirect channel sales. To achieve growth in indirect channel sales, companies will increasingly partner with VARs and dealers as well as develop programs that work with their indirect partners and allow the indirect partners to work with end users. The primary obstacle will remain the same for all: developing programs that are profitable for all participants selling the product.

Melanie Meyer

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Research Newsletter

IMPLICATIONS OF AN ALLIANCE

Many rumors are afoot about a possible alliance involving Compaq, Digital Equipment Corporation (DEC), Microsoft, MIPS, and the Santa Cruz Operation (SCO). The purpose of this newsletter is less that of dealing with rumors than of using this situation as a framework for discussion.

In the current business climate, the world is dividing into sets of competitors resembling clans more than cabals or cartel, as they are usually presented. These alignments tend to be along business, technologies, and market issues and present a new environment for doing business. Dataquest believes that these alignments will become more or less permanent and resemble the business relationships in Japan. This newsletter discusses the issues raised by a possible alignment of the above-named players (the alliance) and the forces driving it.

MARKET DYNAMICS

The survivors in the computer business will exhibit some of the characteristics of the Japanese companies, specifically patience, persistence, an understanding of the interplay between the tactical and the strategic, cooperation, and a deep and close examination of the competitive environment. The major focus of this effort will have to be on small systems—the PC, the workstation, and the small multiuser computer (usually based on a PC or a workstation).

Patience, Persistence, Tactics, and Strategy

Microsoft Corporation exemplifies the characteristics of patience, persistence, and the interplay of tactical and strategic maneuvering to achieve its goals. Microsoft has built a dominant position on the PC desktop through several stages. When the opportunity came to design a PC operating system for IBM Corporation, Microsoft seized the opportunity lost by Digital Research Incorporated.

As the market grew, Microsoft took a position in major applications with Word and Excel and provided major development tools on DOS for independent software vendors (ISVs). An opportunity became a strategy.

Microsoft expanded its strategic position with work on Windows and OS/2. Anyone who has suffered through the introductions of Word and versions of Windows knows of Microsoft's persistence and patience. If this company does not get it right the first time, it certainly will keep at it until it does! No other PC product has led the market as Windows 3.0 has done!

Microsoft is not the only company to exhibit these characteristics, but it is the best example in the largest computer market (PCs).

The Future and Small Systems

A large part of the computer market has looked askance at low-end systems. The PC was often called a toy computer and Microsoft condemned for trying to be UNIX, but forever falling short. Workstations were denigrated as crippled minicomputers. The denigrators usually were focused on large systems, with large margins and large overhead organizations to support.

In justifying their existence, the companies working in the high end overlooked a simple truth, the owner of the low-end market owns the future. The real dynamic in the market is the real world itself!

As economies change, new organizations are formed at a high rate. "New" includes new units and downsized units inside larger organizations. New organizations, by definition, have small budgets, and buy small systems (both desktop and

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multiuser). New organizations are also the major source of new business (as opposed to installed-base sales of new systems). Some new organizations survive and become old large organizations—thus, new organizations are a major source of downstream growth.

In computer business terms, the desktop is the system for new organizations. Small multiuser systems are based on desktop technology. Thus, the owner of the desktop owns the future! There are two major contenders for the desktop: Microsoft, the current champion, and Sun Microsystems, Inc., the new kid on the block.

Cooperation

The computer business is too big for one company to be able to provide all the technology or to reach all the users. Even IBM has limits on what it can develop and what it can deliver. Beyond those limits, each company has its cultural limits. New technologies, products, and markets are accessible only to those companies that believe in and understand these manufacturers.

Product cycles for small systems are in the 9- to 15-month range. Any of the players in the Alliance could put together a system based on a RISC chip. Putting together the right system, with all the required software, and delivering that system through the many sales channels are difficult tasks. These three tasks are so daunting as to make the creation of the hardware portion seem a small task.

The list of systems, networking, and application software needed to sell into multiple markets is very long. Acquiring that software and integrating it is now the major barrier to market entry. The only way to acquire the software is through a combination of alliances and leveraging of standard software platforms.

Microsoft's structure for delivering MS-DOS is one example of cooperation between vendors and leveraging of a standard platform. UNIX International and the Open Software Foundation are other examples from the UNIX world.

Microsoft is the premier example of cooperation and is the only player aligned at some level with all of the warring camps in the computer industry. It remains to be seen how many organizations Microsoft can align with before counterforces set in and break up some of the relationships. The strains appearing in the relationship between Microsoft and IBM exemplify the problem. By definition, a company can have only a limited amount of strategic alliances. Put another way: In a world where everyone cooperates, there is no need for strategy!

The Competitive Environment

The major influences in the competitive environment of the computer industry today are Intel Corporation, IBM, Microsoft, and Sun Microsystems. A considerable amount of the market dynamic revolves around this set of players. A major motivator in the market is to avoid being totally controlled by any one element and avoiding having to pay royalties to a competitor. Freedom of choice and a level playing field are restatements of those major motivators.

Intel

Intel has a large market built around the 80x86 design and PCs. The market is huge and open but Intel seems determined to privatize it. Vendors are nervous at the prospect of Intel being a sole source. Meanwhile, the technologists beat the drum that RISC is the future. If RISC is the future, Intel will certainly have a share, but it won't dominate this market as it has in the PC market. Intel's attempt to control 80x86 technology is a major motivator for companies to seek alternatives.

IBM

Then there is IBM. Obviously, IBM's real interest is not open systems, in spite of the PS/2 and AIX. IBM's corporate direction is to lead users to its System Application Architecture (SAA), PS/2s, OS/2, and to the 390. Many users will follow the IBM track, for many good reasons, and many others will not for as many good reasons. Competitors will still have to operate in and around the IBM environment, but they will take every step they can to avoid paying royalties to IBM for technology. In the past, a company would look for IBM to provide an operational umbrella. IBM is raising the cost of operating under its umbrella.

Microsoft

Microsoft is trying to be the major player on the desktop, in the client/server environment, in networking, and in the data delivery (CD-ROM) games. Microsoft is working to lead the desktop and the client/server markets with its work on a system beyond current OS/2, labeled New Technology (NT). NT will run DOS and Windows

applications, which brings the desktop market to NT. This product will cover UNIX and client/server applications, by being POSIX and XPG3 (X/Open) compliant and providing X Window facilities.

Microsoft is showing considerable success with its strategy but faces two major threats: Sun Microsystems and UNIX. UNIX has the potential to forestall NT as the client/server OS, and the SPARCstation from Sun has the potential to be the new standard desktop. If Microsoft can stop Sun, it may stop UNIX in the bargain.

Sun Microsystems

Sun demonstrates another quality of Japanese companies, learning from the competition. The SPARC strategy is a leaf from the PC book: Create a standard platform and make it accessible to as many other players as possible. The difference between IBM and the PC and Sun and SPARC is that Sun sees the SPARC clones as strategic to its business. Sun also sees the advancement of the SPARC technology as strategic. Scott McNeeley, CEO of Sun Microsystems, has stated that the primary reason IBM fell to a 12 percent share in a PC market it created is that IBM went seven years without any engineering investment in improving the PC. The appearance of 25 SPARC clones to date has caught everyone's interest. Companies are not waiting to see the effect but are taking action now.

TECHNOLOGY

When all is said and done, technology and the issues surrounding its implementation drive the electronics industry. Digital audiotape (DAT) and RISC are facing standards and distribution issues. Surround-sound TV and Windows 3.0 are succeeding by leveraging a standards base. Betamax is taken as an example of the failure to understand standards issues. If we really understand these issues, then why didn't Beta learn from the 8-track, 4-track, cassette-tape battle in the audio market? Why has Super VHS failed? It is not a given that RISC, NT, UNIX, or OS/2 will dominate the low-end market. Any company could, including a player to be named later. It is a matter of execution and luck.

The major deficiency of the IBM PC market has been that it grew so fast that not even IBM and Microsoft did much to improve the technology for many years. The market waited for Intel to engineer better and faster systems. Certainly the other players contributed little, if anything at all, to technological progress in the IBM PC market. The workstation market in the meanwhile has been a maelstrom of change and improvement, and now the day has arrived when workstation pricing is intruding into the PC market.

The Alliance

The above discussion provides a context for the alliance. How can these players come together to dominate a market or a major segment of a market? What are the individual concerns that might bring them together in a (hopefully) synergistic combination? The alliance would be driven very much by the threat of Sun Microsystems and IBM.

MIPS

MIPS, as a chipmaker, is dealing with several competitive threats. Intel-based systems are coming up from the PC into MIPS' market strength (workstations). The various RISC camps are using the PC-clone approach to build a market, i.e., providing chip sets that enable a flood of new competitors to enter the market. The SPARC group is having the most notable success with this approach. Finally, there is the threat that IBM will make the chip set used in its RS6000-series workstations available to system builders.

MIPS needs a breakthrough approach to broaden its market. The alliance, and especially Compaq, could bring in a group of PC vendors looking for differentiation and new markets.

MIPS brings particular strength in the performance of its RISC chip set, the quality of its compilers and operating systems, and high-profile design wins with DEC, Silicon Graphics Inc. (SGI), Wang, and other companies.

Compaq

Compaq faces competition with IBM and the other PC vendors on one hand, while looking at SPARC entries into its market. Compaq differentiated itself initially by producing the first good portable computer, gained a reputation as the quality manufacturer, and then took an architectural path with EISA. If Compaq does not continue down a differentiated path, it faces paying royalties to its competitor (IBM), while playing catch-up on SAA specifications at Fortune 500 companies.

Compaq has put one stake in the ground with EISA; it is clear that Compaq has little intention of

following IBM down its architectural path. The PC-clone issue is no longer IBM PC compatibility, but rather PC-application compatibility. There are several solutions to compatibility without using an Intel-based PC architecture.

Compaq's overtures to SGI bring the issue more into focus. SGI brings entry into the high-end workstation market, high-end servers, symmetric multiprocessing (SMP) on RISC, some of the best graphics systems and MIPS design skills, and a set of MIPS-based workstation graphics boards designed for PCs to a relationship with Compaq.

Compaq has great strength in the PC market. The company has high acceptance in Fortune 1000 companies and a pure undiluted indirect sales channel. Dealers appreciate Compaq because it has no channel conflict. MIPS and SGI have a similar approach to channel management.

Compaq is also the system of choice for many XENIX VARs, which principally sell to small business. A large percentage of Compaq's 386/486 sales are into this small business market. Compaq's SystemPro is an attempt to move up into the minicomputer market and over into the Fortune 1000 server market. It is difficult to sell mini/server systems through a dealer channel, and it is hard to build the sales force and indirect channel without conflict with the dealer channel.

Compaq needs bigger, better, and differentiated systems. The company needs better product for its dealer channel to hold onto its market, and it needs a differentiated (from the PC) system to sell into the upscale market without channel conflict.

DEC

DEC is committed to MIPS technology in its workstations, which have been DEC's most successful desktop systems to date. DEC has never shown strength on the desktop and cannot afford to miss the boat again. Although the company has an excellent relationship with Tandy Corporation for 486 systems, that approach seems more tactical than strategic.

DEC is trying as ever to move into IBM's turf, while IBM seems to be moving DEC's way with the RIOS architecture. DEC also needs an alternative to SAA and OS/2. Like Compaq, DEC does not want to compete with a company to which it also pay royalties.

DEC brings great midrange strength; a strong position in technical markets; and a wealth of networking, system architecture, operating system, and software tool expertise to the party. The networking and market expertise could be DEC's greatest strengths in following the path of a new architecture.

Microsoft

The colossus of Redmond, Washington, has its own problems and viewpoint. The bet on OS/2 has not paid off, while Windows 3.0 has been the greatest breakaway software product since Lotus 1-2-3. IBM has its own agenda for OS/2, called SAA. Because OS/2 has not taken off, Microsoft has been working on a new strategy based on OS/2 3.0, the NT OS. Windows *will* be the interface for NT.

Does the world need another operating system? No! Will it buy one if it is invisible, conforms to standards, performs well, and is cheaper than UNIX? Yes! UNIX has not been a real threat to anything Microsoft does until the last two years. X Window, Motif, and Open Look bring the windowing environment, which looks a lot like what PC users want. Meanwhile, PC ISVs have tired of waiting for the Presentation Manager environment and developed useful UNIX ports. UNIX workstations connect quite well and offer an excellent alternative to PC LANs.

Why then haven't PC users flocked to UNIX workstations instead of PCs? There are several reasons. The cost of UNIX is too high (some systems are priced at $13,000 for a business desktop), and the packaging is not right. UNIX vendors are not selling the right things to the right people. Another reason is that UNIX is all things to all people. UNIX takes a bigger system than OS/2; this is unnecessary. There are too many vendors working on UNIX. It is not where it needs to be for the average office PC desktop. Microsoft's competition is OSF, UI, and others like these.

Microsoft is betting that an OS optimized for the desktop will be better than a UNIX solution if it performs well and is priced right. NT is that bet, and the platform could be a MIPS RISC system designed by DEC and SGI, manufactured and led into the market by Compaq.

SCO

Where does SCO fit into all of this? It is obvious that hardware could be designed and built before NT will be ready. No one wants to be in the position of the IBM RS6000, which was ready a year before the new, improved, AIX version of UNIX. SCO can have both XENIX and its UNIX 5.3.2 with the Open Desktop running as soon as the hardware is ready. UNIX is also an excellent

development platform, and Microsoft and SCO could deliver development tools for NT so that ISVs can be working on product introduction.

SCO's function is purely a tactical one. This company brings real product and applications until the NT is ready. SCO also gains a powerful new platform for its large market of VARs and in-house developers. SCO has been undisturbed in its own niche but is feeling heat from a new generation of systems that offer alternatives to SCO. SCO would also be in a favorable position to be a second source for the NT OS.

Dataquest Perspective

All of the above scenario is speculation. Even if all of the named players are in fact working on an alliance to execute the scenario, it might never happen. Cooperative ventures, like mergers and acquisitions, are fraught with peril. All of these companies have at least one relationship that could be affected adversely by such an enterprise. All have good reason for sticking with what works for them.

Given that all might go wrong, such an alliance has much to recommend it. All of the players have a lot at risk if they stay put. All of the players have many or all of the correct corporate characteristics. There is enough horsepower in the alliance to both execute the technology and make it work in the market.

The major drawback of this scenario is the companies that are excluded. There is a purely American flavor here. Both the Europeans and the Asians may not be pleased if they are not included.

If IBM is not your friend, it's best to have it in your market as a price umbrella. This alliance excludes IBM or conversely, it is hard to see IBM adding this product to its SAA Nexus of the 390, AS 400, RS6000, PS/2, and OS/2.

What are some other possibilities? How about an alliance between AT&T, Motorola Incorporated, Fujitsu, and a Russian group? Or, a working relationship among NeXT Computers, Mach, the Hewlett-Packard Company, Hitachi, NEC Corporation, Bull, and NCR? Or, a working group may be formed by MtXinu, Lynx, Kodak/ISC, Unisys Corporation, Siemens, Tandy, and an aerospace firm to be named later.

The PC market is at a juncture. Will it meet and fight to the death with workstations? Will it move to the Intel 586 or to RISC? Will the architecture be MCA or EISA? Will the operating system be DOS 5.0/Windows, OS/2, or UNIX based? Can all this change be accommodated while still maintaining application compatibility? Other factors are at work. Some SPARC-based systems masked as PCs will enter the market this year or next. PC vendors are evaluating 32-bit and greater processors (both RISC and CISC) and making decisions on their next generation. OS/2 is not taking off, but Windows 3.0 is.

In spite of the conventional wisdom that users do not care about technology, just applications, customers do buy technology. There is not just the cachet of having the latest thing, there is the very real issue of buying safe technology and then facing premature obsolescence of your purchase. As an example, economically, fast 286 PCs are the best buy, and they run everything important—but they *may* not run the new generation of applications being developed for Windows and UNIX. Many users are looking on 386 or 486 PCs as the only reasonable choice.

Meanwhile the workstation market is having a crisis of its own. RISC is taking over. Products are standardizing. Costs are declining, capacity is up. PC vendors are trying to move up into workstation turf. The industry is looking covetously at the office market. With everyone getting connected, workstations with X Window are looking like a good solution. Everyone is running faster to stay in place. The market is changing and at a change point, there is opportunity.

Paul Cubbage

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Research *Bulletin*

SPARCSTATION IPC: PACKAGING, PACKAGING, PACKAGING

THE ANNOUNCEMENT

Location counts in real estate, but in the commodity computer market the three most important features may be packaging, packaging, and packaging. On July 25, Sun Microsystems addressed the look and feel of its product line and announced one new computer, one new distribution channel, and the second version of OpenWindows.

Announced as "the first certified clone of the SPARCstation," the 12-pound SPARCstation IPC essentially is a repackaged SPARCstation 1+, with dimensions of only 9.6 x 10.4 x 4.6 inches. The $8,995 list price buys a diskless 15.8-mips, 16-inch, color workstation with 8 megabytes of memory. The IPC has no GX upgrade capability, but it does offer 2 SBus slots, memory and storage expansibility, and uses only 65 watts of power. The $9,995 configuration includes a 207-megabyte hard disk.

The package for this low-priced machine would not be complete without the announcement of a new distribution channel, which has been dubbed "NVAD" (national value-added dealers). Three national dealer chains, Intelligent Electronics, MicroAge, and NYNEX Business Centers, have signed up to sell the IPC, and Sun expects more than 200 of these dealer outlets to be selling the product within a year. Sun's 300 value-added resellers (VARs) and the direct sales force also will sell the IPC, but the company has taken great care to minimize conflict among these channels, particularly because the VAR program now accounts for 10 percent of Sun revenue. The NVAD selection criteria requires a dealer to have a nationwide presence and to provide full service and support for networked systems.

The third part of the announced package is version 2 of OpenWindows, which offers a faster, updated user interface. OpenWindows will be packaged with every IPC shipped with a hard disk. However, only 100 packages supporting the Open Look user interface currently are available.

DATAQUEST ANALYSIS

The IPC clearly has been positioned to help Sun gain market share in the business environment. Because the new computer basically is a repackaged SPARCstation 1+ with a PC name attached to it, Sun must take care in its sales tactics to avoid creating channel conflict or sales erosion sales of the SPARCstation SLC or the SPARCstation 1+. As it stands now, the SLC remains targeted at low-end commercial users, where X terminals had been encroaching; SPARCstation 1+ remains targeted at traditional technical users. Now the SPARCstation IPC is targeted at high-end commercial users. Although the IPC is likely to capture up to 20 percent of future SPARCstation 1+ sales, we believe that the SPARCstation 1+ will remain the machine of choice for technical users, as it is the entry point for Sun's current GX graphics option (GX) and future high-end graphics development.

Sun now has products targeted at nearly every desktop, evidence of the company's commitment to its goal of being to the work group what PCs were to the single user. Sun has chosen to penetrate the commercial market in incremental steps, and this safe approach is designed primarily to take sales from high-end PCs and the Macintosh. A key challenge in this arena remains software. For example, offering a few of the top general productivity tools cannot compare to the DOS and Macintosh world, where users have multiple choices in any application.

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The IPC, Sun's second attempt to challenge high-end PCs, follows its disastrous initial entry with the 386i. This latest "under $10,000 color" announcement offers no technological innovations but concentrates on a new distribution channel. This new channel is artfully constructed to avoid directly antagonizing most of the existing Sun VARs, because many are focused on technical applications on the SPARCstation 1+. However, these VARs have been anticipating the ugly reality of competition for the highly profitable Sun sales from national dealer chains, and reality has hit them. The outstanding question remains: Without extensive application software, is packaging of product and distribution channel enough to achieve credibility and success in commercial markets?

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Research Newsletter

CAD/CAM/CAE CHARGES INTO THE 1990s: WORLDWIDE CAD/CAM/CAE TRENDS

Dataquest forecasts that the worldwide CAD/CAM/CAE market will experience 16 percent growth in 1990 and a 13 percent compound annual growth rate (CAGR) between 1989 and 1994. Forecast highlights are shown in Table 1 to Table 6. A detailed analysis of each of the major application areas will be discussed in the *Industry Overview* binder. The trends and observations discussed in this newsletter have been considered in preparing the 1990 update to the worldwide CAD/CAM/CAE market forecast.

GENERAL

The following are the overall trends in the general CAD/CAM/CAE market:

- There is strong demand for all applications in established international markets.
- The approach of 1992 is having an impact on investments made in computer-aided design and manufacturing technology.
- There are slowly emerging opportunities in Eastern Europe and China.
- Shrinking US defense budget reduces CAD buys in traditional applications and forces some vendors to explore new commercial markets.
- The price/performance ratio of computers continues to improve, giving incentive to buy new hardware and improving the performance of major application software.
- Host-based systems continue to decline, as users increasingly move to technical workstations and servers.
- By 1994, personal computer vendors serving the CAD/CAE market will be shipping what Dataquest defines today as a workstation, reducing forecast growth in personal computers for CAD/CAE.
- Average selling prices will experience a slow but steady decline in all product configurations over the forecast period.
- Unbundled hardware and software sales will continue to grow approximately twice as fast as turnkey sales over the next five years.
- We continue to believe that CAD/CAE software revenue will grow faster than hardware; software comprised 27 percent of total revenue in 1989, and is forecast to grow to 34 percent of the market in 1994.

MECHANICAL CAD/CAM/CAE

Dataquest forecasts that the mechanical segment of the CAD/CAM/CAE market will experience 12 percent growth in 1990 and a 9 percent CAGR between 1989 and 1994. Our forecast is based on the following trends:

- Major end-user industries are expected to experience modest growth in the next few years.
- Large users of CAD/CAM/CAE technology are making major purchases with strategic vendor partners. The "turnkey solution" is not dead. Pressure from users for integrated solutions is creating opportunity for vendors with strong development, support, and custom service capability.
- Concurrent engineering is being pursued as a major cost savings and time-to-market opportunity. Several government agencies are promoting concurrent engineering and the development of new CAD/CAM/CAE technology. The programs DARPA, RAMP, AAAP, and CAD II are examples of current activity in concurrent engineering

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with the US Department of Defense, US Air Force, and US Navy.

- The penetration levels of MCAD are approaching 30 percent overall; closer to 50 percent for drafting applications. A significant opportunity exists to upgrade or replace the fast-growing population of systems more than three years old.
- Variational and parametric input features will enhance the marketability of many software products, fueling the demand to upgrade existing systems.
- The field of knowledge-based engineering (KBE) is expected to have 50 percent or more growth in the next few years. Several concurrent engineering programs supported by the US government and large corporations are using KBE to organize such activity.
- Integrated vertical applications—such as in plastics part design, electromechanical, and specific automotive applications—are moving to higher levels of integration and broader use across an organization.

TABLE 1
CAD/CAM/CAE Worldwide Forecast by Application
(Millions of Dollars)

	1989	1990	1991	1992	1993	1994	CAGR 1989-1994
All Applications							
Revenue	$12,365	$14,284	$16,181	$18,131	$20,323	$22,815	13.0%
Systems	403,555	488,230	577,790	666,000	756,580	842,130	15.8%
Workstations	439,019	521,080	607,650	691,920	779,430	862,000	14.4%
Mechanical							
Revenue	$6,860	$7,702	$8,402	$8,970	$9,696	$10,417	8.7%
Systems	208,367	245,820	282,440	317,070	350,240	377,270	12.6%
Workstations	233,280	268,470	303,310	335,530	367,270	392,580	11.0%
AEC							
Revenue	$1,662	$1,970	$2,268	$2,585	$2,920	$3,273	14.5%
Systems	97,803	122,440	148,930	174,670	197,840	219,540	17.6%
Workstations	102,100	126,440	152,380	177,410	199,970	221,220	16.7%
Mapping							
Revenue	$1,008	$1,265	$1,527	$1,837	$2,203	$2,639	21.2%
Systems	21,159	28,780	37,550	46,990	55,730	64,540	25.0%
Workstations	23,889	31,430	40,020	49,100	57,430	65,890	22.5%
Electronic CAE							
Revenue	$1,391	$1,706	$2,090	$2,531	$2,950	$3,504	20.3%
Systems	37,128	44,610	54,140	63,310	76,170	90,770	19.6%
Workstations	38,122	45,510	54,890	63,930	76,730	91,340	19.1%
IC Layout							
Revenue	$386	$448	$541	$633	$733	$873	17.7%
Systems	7,492	10,030	13,000	15,360	17,910	21,280	23.2%
Workstations	7,495	10,180	13,140	15,490	18,040	21,380	23.3%
PCB Layout							
Revenue	$1,058	$1,193	$1,353	$1,576	$1,821	$2,109	14.8%
Systems	31,605	36,560	41,720	48,600	58,690	68,730	16.8%
Workstations	34,133	39,030	43,910	50,450	59,990	69,580	15.3%

Source: Dataquest (July 1990)

TABLE 2
CAD/CAM/CAE Worldwide Forecast by Region
(Millions of Dollars)

	1989	1990	1991	1992	1993	1994	CAGR 1989-1994
Worldwide							
Revenue	$12,365	$14,284	$16,181	$18,131	$20,323	$22,815	13.0%
Systems	403,555	488,230	577,790	666,000	756,580	842,130	15.8%
Workstations	439,019	521,080	607,650	691,920	779,430	862,000	14.4%
North America							
Revenue	$4,700	$5,136	$5,748	$6,448	$7,285	$8,204	11.8%
Systems	200,410	235,470	272,710	310,640	351,410	388,920	14.2%
Workstations	212,895	245,900	281,830	318,580	358,630	395,240	13.2%
Europe							
Revenue	$4,279	$5,070	$5,694	$6,320	$7,061	$7,965	13.2%
Systems	126,905	156,410	188,790	219,980	251,550	282,290	17.3%
Workstations	141,285	170,500	201,750	231,110	261,330	291,010	15.5%
Far East							
Revenue	$3,124	$3,750	$4,311	$4,850	$5,387	$5,969	13.8%
Systems	66,272	82,650	97,880	112,370	125,640	137,170	15.7%
Workstations	73,636	89,580	104,170	117,700	130,000	140,640	13.8%
Rest of World							
Revenue	$261	$328	$429	$514	$589	$677	21.0%
Systems	9,968	13,700	18,410	23,010	27,990	33,750	27.6%
Workstations	11,202	15,100	19,900	24,520	29,470	35,110	25.7%

Source: Dataquest (July 1990)

TABLE 3
CAD/CAM/CAE Worldwide Forecast by Platform
(Millions of Dollars)

	1989	1990	1991	1992	1993	1994	CAGR 1989-1994
All Platforms							
Revenue	$12,365	$14,284	$16,181	$18,131	$20,323	$22,815	13.0%
Systems	403,555	488,230	577,790	666,000	756,580	842,130	15.8%
Workstations	439,019	521,080	607,650	691,920	779,430	862,000	14.4%
Technical Workstations							
Revenue	$6,113	$7,884	$9,796	$11,954	$14,281	$16,914	22.6%
Systems	110,530	150,660	201,340	260,230	330,290	404,750	29.6%
Workstations	110,515	150,660	201,340	260,230	330,290	404,750	29.6%
Host-Dependent/Servers							
Revenue	$3,981	$3,804	$3,554	$3,162	$2,876	$2,615	(8.1%)
Systems	15,606	16,230	16,120	15,260	14,690	13,910	(2.3%)
Workstations	51,084	49,070	45,980	41,170	37,540	33,780	(7.9%)
Personal Computers							
Revenue	$2,271	$2,596	$2,832	$3,015	$3,165	$3,286	7.7%
Systems	277,420	321,340	360,330	390,510	411,600	423,470	8.8%
Workstations	277,420	321,340	360,330	390,510	411,600	423,470	8.8%

Source: Dataquest (July 1990)

TABLE 4
CAD/CAM/CAE Worldwide Average Price per Seat Forecast by Platform
(Thousands of Dollars)

	1989	1990	1991	1992	1993	1994	CAGR 1989-1994
Turnkey and Hardware-Only							
Technical Workstation	$38.5	$35.5	$32.0	$29.3	$27.0	$25.5	(7.9%)
Host-Dependent/Server	$193.9	$178.5	$167.9	$158.2	$148.5	$141.4	(6.1%)
Personal Computer	$5.8	$5.7	$5.5	$5.3	$5.2	$5.1	(2.5%)
All Platforms	$22.0	$20.7	$19.3	$18.2	$17.5	$17.2	(4.8%)
Turnkey							
Technical Workstation	$54.7	$52.8	$50.6	$49.3	$48.6	$48.5	(2.4%)
Host-Dependent/Server	$248.5	$223.7	$211.3	$199.5	$190.7	$185.9	(5.6%)
Personal Computer	$16.9	$17.0	$16.7	$16.4	$16.0	$15.9	(1.2%)
All Platforms	$60.2	$56.3	$53.5	$51.5	$50.2	$49.8	(3.7%)
Hardware-Only							
Technical Workstation	$15.9	$14.9	$13.8	$13.2	$12.8	$12.7	(4.4%)
Host-Dependent/Server	$141.1	$134.6	$126.8	$119.1	$109.9	$101.3	(6.4%)
Personal Computer	$4.7	$4.7	$4.7	$4.6	$4.5	$4.5	(0.9%)
All Platforms	$9.9	$9.5	$9.0	$8.7	$8.7	$8.8	(2.3%)

Source: Dataquest (July 1990)

AEC

Dataquest forecasts that the AEC market will experience 19 percent growth in 1990 and 15 percent CAGR between 1989 and 1994. Our forecast is based on the following trends:

- Client demand to receive designs in electronic form will drive architects to increase CAD use.
- CAD systems will become more attractive to this drawing-intensive sector attributable to the following factors:
  - Falling costs for converting existing paper drawings to either raster or vector electronic data
  - Reduced cost of hard copy due to price wars in plotter and printer products
- Some vendors previously in AEC civil engineering and facility management will recast themselves as GIS suppliers, shifting revenue from one recognized market segment to another.
- More architects will begin successfully using CAD as part of the sales process, forcing nonusers to experiment with CAD in order to compete.
- New design tools derived from mechanical CAD applications (primarily KBE and parametric input) will compel existing users to buy additional CAD/CAE products.
- Reduced defense spending is not likely to result in significant "peace dividend" investment in the US infrastructure; however, the outcome of this issue is unpredictable, as it will be decided by politics rather than market demand.
- Capabilities of the PC platform will satisfy most users during the next five years.
- Despite the many positive conditions in the AEC market, architects' traditional resistance to computers will not be eliminated within the forecast period.

GIS/MAPPING

Dataquest forecasts that the GIS/Mapping market will experience 26 percent growth in 1990 and a 21 percent CAGR between 1989 and 1994.

TABLE 5
CAD/CAM/CAE Worldwide Forecast by Distribution Class
(Millions of Dollars)

	1989	1990	1991	1992	1993	1994	CAGR 1989-1994
Total Hardware and Software Revenue							
Turnkey	$5,838	$6,701	$7,281	$7,816	$8,322	$8,891	8.8%
Unbundled	4,583	5,359	6,382	7,490	8,824	10,335	17.7%
Total	$10,421	$12,060	$13,663	$15,307	$17,146	$19,226	13.0%
Hardware Revenue							
Turnkey	$4,078	$4,666	$5,017	$5,330	$5,617	$5,994	8.0%
Unbundled	3,040	3,380	3,847	4,310	4,911	5,569	12.9%
Total	$7,118	$8,046	$8,864	$9,640	$10,528	$11,563	10.2%
Software Revenue							
Turnkey	$1,760	$2,035	$2,264	$2,487	$2,704	$2,897	10.5%
Unbundled	1,543	1,979	2,536	3,180	3,914	4,766	25.3%
Total	$3,303	$4,014	$4,800	$5,667	$6,618	$7,663	18.3%
Workstation Shipments							
Turnkey	116,497	133,430	147,620	160,230	171,220	181,670	9.3%
Unbundled	322,522	387,650	460,030	531,690	608,210	680,330	16.1%
Total	439,019	521,080	607,650	691,920	779,430	862,000	14.4%

Source: Dataquest (July 1990)
Note: Columns may not add to totals shown because of rounding.

TABLE 6
CAD/CAM/CAE Worldwide Forecast by Revenue Source
(Millions of Dollars)

	1989	1990	1991	1992	1993	1994	CAGR 1989-1994
All Platforms							
Hardware	$7,118	$8,046	$8,864	$9,640	$10,528	$11,563	10.2%
Software	3,303	4,014	4,800	5,667	6,618	7,663	18.3%
Service	1,931	2,223	2,516	2,823	3,176	3,587	13.2%
Total	$12,365	$14,283	$16,179	$18,130	$20,322	$22,813	13.0%
Technical Workstations							
Hardware	$3,045	$4,033	$4,861	$5,782	$6,805	$7,934	21.1%
Software	1,944	2,433	3,185	4,049	4,953	6,002	25.3%
Service	1,110	1,418	1,749	2,122	2,522	2,976	21.8%
Total	$6,113	$7,884	$9,795	$11,953	$14,280	$16,912	22.6%
Host-Dependent/Servers							
Hardware	$2,593	$2,336	$2,176	$1,931	$1,739	$1,608	(9.1%)
Software	682	792	748	673	631	548	(4.3%)
Service	705	676	629	557	505	459	(8.2%)
Total	$3,981	$3,804	$3,553	$3,162	$2,876	$2,614	(8.1%)
Personal Computers							
Hardware	$1,480	$1,677	$1,827	$1,927	$1,984	$2,022	6.4%
Software	677	789	866	945	1,033	1,113	10.4%
Service	116	129	138	144	148	152	5.6%
Total	$2,271	$2,596	$2,832	$3,015	$3,166	$3,286	7.7%

Source: Dataquest (July 1990)
Note: Columns may not add to totals shown because of rounding.

Our forecast is based on the following trends:

- Dropping costs for converting existing paper maps and drawings to raster and vector electronic data will enhance the payoffs for buying CAD systems.
- Inexpensive spatial data, both public and private, will become increasingly available, dissolving a traditional obstacle to growth in the GIS/mapping segment.
- GIS/mapping market growth will continue in every world region.
- The significant number of traditional GIS/mapping projects stuck in the pilot phase will reduce demand for new products, as users struggle to implement existing purchases.
- Several large vendors have targeted GIS as a growth market; the sheer size of their investment will create some sales, particularly among new users.
- Demand for GIS systems from users in state and local governments will continue, with developer's fees providing a key funding source for the investment.
- Several new applications in GIS are destined to become a feature in another software program, rather than a standalone product in the GIS market.

EDA

Dataquest forecasts that the EDA market will experience 18 percent growth in 1990 and an 18 percent CAGR between 1989 and 1994. Our forecast is based on the following trends:

- Major segments of the market are making the transition from mainframe-based EDA tools developed in-house to workstation-based systems.
- There is an increasing awareness of, and sensitivity to, the need to meet market windows, and EDA is viewed as a necessary vehicle for coping with time-to-market constraints.
- Standards have begun to emerge in the EDA industry, which is providing an aura of stability and security to the commercially available EDA products.
- The price/performance ratio of workstations continues to improve, translating to new levels of design productivity for engineers equipped with workstation-based EDA tools.
- There is a healthy demand for CAE products—such as schematic entry systems, logic synthesis tools, and mixed-level simulators—for the design of printed circuit boards and application-specific ICs.
- There is intense competition in the semiconductor industry as well as pent-up demand for state-of-the-art physical design tools—the combination is creating a robust IC CAD market.
- New packaging technologies, the need for PCB layout systems that are integrated with CAE systems, and the need to reduce manufacturing costs while improving product quality are creating a fairly strong demand for commercial PCB layout systems.

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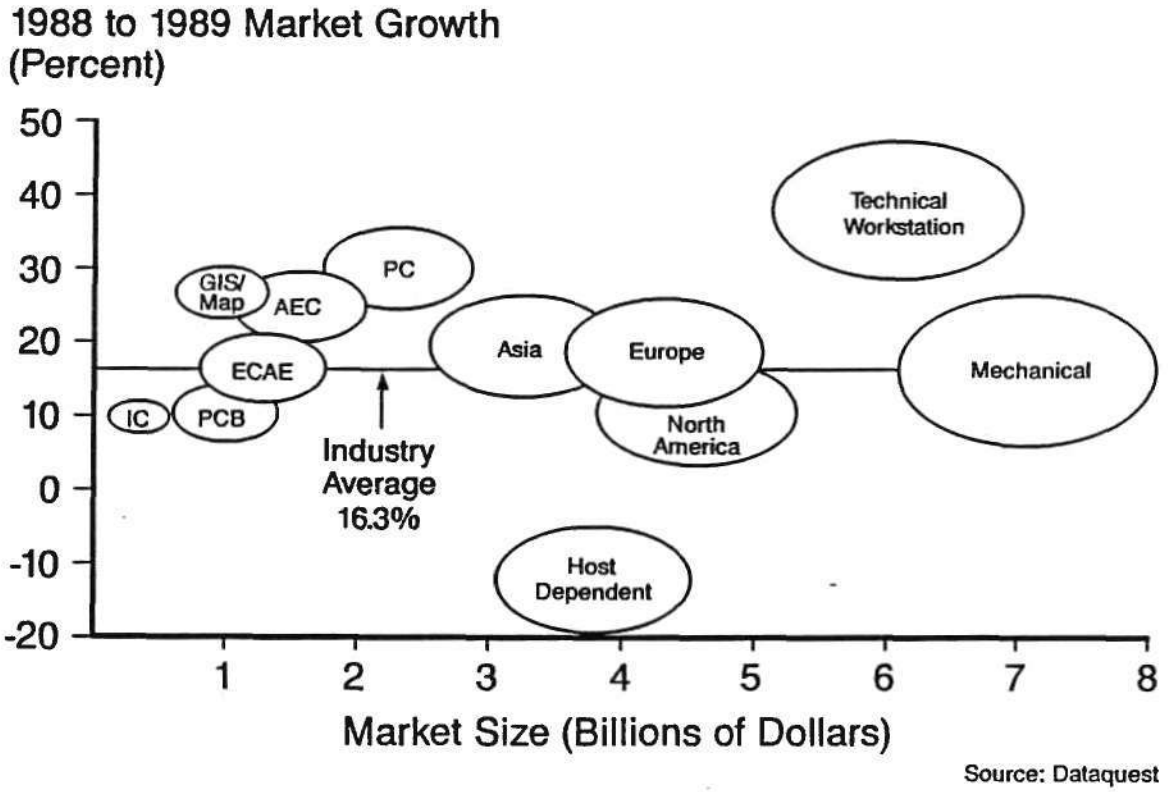
Research Newsletter

CAD/CAM/CAE INDUSTRY LEAVES THE 1980s ON A STRONG NOTE

SUMMARY

Dataquest recently completed its comprehensive CAD/CAM/CAE 1989 market analysis (see Figure 1 and Tables 1 through 4 at the end of this newsletter). Our research shows that the industry experienced robust growth, expanding 16.3 percent from $10.7 billion in 1988 to $12.4 billion in 1989. We believe that such strong growth in the face of industry instability is clear evidence of vitality as well as the market's insatiable demand for leading-edge CAD/CAM/CAE products. This healthy expansion was set against a backdrop of volatility and instability, with merger and acquisition activities that continued unabated throughout 1989. Advances in core technologies added fuel to the growth by creating new applications and adding value to proven applications. This newsletter discusses the high-level issues that impacted the CAD/CAM/CAE market and the top ten vendors.

FIGURE 1
Worldwide CAD/CAM/CAE Industry Market



Source: Dataquest

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SUMMARY OF SUCCESSES

In 1989, there were a myriad of successes, including the following (which are summarized by application):

- Mechanical CAD/CAM/CAE
  - In addition to being market leaders, each of these vendors gained revenue in 1989—Autodesk, IBM, Intergraph, McDonnell Douglas, Prime/ComputerVision, Schlumberger, and SDRC.
    - Autodesk and SDRC were the fastest-growing market leaders with revenue growth of 47 and 35 percent, respectively.
    - IBM remained the largest vendor with over $225 million in software revenue.
  - Parametric Technology combined parametric user input and editing with solid modeling technology. This combination proved to be a winner fueling growth by a 20 percent increase in revenue per quarter.
  - PDA Engineering and SDRC both invested heavily in new user interfaces and underlying technology to enhance user appeal. Both companies had excellent results.
  - Aries Technology gained significant momentum with a $3 million investment from Ford Motor Company.
- Electronic Design Automation (EDA)
  - Mentor Graphics continued to dominate the EDA market.
  - Cadence rapidly ascended to the number two position in the EDA software market.
  - Synopsys had tremendous growth in the logic synthesis market, with company revenue reaching approximately $10 million.
- Architecture, Engineering, and Construction (AEC) and GIS/Mapping
  - AEC and geographic information systems (GIS)/mapping delivered the strongest 1989 performances of any CAD/CAE application, growing 24.6 and 26.3 percent, respectively, with equivalent growth rates in software.
  - Many vendors had a good year. Major vendors Autodesk, ESRI, McDonnell Douglas, Siemens, and Synercom had above average growth rates in AEC and GIS/mapping, as did many of the 125 smaller software vendors.
  - Geographic information systems clearly is both a high-growth market and a mandatory product buzzword. In addition to traditional mapping vendors recasting themselves as GIS vendors, AEC application vendors, such as McDonnell Douglas, began identifying themselves as being GIS suppliers in 1989.

SUMMARY OF DISAPPOINTMENTS

There also were some very big disappointments in 1989, including the following:

- Mechanical CAD/CAM/CAE
  - Knowledge-based engineering (KBE) has evolved slowly from an academic environment to a working engineering tool. The promise of capturing engineering intent or design insight has been proven effective in a variety of applications. Perhaps 1990 will be the year that KBE wins major acceptance by the leading CAD/CAM/CAE vendors and a plethora of satisfied users.
- Electronic Design Automation
  - Dazix's market position declined precipitously, an event ignited by the unsuccessful merger between Daisy Systems and Cadnetix.
- AEC and GIS/mapping
  - Despite vendor and media excitement about the GIS/mapping market, many users in government and utilities are stuck in pilot projects, struggling to implement their purchases.
  - Intergraph's long-awaited Tigris software is appearing slowly and now is directed only at limited markets.

CURRENT INDUSTRY TRENDS

During 1989, a number of important underlying trends impacted the performance of the worldwide CAD/CAM/CAE industry as a whole. These trends are ranked in the following order of importance:

- Intense competition in end-user markets
- Market globalization
- Pushing the price/performance envelope
- Growing overlap between PCs and workstations

Intense Competition in the End-User Markets

Strong demand for CAD/CAM/CAE products reflects the fierce competition in the markets that rely on the technology. Indeed, shrinking product life cycles and tighter market windows are by-products of the penetration of today's advanced CAD/CAM/CAE systems. By the end of the 1980s, it was clear to buyers that the competitive environment required the use of sophisticated design automation tools. The market has clearly acknowledged that CAD/CAM/CAE is no longer a luxury. This is true in all applications, and is especially true in the EDA market.

Despite widespread agreement that CAD/CAM/CAE is mandatory, Dataquest's market research uncovered a symptom of a basic problem that began to emerge in 1989. The symptom is that some companies are realizing tremendous gains from the tools, while others are experiencing only marginal results. The problem is that large segments of the market are ineffectively applying the tools to the design problem. Dataquest believes that this problem is a result of the following several factors:

- Inefficient organizational structure
- Failure of users to update procedures to utilize fully later software releases
- Inefficiency in sharing design information between applications and work groups. Basically, many companies are simply not being aggressive in organizational changes or procedures to exploit the power of CAD/CAM/CAE technology fully.

Dataquest believes that CAD/CAM/CAE suppliers in the 1990s will have to provide customers with organizational and operational guidance as it pertains to the exploitation of design automation tools. Suppliers that can help customers extract the maximum productivity from the tools will enhance their market success in the 1990s.

Globalization of the Market

Asia

Japan continues to be a hotbed of activity for CAD/CAM/CAE vendors, although the Korean and Taiwanese markets are also exhibiting signs of strength. In 1989, the Asian market grew to $2.8 billion, a 18.9 percent increase over 1988. Japan continued to dominate the Asian CAD/CAM/CAE market with a 92.0 percent share of the total Asian market. Korea experienced the highest growth rate at 25.6 percent.

Mergers and acquisitions continue to be of great concern to the Japanese market. Merger and acquisition activity among the largest CAD/CAM/CAE vendors has caused Japanese distributors to lose product lines and rights to distribution channels. Distributors now are focusing on adding local content to the products they resell, in an effort to bind their relationships with international suppliers.

Access to new products from US-based start-ups brings new software or hardware technology but carries the risks of typical start-up instabilities, merger and acquisition threats, and difficulty in servicing an overseas client base. Many Japanese companies have been investing directly in start-up ventures to ensure viability and high-quality support. However, a major concern of these young companies is whether or not the distributors will absorb the costs of training their sales forces. Given the intensifying competition among distributors in Japan, capturing the distribution rights of "hot" products will require distributors to share more of the distribution costs as well as demonstrate their expertise and ability to sell the product line.

Europe

The European market surpassed all forecasts in gaining even more ground as the largest regional consumer of CAD/CAM/CAE tools. Europe now represents more than 34.0 percent of the world market, up 18.9 percent to $4.25 billion in 1989.

The large European manufacturers have been investing heavily in CAD/CAM/CAE technology. The trend in Asia toward direct company investment and perhaps a distribution agreement is not typical in the European market. The market is more mature on the demand side, with major suppliers having a large installed base. Additionally, the largest European users recognize the value of integration that the larger turnkey vendors provide.

The strength of the European market, as viewed from a high level, masks the amazing diversity in each specific country. The growth of CAD/CAM/CAE sales into each country is a result of many economic, industrial, and historical factors. High interest rates and a sluggish economy has taken the momentum out of the UK market. West Germany has undergone significant change in

preparation for the East/West unification effort. The potentially unstable situation is pointing toward high expectations as a modern manufacturing economy is overlaid with an eager work force and consumer base in East Germany. The Italian market continued a high growth trend that started two years ago. Spain, which is also on a high growth curve, is showing diversity in application interest and growing sophistication in high-end workstation-based products.

Pushing the Price/Performance Envelope

Increasing workstation performance and fierce price competition among computer vendors continued to be a driving force behind the CAD/CAM/CAE market's strong growth. In 1989, there was a continuation of the mip/mflop war at the high end and eroding prices at the low end, both of which have become hallmarks of the workstation hardware industry. These extraordinary price/performance characteristics continue to fuel demand for CAD/CAM/CAE applications as users continue to swap older hardware in favor of faster and more functional workstations. Dataquest's research indicates that today's CAD/CAM/CAE software that is running on the current generation of workstation platforms is yielding significantly higher productivity gains compared with older-generation systems. We expect the mip/mflop and price erosion phenomena to continue unabated, which will continue to act as a catalyst for CAD/CAM/CAE applications.

Growing Overlap between PCs and Workstations

In 1989, the overlap in price/performance between PCs and workstations grew even larger. Average selling prices (ASPs) of PCs in CAD markets rose, while workstation prices dropped. CAD dealers successfully sold both FEM/FEA software and Autocad on PCs and Sun workstations. The performance of optimized 486-based machines now overlaps many RISC workstations, and prices of RISC workstations are now lower than some PC models.

Today, the most important difference between the two platforms is the available software. PC users still have a limited range of CAD/CAM/CAE software and a vast selection of low-cost productivity software available to them. Workstation users still have limited productivity software and a vast selection of state-of-the-art engineering software available to them. Operating system suppliers continue to refuse to supply CAD users with viable options to use more than one operating system per computer, helping to perpetuate the necessity for differentiation between PCs and workstations.

MARKET SHARE ANALYSIS

Table 1 lists the worldwide CAD/CAM/CAE vendor market share of the leading vendors ranked by revenue. There was only one new company in the top ten market share list from 1988 to 1989: Sun Microsystems, now number eight, displaced NEC on the list.

The following paragraphs analyze the performance of the top ten companies in total revenue.

IBM

It is clear that IBM views CAD/CAM/CAE as a major strategic thrust in providing effective computing solutions in the engineering environment. To solidify this commitment to its users and gain leverage with its software partners, it made several major strategic investments, including CADAM, Valisys, and, most recently, Valid. Worldwide, the leading revenue-generating software product still is CADAM, closely followed by Catia and Caeds, each with 15 percent revenue share in 1989. A modest 7 percent growth rate for CAD/CAM/CAE revenue in 1989 brought IBM's worldwide total to just over $1.6 billion.

A key element of IBM's future in this market lies in its ability to make the RS/6000 (which was finally unveiled in February 1990) an industry standard computing platform. The availability of leading software packages offered in an integrated environment could quickly build momentum for the workstation product. A key challenge will be for IBM to profitably manage the transition from selling host-based systems to workstations.

The PS/2 gained some ground in 1989 over its disappointing showing in 1988. However, it is far from certain that the machine will be able to capture a dominant share of the market in a manner similar to the PC AT.

Digital Equipment

Digital Equipment experienced continued growth in the CAD/CAM/CAE market with an 8 percent revenue increase in 1989 over 1988.

CAD/CAM/CAE applications drove approximately 23 percent of the total company revenue in 1989. Digital continued to leverage the vast VAX installed base by selling a significant number of processors as add-ons into cluster systems.

Digital continued to have difficulties penetrating the UNIX workstation market because of the strength of installed base using the VMS operating system. Indeed, 80 percent of the company's 1989 revenue was generated by sales of host-based systems.

Mechanical applications continued to represent the majority of revenue.

Prime/ComputerVision

Despite the fact that Prime/ComputerVision had to fight a hostile takeover and absorb several CAD/CAM/CAE acquisitions, it was able to grow more than 2 percent. In 1989, Prime/ComputerVision made great strides in allaying its customers' fears about the viability and strategic direction of the company. Thus, it was able to protect its most valuable asset: its installed base. Prime/ComputerVision has shipped over 54,000 workstations to date. However, it is becoming increasingly clear that the company will have to become more aggressive in introducing state-of-the-market applications in order to stave off the focused niche suppliers that continue to assault its customer base.

Intergraph

Growing a modest 7 percent in 1989, Intergraph nonetheless retained its dominant market positions in the mapping and AEC segments and in the North American CAD/CAM/CAE market. The modest growth was caused by market demand to drop workstation ASPs and softening in spending in both the North America commercial and U.S. defense mapping markets, two markets that Intergraph particularly depends upon. Delays and changes in the company's GIS/mapping products also delayed purchases in a typically strong application area.

Intergraph continues to be one of the most successful CAD/CAM/CAE vendors. A growing market among large users that favor a single integrated vendor solution is supporting its turnkey strategy. The hardware business has had growing success with the recent porting of several software packages. Speculation continues concerning the long-term opportunity for Intergraph as an independent computer manufacturer, given the R&D drain required to fund computer development and vested interests as a software vendor. The main argument for continuing this activity offers the best of both worlds—a UNIX platform meeting industry standards and a single vendor that can optimize software/hardware system offerings. If the price/performance wars continue to escalate, competing as both a hardware and software supplier may be inadvisable.

Intergraph's challenge, therefore, is to maintain parity in computer price/performance while remaining competitive in each of its major software vertical applications, particularly in AEC and GIS/mapping.

Hewlett-Packard

Hewlett-Packard's (HP's) strong 1989 performance was due to the fact that the company sells a wide range of products and was able to take advantage of a strong CAD/CAE market across multiple product lines. The company's established $284 million turnkey business and growing PC business (at $100 million) performed particularly well in Europe. Supported by a reasonable supply of third-party application software, the unbundled 9000 series workstation business contributed another $145 million to HP's revenue. Although the Apollo product line was relatively flat, the unbundled and OEM workstation sales combined to reach $400 million.

Although Dataquest does not include OEM revenue in calculating the $12.4 billion 1989 CAD market in order to avoid double-counting, OEM sales represent real dollars to individual companies such as HP. Furthermore, HP's nearly $300 million plotter business and nearly $2.7 billion laser printer business are both virtually uncounted in these calculations, but both product lines are well represented in CAD/CAE installations. In sum, although the company has an influence in CAD/CAE markets through its own application software, HP's primary strength is as a leading hardware presence with a tremendous number of CAD installations.

Hewlett-Packard has succeeded in keeping its name in the forefront of its traditional stronghold, the engineering community. The key strategic issue facing the company is to create a coherent image. For example, despite the fact that Hewlett Packard's acquisition of Apollo was a positive step for

both companies, it left much uncertainty in the market as to the combined companies' product line integration strategy and future product development plans.

Mentor Graphics

Mentor Graphics maintained its leadership position in the EDA industry, recording CAE/CAD revenue of $376.0 million. This figure represented a 27 percent increase over the company's 1988 performance of $295.9 million. Mentor's strength comes from its stability in the marketplace, strong management, solid account control, and well-honed business model.

Unlike several of its closest competitors, Mentor's financial position remains very strong. The company's operating income held steady at 15 percent of revenue in 1989, and by the end of year, Mentor had stockpiled over $140 million in cash and marketable securities. With the recent financial problems of Dazix and others, the market has become very concerned about the long-term viability and stability of EDA suppliers. Mentor used its financial strength as a competitive weapon throughout 1989.

Mentor still supports only the Apollo line of workstations, although the company announced plans to port its products to the Sun Microsystems platforms in 1991. Mentor has enjoyed such a strong position over the past few years that it has been able to offer the customer only a limited choice of platforms. But conditions have changed as competitors such as Cadence have grown. Nonetheless, supporting just a single platform enables Mentor to keep its service, support, and manufacturing costs to a minimum, allowing the company to focus its resources on sales, marketing, and software research and development.

In 1989, Mentor took a bold step in announcing its so-called OpenDoor program. The program's goal is to allow third-party design automation vendors to integrate their products into the Mentor environment. This program represents a new thrust for Mentor. The company's strategy seems clear—allow third parties to integrate into the Mentor environment but do not lose control of the account. The full thrust of the OpenDoor program will show when the company begins shipping its new framework-based Release 8.0 software in the second half of 1990. Making OpenDoor a success and completing Release 8.0 are among Mentor's greatest challenges.

Finally, to bolster its fledgling IC CAD business, Mentor acquired Silicon Compiler Systems in early 1990. The combined forces of the two companies yielded an IC CAD supplier with a market share that is second only to Cadence Design Systems. However, Mentor will have to be aggressive in integrating the SCS product line if it wishes to capture market share from Cadence.

Compaq

Brand recognition, good systems engineering and product development, and a very stable employee base all have helped Compaq continue on its CAD/CAM/CAE roll. Once again, Compaq leads in the number of CAD workstations shipped worldwide. In 1989, the company's new graphics board began to claim some of the revenue previously taken by third-party board manufacturers, which resulted in raising ASPs for Compaq CAD systems.

The primary challenge facing Compaq is controlling erosion of mindshare among its best CAD dealers—dealers that seem to be thinking more about Sun Microsystems lately. Compaq's key advantage in this battle boils down to its years of experience in moving products through dealers. The company is well past the trial-and-error phase in dealer development, while workstation vendors are still learning the territory.

Sun Microsystems

Sun Microsystems continued its assault on the CAD/CAM/CAE market in 1989, although the company stumbled halfway through the year, reporting a loss of $20.0 million in the quarter ending June 30, 1989. Much of this was due to a bumpy product transition period as well as manufacturing and operations problems. By the end of the year, however, Sun appeared to be back on track, posting a profit of $5.2 million in the following quarter. In 1989, 34 percent of the company's revenue was derived from the CAD/CAM/CAE market.

Sun's overall success in 1989 was largely because of its ability to capitalize on the turmoil in the workstation industry among vendors such as Digital, Hewlett Packard, and IBM. At the same time, Sun lost ground to Silicon Graphics in the high-end graphics workstation market. Sun's most significant challenge will be to keep up with the

price/performance pace being set by other workstation vendors. For example, IBM's RS/6000 currently leads the pack with a price/performance ratio of $472 mip.

Sun boasted several strengths as it entered the 1990s. It has an excellent track record in driving standards and licensing its technology—key elements of Sun's past and future corporate strategy (e.g., SPARC, UNIX International). Sun shipped over 27,000 workstations by the end of 1989, which gives the company tremendous market power. Sun also has maintained its momentum in the marketplace despite its financial problems in 1989, for market demand for Sun workstations remains strong.

Sun's focus will likely be on competing in the mips and flops wars with less emphasis on the very high-end graphics market, where it continues to be vulnerable. However, we expect Sun to remain competitive in offering systems for mainstream low-end and midrange graphics applications.

With workstation prices and margins continuing to tumble, distribution has become a major concern among workstation vendors. It is simply not feasible for a direct sales force to sell $5,000 machines, unless it is to a particularly large customer or strategic account. As a result, we expect Sun to begin strengthening its low-end distribution channel in the second half of 1990.

Fujitsu

Fujitsu strengthened its position in the CAD/CAM/CAE market in 1989, with revenue growing by 13.7 percent to $269 million. The company continues to be among the major OEMs of Sun Microsystems workstations. Through this relationship, Fujitsu has been aggressively shifting its revenue stream from mainframe sales to workstation sales. In 1989, the company's workstation revenue grew to $122 million, a 63 percent increase over 1988. Software sales grew by 35 percent, from $66.7 million in 1988 to $90.1 million in 1989.

Fujitsu boasts a well-balanced revenue split across most CAD/CAM/CAE applications. In the mechanical CAD market, Fujitsu's revenue grew to $122 million; in the AEC and mapping markets, the company holds the leading market share position, with revenue growing to $92 million and $31 million, respectively.

The key strategic issue to be resolved concerns the recent IBM acquisition of CADAM, which develops Fujitsu's primary CAD/CAM product. Short-term announcements have been made by IBM to honor contractual commitments; however, a continued long-term agreement is unlikely.

McDonnell Douglas

McDonnell Douglas (MDC) had a good year in 1989, particularly in mechanical applications in the aerospace industry and in the AEC and GIS/mapping market in Europe. Software revenue growth from 1988 to 1989 was over 31 percent. New technology in the form of a solid modeling engine, Parasolids, added years to the useful life of MDC's mechanical product line. The association with GM and EDS helped underwrite porting to a wide variety of workstation platforms. DEC, HP, and Sun all are represented. A disappointing side issue comes from the low level of sales from the GM-EDS relationship. Hundreds of seats have been installed instead of the thousands that were anticipated. This agreement could provide a good long-term relationship based on a more aggressive use of MDC CAD/CAM tools and more aggression by EDS in promoting competitive integration services.

The Autodesk Phenomenon

Although not among the top ten vendors, the Autodesk phenomenon continues unabated. Autocad now represents approximately one out of every four legally installed CAD seats worldwide, which is the best perspective from which to evaluate the company's influence. Combined with its acquisition of Generic Software, Autodesk vaulted to third place in CAD software revenue in 1989, despite the fact that the company primarily sells core software through resellers—which allows dealers, add-on software vendors, and hardware manufacturers to share in the bounty.

Although Autodesk continues to develop its CAD products effectively through both regular product releases and alliances with such companies as Applied Geometry, D-Cubed, Ithaca Software, and Spatial Technology, the company believes that its higher calling is to return to its founding fathers' charter: to create major new software for mainstream (non-CAD) users. Autodesk's challenge will be to maintain CAD market presence while using CAD profits to fund creative new applications.

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Table 1
Worldwide 1989 Market Share—Top 25 Vendors
All Applications, All Platforms
(Millions of Dollars and Actual Units)

	Total	Hardware	Software	Wkstns	Market Share			
	Total	Hardware	Software	Wkstns	Total	Hardware	Software	Wkstns
Company	Revenue	Revenue	Revenue	Shipped	Revenue	Revenue	Revenue	Shipped
IBM	1,615.6	1,101.4	261.6	51,767	13.0%	15.5%	7.8%	11.8%
Digital	899.6	674.1	.0	6,530	7.2%	9.5%	.0%	1.5%
Computervision	898.0	385.5	250.2	6,692	7.2%	5.4%	7.4%	1.5%
Intergraph	860.1	457.2	169.1	8,779	6.9%	6.4%	5.0%	2.0%
Hewlett-Packard	731.0	537.2	66.7	43,970	5.9%	7.6%	2.0%	10.1%
Mentor Graphics	376.0	130.2	177.9	4,996	3.0%	1.8%	5.3%	1.1%
Compaq	347.5	347.5	.0	57,916	2.8%	4.9%	.0%	13.2%
Sun	325.3	292.7	.0	19,516	2.6%	4.1%	.0%	4.5%
Fujitsu	311.8	181.3	94.1	6,983	2.5%	2.6%	2.8%	1.6%
McDonnell Douglas	282.1	152.0	90.2	3,960	2.3%	2.1%	2.7%	.9%
NEC	265.0	186.4	57.4	12,950	2.1%	2.6%	1.7%	3.0%
Apple Computer	208.0	183.0	.0	40,000	1.7%	2.6%	.0%	9.1%
Control Data	183.7	130.4	22.0	1,960	1.5%	1.8%	.7%	.4%
Autodesk	182.6	.0	182.6	0	1.5%	.0%	5.4%	.0%
Nihon Unisys	181.0	125.9	20.7	1,550	1.5%	1.8%	.6%	.4%
Hitachi	180.0	95.2	66.8	4,800	1.4%	1.3%	2.0%	1.1%
Valid	174.0	43.1	99.6	1,511	1.4%	.6%	3.0%	.3%
Dazix	153.7	57.1	68.5	1,476	1.2%	.8%	2.0%	.3%
Schlumberger (Applicon)	141.1	49.0	50.8	1,558	1.1%	.7%	1.5%	.4%
Siemens	133.8	79.0	40.1	2,967	1.1%	1.1%	1.2%	.7%
Cadence	133.1	.0	115.0	0	1.1%	.0%	3.4%	.0%
Silicon Graphics	113.8	101.9	.0	2,280	.9%	1.4%	.0%	.5%
Mutoh Industries - No OEM	99.0	51.2	36.9	2,500	.8%	.7%	1.1%	.6%
Racal-Redac	89.3	8.1	68.7	377	.7%	.1%	2.0%	.1%
Hitachi Zosen Info Systems	82.7	42.2	32.2	750	.7%	.6%	1.0%	.2%
Other Companies	1,594.3	981.9	507.7	120,862	12.8%	13.8%	15.1%	27.6%
All Companies	12,418.6	7,108.5	3,365.0	437,325	100.0%	100.0%	100.0%	100.0%
All U.S.-Based Companies	9,623.3	5,674.7	2,327.9	380,620	77.5%	79.8%	69.2%	87.0%
All Asian-Based Companies	1,829.3	1,052.8	573.2	40,483	14.7%	14.8%	17.0%	9.3%
All European-Based Companies	966.0	381.0	463.9	16,223	7.8%	5.4%	13.8%	3.7%
All Hardware Companies	3,344.1	2,929.4	.6	319,351	26.9%	41.2%	.0%	73.0%
All Turnkey & SW Companies	9,074.5	4,179.0	3,364.3	117,973	73.1%	58.8%	100.0%	27.0%

Source: Dataquest (June 1990)

Table 2
Software Revenue Application

	1988	1989	% Chg.	SOM
MECHANICAL				
IBM	306.9	225.0	-26.7%	13.70%
Computervision	185.5	203.5	9.7%	12.39%
Autodesk	48.1	74.6	55.2%	4.55%
McDonnell Douglas	51.5	67.7	31.3%	4.12%
SDRC	42.0	56.6	34.8%	3.45%
Hitachi	28.3	53.2	88.1%	3.24%
AEC				
Autodesk	46.9	75.3	60.4%	19.12%
Intergraph	47.7	46.0	-3.7%	11.68%
Fujitsu	20.0	29.4	47.2%	7.47%
Computervision	33.8	25.1	-25.8%	6.38%
IBM	13.6	20.9	54.5%	5.32%
ISICAD	9.0	14.2	58.0%	3.61%
MAPPING				
Intergraph	60.9	61.4	.8%	22.19%
ESRI	24.5	35.7	45.8%	12.88%
Autodesk	10.6	16.5	56.5%	5.97%
Siemens	4.3	15.9	271.6%	5.76%
McDonnell Douglas	4.7	13.5	185.0%	4.88%
Synercom	7.9	10.7	35.2%	3.86%
ELECTRONIC CAE				
Mentor Graphics	100.2	120.2	20.0%	21.04%
Valid	39.9	68.6	71.9%	12.01%
Dazix	53.0	49.0	-7.4%	8.58%
Cadence	7.7	38.8	406.4%	6.79%
Racal-Redac	18.4	19.6	6.5%	3.42%
EESOF	10.1	16.2	60.9%	2.84%
IC LAYOUT				
Cadence	43.8	76.2	74.0%	48.00%
Silicon Compiler Systems	21.0	23.0	9.1%	14.46%
Mentor Graphics	12.5	14.3	14.9%	9.03%
Valid	3.6	10.8	203.7%	6.79%
Seiko Instruments	17.8	7.8	-56.3%	4.91%
VLSI Technology	6.8	6.7	-1.2%	4.23%
PCB LAYOUT				
Racal-Redac	43.3	49.7	14.7%	15.42%
Mentor Graphics	28.9	39.6	37.1%	12.29%
Zuken	19.0	28.6	50.1%	8.88%
Valid	7.9	20.2	155.8%	6.28%
Dazix	23.7	18.4	-22.6%	5.71%
Computervision	11.2	14.3	28.3%	4.44%

Source: Dataquest (June 1990)

Table 3
Total Revenue by Region
1989 Top 25 CAD/CAM Vendors

	Worldwide Revenue	North American Revenue	European Revenue	Asian Revenue	ROW Revenue
IBM	1,615.6	441.7	588.9	532.9	52.1
Digital	899.6	431.8	359.8	81.0	27.0
Computervision	898.0	323.0	458.0	108.0	9.0
Intergraph	860.1	493.0	288.4	31.7	47.1
Hewlett-Packard	731.0	242.1	352.6	122.1	14.2
Mentor Graphics	376.0	185.8	105.8	84.4	.0
Compaq	347.5	191.1	139.0	7.0	10.4
Sun	325.3	191.9	66.3	58.0	9.1
Fujitsu	311.8	.0	.0	305.9	5.9
McDonnell Douglas	282.1	180.9	86.9	8.7	5.6
NEC	265.0	.0	.0	265.0	.0
Apple Computer	208.0	147.7	49.9	8.3	2.1
Control Data	183.7	71.7	93.7	11.0	7.4
Autodesk	182.6	101.9	57.9	21.2	1.7
Nihon Unisys	181.0	.0	.0	181.0	.0
Hitachi	180.0	.0	.0	180.0	.0
Valid	174.0	90.5	43.5	40.0	.0
Dazix	153.7	67.6	55.3	30.7	.0
Schlumberger (Applicon)	141.1	63.5	70.4	7.2	.0
Siemens	133.8	.0	127.1	6.7	.0
Cadence	133.1	74.3	10.1	48.7	.0
Silicon Graphics	113.8	48.6	19.1	46.1	.0
Mutoh Industries	99.0	.0	.0	99.0	.0
Racal-Redac	89.3	18.6	46.0	24.5	.1
Hitachi Zosen Info Systems	82.7	.0	.0	82.7	.0
Other	1,594.3	732.7	591.1	223.5	47.0
All Companies	12,418.6	4,638.4	4,233.4	3,290.1	256.7
All U.S.-Based Companies	9,623.3	4,589.2	3,364.2	1,422.1	247.8
All Asian-Based Companies	1,829.3	.0	.0	1,823.3	5.9
All European-Based Companies	966.0	49.2	869.1	44.7	3.0
All Hardware Companies	3,344.1	1,717.8	1,168.4	362.4	95.5
All Turnkey & SW Companies	9,074.5	2,920.7	3,064.9	2,927.7	161.2

Source: Dataquest (June 1990)

Table 4
Total Revenue by Type
1989 Top 25 CAD/CAM Vendors

	DQ Reports						TOTAL
	Total Revenue	Turnkey Revenue	Unbundled Hardware Revenue	Unbundled Software Revenue	Service Revenue	OEM Revenue	Revenue Including OEM
IBM	1,615.6	916.9	446.0	.0	252.7	.0	1,615.6
Digital	899.6	.0	674.7	.0	224.9	430.5	1,330.1
Computervision	898.0	578.7	18.0	38.7	262.7	.0	898.0
Intergraph	860.1	607.1	.0	21.7	231.4	.0	860.2
Hewlett-Packard	731.0	284.2	325.2	.0	121.6	174.8	905.8
Mentor Graphics	376.0	280.9	.0	29.2	65.9	.0	376.0
Compaq	347.5	0.0	347.5	.0	.0	.0	347.5
Sun	325.3	0.0	292.8	.0	32.5	400.2	725.5
Fujitsu	311.8	211.9	63.1	.0	36.3	.0	311.3
McDonnell Douglas	282.1	204.4	5.6	32.1	39.9	2.0	284.0
NEC	265.0	124.0	119.0	.0	21.2	.0	265.0
Apple Computer	208.0	0.0	183.0	.0	25.0	.0	208.0
Control Data	183.7	150.6	.0	1.8	31.2	.0	183.7
Autodesk	182.6	.0	.0	182.6	.0	.0	182.6
Nihon Unisys	181.0	23.5	106.0	17.1	34.4	.0	181.0
Hitachi	180.0	162.0	.0	.0	18.0	.0	180.0
Valid	174.0	100.5	.0	42.1	31.3	.0	174.0
Dazix	153.7	100.5	.0	26.2	27.0	.0	153.7
Schlumberger (Applicon)	141.1	78.4	.0	21.8	40.9	1.9	143.0
Siemens	133.8	119.1	.0	.0	14.7	.0	133.8
Cadence	133.1	0.0	.0	114.6	18.1	3.5	136.0
Silicon Graphics	113.8	0.0	102.3	.0	11.6	11.9	125.0
Mutoh Industries	99.0	86.0	.0	2.1	10.9	.0	99.0
Racal-Redac	89.3	23.8	.0	54.1	11.4	2.8	92.1
Hitachi Zosen Info Systems	82.7	74.4	.0	.0	8.3	.0	82.7
Other	3,451.0	1,270.9	826.6	983.2	371.9	91.9	3,544.7
All Companies	12,418.6	5,397.7	3,509.7	1,567.3	1,943.7	1,119.5	13,538.1

Source: Dataquest (June 1990)

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Research Newsletter

A/UX 2.0: APPLE UNVEILS "MAC" UNIX

SUMMARY

Apple Computer, Inc., finally has introduced a version of UNIX that contains the benefits of the Macintosh user interface. A/UX 2.0 effectively bridges the Mac OS, X Window, and UNIX worlds under Apple's famous proprietary interface. Apple plans to do for UNIX what it has done for the computer industry—remove the intimidation and make UNIX easy to use.

Unfortunately, Apple is ignoring other market opportunities that exist beyond its own installed base. Apple's decision not to use System V Release 3.2 (SVR3) and not to conform to X/Open's XPG3 at this time may be a business oversight. Apple is ignoring the XENIX ISVs who would love to be able to sell their applications for a Mac, and the lack of XPG3 conformance may limit the ISVs' ability to sell A/UX 2.0 into European markets.

A/UX 2.0 MAKES UNIX LOOK FRIENDLY

A/UX 2.0 contains all the features of the Macintosh desktop that made Apple computers so popular—icons, menus, and mouse functionality—while providing a seamless integration with other Macintosh applications and the X Window system. The Macintosh desktop shields users from the complexities of UNIX's command language. Apple has made the integration of UNIX and Mac OS so transparent that users can ignore the presence of A/UX and run only Macintosh applications, or they can load the X Window system, log into X, and turn the Macintosh into a dedicated X Workstation with no access to the Mac operating system.

A/UX 2.0, like its predecessor, is based on System V Release 2.2 (SVR2.2) with BSD extensions. It supports the BSD fast file system, the System V file system, and the Macintosh HFS. A/UX supports TCP/IP, Sun's NFS, and AppleTalk. Apple provides the Motif graphical user interface for those customers that wish to use it. A/UX 2.0 complies with most of the major UNIX standards, including POSIX 1.003.1, SVID Release 2, ISO 9945-1, and FIPS 151-1. In the future, Apple expects to offer a Communications Toolbox that will furnish applications with standard communications functions such as data connections, terminal emulations, and file transfer protocols. Apple has not indicated when it intends to comply with X/Open's XPG3 and SVID Release 3 or 4.

The user finally can run multiple Macintosh and UNIX applications simultaneously. Most of the popular "32-bit clean" (well-behaved) Mac OS applications now run under A/UX. The Macintosh requires 4 Mbytes of memory just to run the operating system, and at least 5 Mbytes of memory are needed to run X Window applications.

Users that have never worked with UNIX can open, close, rename, remove, print, and edit UNIX files just like they have always done. They can cut and paste text and data between UNIX and Macintosh applications. They can choose to work with icons and click and drag features of the Macintosh, or they can use the UNIX command line interface. A/UX supports the C, Bourne, and Korn shells. A special feature called Commando lets the novice UNIX user build command lines by inserting pop-up dialog boxes that offer choices of how to complete a specified command. The programmer can use the mouse to choose command line arguments, options, and redirection of output. Local printing and modem support are available through the serial ports. However, the user will need some traditional UNIX knowledge in order to do some of the necessary system administrative tasks such as configuration, back up, and adding users.

Apple has implemented a special version of the Mac OS Multifinder interface that runs as a

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process under UNIX. If the user runs AU/X with Multifinder turned on, the A/UX Macintosh desktop appears identical to the desktop found on all other MAC OS-based computers. Although UNIX programs can be launched from Multifinder, they do not run under Multifinder's control and fixed memory allocation. A/UX programs run as UNIX processes and can dynamically allocate memory as needed.

When asked about plans to comply with XPG3 and SVID Release 3, Apple officials admitted that their goal was first to introduce UNIX to their installed base of users that need UNIX functionality, and then to conform to the remaining industry standards as their customers request them to do so. CEO John Sculley said that Apple wants to wait until OSF/1 is available to evaluate both it and System V Release 4 before making the next operating system upgrade.

Pricing for A/UX 2.0 has not been set, and Apple expects the first customer shipments to begin this summer.

DATAQUEST ANALYSIS

Apple has done a good job in bridging the Mac OS, X Window, and UNIX worlds. This is the product it should have introduced last year. Dataquest believes that A/UX 2.0 will be popular among Macintosh users that need to develop or perform UNIX tasks on a part-time basis or are trying to secure federal bids for Macintosh computers.

Dataquest believes that Apple missed two sales opportunities by not building A/UX on the SVR3 platform. Many PC ISVs would love to have their XENIX applications running on a Mac. Apple cannot do an effective job in capturing the XENIX ISV applications market because SVR2.2 does not provide source compatibility with XENIX programs. We also believe that sales of this product into Europe may be hindered because A/UX 2.0 does not conform to X/Open's XPG3 or to SVID Release 3, both of which are specified by many European companies and countries.

Dataquest believes that, as prices for DRAMs drop, in the future it will not make sense for Apple to continue supporting and developing two different operating systems. Since Mac OS and A/UX work together in a manner that is transparent to the user, it might make sense for Apple to eventually migrate all its proprietary operating system efforts to UNIX. That would give the Apple user access to all available UNIX, Mac OS, and XENIX programs.

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David Burdick
Rikki Kirzner

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Research Newsletter

IBM DECLARES WAR ON WORKSTATION VENDORS WITH ITS RISC SYSTEM/6000

SUMMARY

IBM has learned that it takes more than the IBM logo to win in the workstation market. To win today in that market, a vendor must offer attractive price, performance, and third-party applications. On February 15, 1990, IBM announced a family of workstations, the RISC/6000 Systems, designed to meet these needs. The RISC/6000 Systems consist of nine models (four workstations and five servers), with three clock speeds giving the user a selection of three performance levels. This wide performance range (27.5, 34.5, and 41 mips) has an equally wide pricing structure of $12,995 through $92,885. Volume shipments will start in the second quarter of 1990 for some models; with the most advanced, 730, not shipping until the fourth quarter of 1990. Tables 1 and 2 list the configurations and base prices of the RISC/6000 Systems.

STRENGTHS

Some of the important strengths of this introduction are the following:

- Impressive mips and mflops per dollar
- A broad range of workstations from desktop to high end

TABLE 1
IBM RISC System/6000 Workstations

	POWERstation 320	POWERstation 520	POWERstation 530	POWERstation 730
Integer Performance	27.5 mips	27.5 mips	34.5 mips	34.5 mips
Floating Point	7.4 mflops	7.4 mflops	10.9 mflops	10.9 mflops
Processor	Power	Power	Power	Power
Clock Speed	20 MHz	20 MHz	25 MHz	25 MHz
Main Memory	8-32MB	8-128MB	16-128MB	16-128MB
2-D Color/Gray Scale	125K/72K	125K/72K	131K/76K	
3-D Color/Graphics				
Vectors/Second	90K	90K	90K	990K (est.)
Polygons/Second	10K	10K	10K	120K
Internal Disk	120-640MB	355MB-2.5GB	355MB-2.5GB	355MB-2.5GB
Base Price Configuration	8MB memory, 120MB 19-inch display Gray Scale (16) Diskette KB, Mouse AIX, GUI, Ethernet	8MB memory, 355MB 19-inch display Gray Scale (16) Diskette KB, Mouse AIX, GUI, Ethernet	16MB memory, 355MB 19-inch display Gray Scale (16) Diskette KB, Mouse AIX, GUI, Ethernet	16MB memory, 355MB 19-inch color Supergraphics Diskette KB, Mouse AIX, GUI, Ethernet
Base Price	$12,995	$27,245	$42,705	$73,815

Source: IBM Corporation
Dataquest
March 1990

Dataquest Incorporated, 1290 Ridder Park Drive, San Jose, CA 95131-2398 / (408) 437-8000 / Telex 171973 / Fax (408) 437-0292

TABLE 2
IBM RISC System/6000 Servers

	POWERserver 320	POWERserver 520	POWERserver 530	POWERserver 540	POWERserver 930
Integer Performance	27.5 mips	27.5 mips	34.5 mips	41.1 mips	34.5 mips
Floating Point	7.4 mflops	7.4 mflops	10.9 mflops	13.0 mflops	10.9 mflops
Typical Work Group	5-50	25-150	25-150	25-150	50-250
Processor	Power	Power	Power	Power	Power
Clock Speed	20 MHz	20 MHz	25 MHz	30 MHz	25 MHz
Main Memory	8-32MB	8-128MB	16-128MB	64-256MB	16-128MB
Internal Disk	120-640MB	355MB-2.5GB	355MB-2.5GB	640MB-2.5GB	670MB-11.9GB
Base Price Configuration	16MB memory, 320MB storage Ethernet, SCSI Diskette 1/4-inch tape AIX base	16MB memory, 355MB storage Ethernet, SCSI Diskette 1/4-inch tape AIX base	16MB memory, 355MB storage Ethernet, SCSI Diskette 1/4-inch tape AIX base	64MB memory, 640MB storage Ethernet, SCSI Diskette 1/4-inch tape AIX base	16MB memory, 670MB storage Ethernet, SCSI Diskette 8mm, CD-ROM AIX base
Base Price	$20,375	$30,425	$41,125	$92,885	$62,230

Notes: Integer (mips): Computed using dhrystone 1.1 results compared with VAX 11/780. VAX is a trademark of Digital Equipment Corporation.
Floating points (mflops): Double precision, 64-bit, all-FORTRAN linpack, n=100.
SPECmark: Geometric mean of the 10 benchmark tests. Configurations and individual test results are available from IBM. SPEC is a trademark of the Standard Performance Evaluation Corporation.

Source: IBM Corporation
Dataquest
March 1990

- Connectivity paths to other IBM products with such features as SAA to AIX connectivity, mail exchanges, and common languages
- Support for Motif, NextStep, and a new X Terminal

WEAKNESSES

Some of the weaknesses of the IBM introductions are the following:

- IBM is very late entering this market and is up against strong competitors.
- The Model 730 allows IBM access to the high-end 3-D market and will make a significant impact. However, the 730 will need additional performance and features to win against the highest performance 3-D workstations.
- IBM will use its traditional sales force to sell RISC/6000 Systems; this is unfamiliar territory for the sales force.
- An impressive number of third-party software vendors were listed by IBM, but the list falls short in some areas (e.g., EDA and CIM).

DATAQUEST ANALYSIS

Although it is clear that IBM has carefully studied the workstation market, it will be competing against well-established vendors such as Sun Microsystems, Inc., Hewlett Packard Company/Apollo, Digital Equipment Corporation, and Silicon Graphics, Inc. We predict that these established vendors will continue their aggressive introduction schedules, providing higher-performance products this year. IBM's stated goal is to become the leading workstation vendor by 1992. To achieve this goal starting from a very small market presence might well be impossible for anyone but IBM. IBM has made an excellent entry into the market. It appears that IBM is willing to allocate the necessary resources. The challenge now for IBM is to create a market perception that it has the most comprehensive and cost-effective workstations available.

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David Burdick
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Research Newsletter

TECHNICAL COMPUTERS IN 1989: THE YEAR IN REVIEW

INTRODUCTION

The technical computer industry continues to be one of the most exciting industries in business. It was rocked by fundamental changes as it matured through 1989. This newsletter provides Dataquest's year-end revised forecast for the technical computer industry in 1989 and discusses the elemental changes that affected it.

This newsletter includes a snapshot of the market segmentation sizes, the expected factory revenue of the players, a summary of major events, and an insight into evolving trends as Dataquest sees them.

THE MARKET SNAPSHOT

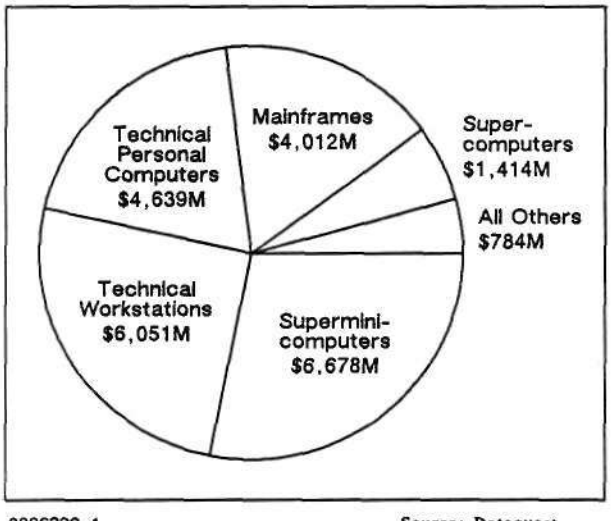
Dataquest projects the 1989 revenue for the technical computer industry to be $23.6 billion, a 17.1 percent increase over 1988. Figure 1 indicates the six segments that make up the industry and their rank order of performance.

Superminicomputers, as expected, have once again placed in the number-one position, accounting for 28 percent of the industry. For the first time in history, however, technical workstations have outsold mainframes. All trends indicated that this would happen eventually; 1989 was the year. Mainframes grew at a compound annual growth rate (CAGR) of 7.9 percent between 1984 and 1988; the CAGR for technical workstations over the same period was 73.8 percent.

Table 1 denotes the top ten players in this industry, which account for nearly 66 percent of the factory revenue.

Digital and IBM have been running neck and neck all year, with IBM pulling ahead for the number-one position. Hewlett-Packard's acquisition of Apollo earned that company the number-three revenue position, with a dramatically increased portion of the workstation market share. Sun's phenomenal growth has continued despite much-heralded financial problems this past year. That growth has earned the company the number-four position behind IBM, Digital, and HP—certainly heady company for such a young firm to be rubbing shoulders with.

FIGURE 1
Technical Computer Systems Industry Estimated 1989 Factory Revenue
(Millions of Dollars)



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Source: Dataquest December 1989

Dataquest Incorporated, 1290 Ridder Park Drive, San Jose, CA 95131-2398 / (408) 437-8000 / Telex 171973 / Fax (408) 437-0292

TABLE 1
Estimated 1989 Worldwide Factory Revenue and Market Share for Technical Computers Sold by the Top Ten Vendors (Millions of Dollars)

Vendor	Revenue	Market Share
IBM	$4,662	19.8%
Digital	$4,467	18.9%
HP/Apollo	$2,224	9.4%
Sun	$1,735	7.4%
Apple	$ 650	2.8%
Cray Research	$ 616	2.6%
Harris	$ 387	1.6%
Intergraph	$ 365	1.5%
Silicon Graphics	$ 315	1.3%
Concurrent	$ 271	1.1%

Source: Dataquest
January 1990

RESEARCH METHODOLOGY

This revised forecast (for original 1989 forecast, see TCSIS newsletter number 1989-19, entitled "Technical Computers Deliver Sizzling Performance in 1988") is a six-step process based on projections for each vendor's year-end financial results, historical contribution to each product segment (i.e., supercomputers, mainframes), and analytic insight.

In brief, Dataquest projects year-end vendor gross revenue based on topical industry news and quarterly reports (when available). We combine historical information detailing vendor contribution to industry segment along with analytic insight to form a projection for 1989. We can then back our way into an absolute dollar estimate for each vendor for each industry segment. As a final check, we assess anticipated market share data against historical market share and current events.

SUPERCOMPUTERS

The year 1989 proved to be one of turmoil in which very little growth occurred. The industry had surprises in every segment. Many companies were affected; some merged, some split, and others went under. The industry shakeout hit a peak in 1989 as a significant trend developed toward smaller supercomputers.

Table 2 details expected results for the top five competitors in the supercomputer marketplace.

In balancing the successes and failures of 1989, it is important to note that the sale of as few as 15 units can mark the difference between a strong and weak performance for the industry or an individual company. Dataquest believes that factors such as technologies, applications, and user-based development should be considered when analyzing the supercomputer industry. As such, we encourage the TCSIS supercomputer clients to consult the newsletter entitled "Supercomputing in 1989: A First Look" (TCSIS Code: Newsletters 1990-2) for a more complete review.

MAINFRAMES

Despite the many dire predictions for mainframes, the continuing onslaught of superminicomputers and technical workstations enabled the mainframe marketplace to hold its own; it grew nearly 4 percent in 1989 from the previous year.

TABLE 2
Estimated 1989 Worldwide Factory Revenue and Market Share for Supercomputers Sold by the Top Five Vendors (Millions of Dollars)

Vendor	Revenue	Market Share
Cray Research	$616	38.5%
IBM	$255	15.9%
Convex	$127	7.9%
Silicon Graphics	$ 95	5.9%
Fujitsu	$ 84	5.3%

Source: Dataquest
January 1990

Table 3 indicates the top factory revenue producers in 1989.

Many vendors are seeing the mainframe as the last bastion of hardware profit margins, and 1989 saw the introduction of several new systems. CDC introduced its new top-end Cyber 2000 mainframe. The air-cooled machine is rated at twice the power of the Cyber 990 and is described as providing the best attributes of both a mainframe and a supercomputer.

Digital has altered its strategy and is claiming that a mainframe is now an appropriate addition to clustered computing. The new VAX 9000 is a powerful, air-cooled machine emphasizing balanced performance between raw compute power and high I/O rates.

IBM continues to be the absolute market leader in mainframes, both technical and commercial, and is extending the life of the 3090 family by introducing the J series of models. The industry anxiously continues to await the arrival of the follow-on family, often referred to as Summit. Dataquest currently expects Summit to be announced in early to mid-1991.

Dataquest expects the mainframe to continue to be a dominant player in each of the evolving compute architectures. Regardless of whether the standalone compute concept, three-tier strategy, or client-server architecture becomes dominant, there will always be a healthy need for mainframes.

Mainframes increasingly will be positioned as database managers and file servers in the technical computer industry. The mainframes will provide data management, security, and integrity functions for the distributed technical workstations and personal computers. Product improvements increasingly will come along the lines of increased I/O bandwidth and enhanced communications to their proprietary operating systems.

The major vendors will continue to hedge their bets by providing increasingly powerful and easy-to-use vector facilities to enhance raw compute power. Compiler design, and development of applications that use the vector facilities, will continue to be great priorities with the vendors.

SUPERMINICOMPUTERS

The year 1989 was time of transition for superminicomputer vendors as systems shifted from their traditional roles and vendors realigned for more effective positions in the market. The continued push toward standards brought some changes to the fundamental way vendors did business.

Overall, the superminicomputer market kept a steady rate of growth, with a 7.8 percent increase over 1988 revenue. Table 4 outlines the predominant players.

Digital maintained its dominant position with new additions to its product line, both in its proprietary VAX architecture and a RISC-based product family that utilizes the MIPS R3000 processor. Digital demonstrated its commitment to standards by introducing a high-end, RISC-based system that utilizes a UNIX operating system.

The number two player, IBM, appears to be still scratching its collective head about the strategic direction of its "VAXkiller," the 9370. The 9370, which has suffered much criticism because of lack of software and power/memory to run MVS, did get a boost in image when IBM announced it will continue to enhance DOS/VSE.

TABLE 3
Estimated 1989 Worldwide Factory Revenue and Market Share for Technical Mainframe Computers Sold by the Top Five Vendors (Millions of Dollars)

Vendor	Revenue	Market Share
IBM	$3,059	76.2%
Amdahl	$ 236	5.9%
Unisys	$ 166	4.1%
Hitachi Data Systems	$ 90	2.2%
Control Data	$ 68	1.7%

Source: Dataquest
January 1990

TABLE 4
Estimated 1989 Worldwide Factory Revenue and Market Share for Technical Superminicomputers Sold by the Top Five Vendors (Millions of Dollars)

Vendor	Revenue	Market Share
Digital	$3,365	50.4%
IBM	$ 658	9.9%
Hewlett-Packard	$ 459	6.9%
Harris	$ 387	5.8%
Concurrent	$ 271	4.1%

Source: Dataquest
January 1990

Even though DOS/VSE primarily is a commercial operating system, the move indicates that the 9370 will be with us for some time to come. On the technical side, Dataquest believes that the 9370 will continue to find its home as a standalone machine and distributed network server.

Two of the top five vendors, HP and Concurrent, merged with other companies (Apollo and MASSCOMP, respectively), resulting in some difficulties for both companies. For Concurrent and MASSCOMP, problems in manufacturing and product line integration initially dampened the synergy of the two firms.

HP has embraced standards-based computing as it announced three new additions to the HP 9000 800 family. HP has shifted its position regarding the HP 9000 family being used solely for technical applications; the company now is positioning the HP 9000 computers as general-purpose (i.e., including commercial) machines. For Harris, 1989 brought the introduction of the Nighthawk 4000 computer system and a corporate restructuring.

The role of superminicomputers has evolved as the idea of client/server relationships has permeated through the user community and system vendors. In 1989, superminicomputers were positioned to be file and database servers in addition to their familiar role as standalone machines.

The superminicomputer vendors face danger as standards-based computing becomes more predominant. The vendors will continue to enhance their proprietary operating systems to entice customers with a high degree of functionality. They will, however, need to scramble to differentiate their standards-based products and services as hardware becomes more of a commodity. The difference in profit margins between proprietary and standards-based equipment is huge, as the difference in list price is often a 2:1 ratio.

And finally, a relative newcomer to watch will be MIPS Computer Systems. MIPS has a broad distribution strategy for its technology, which has received broad acceptance by the other manufacturers, and the company recently announced its own 55-mips and 13.3-mflops uniprocessor. Its new machine, which is a standards-based RISC and UNIX box, is positioned to be a very competitive player in the market.

TABLE 5
Estimated 1989 Worldwide Factory Revenue and Market Share for Technical Workstations Sold by the Top Five Vendors (Millions of Dollars)

Vendor	Revenue	Market Share
Sun	$1,735	28.7%
HP	$1,595	26.4%
Digital	$ 960	15.9%
Intergraph	$ 365	6.0%
Silicon Graphics*	$ 315	5.2%

*Includes $95 million of revenue that also is included in the supercomputer category.

Source: Dataquest January 1990

TECHNICAL WORKSTATIONS

The high-flying technical workstation marketplace entered a period of more-controlled expansion in 1989. The typical characteristics of a market in this stage—lower margins and a good acquisition climate—were clearly seen this past year.

Table 5 lists the expected results for the top vendors.

Industry leader Sun was placed in a vulnerable position with Hewlett-Packard's acquisition of Apollo early in 1989. Sun's contender, HP, is now facing two issues: integrating its 68XXX product line and deciding which RISC architecture to emphasize.

Sun saw its first stumble as it announced a $20 million loss for fiscal year 1989 fourth quarter, which ended in June. In conjunction with this falter, Sun has revamped its product line to emphasize the SPARC products.

Digital announced a family of workstations that, outside of Data General's product line, are the current industry leaders in price/performance for RISC-based technical workstations.

The year 1989 saw the merger of two fierce competitors, Ardent and Stellar. Stardent, the resulting company, must now work out the problems associated with redundancy in management and support of two architectures. Stardent plans to have a unified product line with a single instruction set by early 1991.

Margins are being buffeted as price wars are now being waged at the low end. After the HP buyout, Apollo announced a new low-end 68030 workstation, starting at approximately $4,000, the lowest-priced 68030 workstation available today. Silicon Graphics also announced price cutting in its low-end product line as it enhanced performance.

Dataquest expects the technical workstation industry to continue to grow at a CAGR of 30 percent for the next five years and become a $16.0 billion industry by 1993. Dataquest expects RISC technology to overtake CISC in 1993, becoming responsible for 61 percent of the factory revenue generated in the industry.

For a more elaborate discussion of the key events and underlying trends in the technical workstation industry, we encourage the TCSIS workstation clients to refer to the TCSIS newsletter 1990-3, entitled "Workstations: The Battleground for the 1990s."

TECHNICAL PERSONAL COMPUTERS

The battle for the desktop continued to rage as the performance level of technical PCs increased dramatically. The dividing line between technical PCs and technical workstations became even less distinct. As a result, personal computers being used in technical applications gained ground in 1989.

The three top vendors in this market made strong gains during this time period, with systems for the technical applications market. See Table 6 for the expected results of the three major competitors.

Apple introduced more-powerful versions of the Macintosh II (i.e., Macintosh IIcx) that are effective alternatives to entry-level workstations. IBM introduced a 486-based daughterboard for its PS/2 Model 70 computer in order to boost its offerings in the performance-class PC category.

At Comdex, IBM demonstrated its 486 system with MCA architecture, running five RISC-based, i860 Bus Master cards.

Compaq announced its DeskPro 486/25, a 486-based 25-MHz PC that adds a high-end complement to the company's recent introductions of DeskPro 386/25 and SystemPro 386/33 machines. Compaq continued to compete against the low end of the workstation market and the minicomputer market by introducing its SystemPro series, which will incorporate the 486 33-MHz chip when it is available. The SystemPro functions as a multiuser PC server, one with a new 32-bit fixed disk drive array technology. Up to eight 210Mb drives may be added to provide disk mirroring and data guarding, enhancing its role as a server.

The technical PC segment continued its growth as technical PCs became stronger alternatives to low-end technical workstations and were used as PC file servers, contributing to the eroding minicomputer market. With the introduction of Intel's 80486 chip and the use of UNIX emulators, technical PCs not only have become more of a threat to the workstation market, but also can outperform the 16-bit proprietary-based minicomputer at a lower cost per seat.

OTHER TECHNICAL COMPUTERS (MINICOMPUTERS AND MICROCOMPUTERS)

This market segment clearly is in the advanced stages of decline. The market has continued to erode from the pressure of smaller, higher-performing PCs and powerful workstations. See Table 7 for a list of vendors competing in this area.

IBM continued its lead in this segment of the market, with older offerings and multiuser versions of desktop systems. All of the top five vendors' systems are based on proprietary operating systems, which, considering the current emphasis on standards, does not bode well. Almost all vendors had declining revenue for these market segments, with the exception of IBM in microcomputers and HP in minicomputers.

The minicomputer still retains a role as a single-solution machine and as a server to link smaller systems to computationally intensive machines. However, in the majority of technical applications, personal computers, with their more sophisticated bus structures and mighty CPUs, have taken over the functionality that once was the domain of minicomputers.

TABLE 6
Estimated 1989 Worldwide Factory Revenue and Market Share for Technical Personal Computers Sold by the Top Three Vendors (Millions of Dollars)

Vendor	Revenue	Market Share
Apple	$650	14.0%
IBM	$400	8.6%
Compaq	$200	4.3%

Source: Dataquest
January 1990

TABLE 7
Estimated 1989 Worldwide Factory Revenue and Market Share for Technical Minicomputers and Microcomputers Sold by the Top Five Vendors (Millions of Dollars)

Vendor	Revenue	Market Share
IBM	$180	23.0%
HP	$170	21.7%
Digital	$142	18.1%
Encore	$ 49	6.2%
Data General	$ 36	4.6%

Source: Dataquest
January 1990

DATAQUEST CONCLUSIONS

The technical computer industry is being rocked by several fundamental changes. The industry has shifted from being technology-driven to market-driven. And the primary vendors are scrambling to realign their corporate strengths (and internal cost structures) as acceptance of proprietary standards begins to decline, RISC begins to overrun CISC, the division between PCs and technical workstations blurs, the file server market continues to develop, mainframes with vector hardware facilities become more readily accepted, and vendors rush to embrace standards while continuing to enhance and lock in customers with proprietary systems.

The evolution of software architectures will take on a greater role in the future as client-server applications become more sophisticated, perhaps to the point where networked computers become distributed parallel processors. The technical computer industry has continued to grow, in terms of units and revenue, through this turmoil; it is still on track to becoming a nearly $45 billion industry by 1993.

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Research Newsletter

WORKSTATIONS: THE BATTLEGROUND FOR THE 1990s

EXECUTIVE OVERVIEW

As we approach the end of the 1989 calendar year, Dataquest pauses to review the events of the fastest-growing computer industry—the workstation market. For the first time in the workstation market's history, a consolidation occurred: Hewlett-Packard bought Apollo to gain market share, and Ardent and Stellar merged to compete more aggressively in the high-end workstation market.

Workstation vendors are still fighting the price/performance battle, keeping the workstation industry constantly on the move. Vendors are in the never ending stages of price slashing and performance enhancements. But will this be enough to keep the installed base satisfied in the 1990s? In the 1980s, vendors captured market share by offering high-performance systems; in the future, this will not be the case! Users want freedom of choice—they do not want to be owned by a vendor's architecture; they want to own the architecture. The power has moved to the user. This newsletter sheds some light on trends, issues, and strategies vendors must investigate, other than "mips-manship," in order to stay ahead of the game.

Table 1 shows Dataquest's estimate of the 1989 market share in terms of revenue.

THE LINEUP

As you will notice, fewer players are in the lineup this year. Two alliances occurred this year, Hewlett-Packard/Apollo and Ardent/Stellar, now dubbed Stardent.

Once the star of the show, Sun Microsystems is becoming overshadowed by its competitors. Sun Microsystems now has a narrower margin in market share, and Hewlett-Packard/Apollo has encroached on Sun's market share because of the merger. Digital has learned from the past that one

TABLE 1
Estimated 1989 Worldwide Revenue and Market Share of Dominant Workstation Vendors (Millions of Dollars)

Vendors	Revenue	Market Share	1988-1989 Growth
Sun	$1,735	28.7%	48.9%
HP/Apollo	1,595	26.4	27.0%
Digital	960	15.9	26.5%
Intergraph	365	6.0	23.7%
Silicon Graphics	315	5.2	75.0%
Others	1,081	17.8	63.8%
Total	$6,051	100.0%	40.2%

Source: Dataquest
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must make haste in order to gain market share, Intergraph is maintaining its market share, and Silicon Graphics has been busy churning out new products.

THE WORKSTATION OUTLOOK

Despite the cutthroat competition, the workstation market is still revealing breakneck growth. Dataquest anticipates that the workstation market will experience 30 percent growth in sales over the next five years, whereas the total technical computing industry anticipates a compound annual growth rate (CAGR) of 17 percent in sales for that period. Nevertheless, to maintain this growth, vendors must look beyond selling hardware solutions. Vendors must focus their efforts on the following issues in order to maintain market share:

- Globalization of market
- Expansion of distribution channels
- Sales to nonengineering environments
- Service and support
- Shortened development cycles
- Standards as an ideal situation
- High-speed LANs
- Client/server configurations
- Multivendor environments
- Distributed systems
- Partnerships

Selling into the commercial market will provide a greater opportunity for workstation vendors. It will increase market share, strengthen the installed base, and increase profitability. But workstation vendors must realize that penetrating this market requires skills different from those required to reach the technical community. For instance, commercial users are not enthused about UNIX and RISC, which were the factors that drove the growth in the technical markets. The crossover of workstations into the commercial market still is not complete; it is blocked mostly by lack of commercial software.

The industry is moving from a standalone environment into a heterogeneous environment. Users want a coherent, integrated network environment. Hardware basically will look the same, but the software will be the driving force. The software will make the workstation look like an integrated system. Users will not know or care what hardware they are working on. The more pressing issue for workstation vendors is not performance alone; instead, software support and professional services are the key issues for success.

THE PLAYERS

Sun Microsystems

A cloud has been forming over Sun Microsystems' sunrise. Sun Microsystems felt some hard times in the 1989 time frame. Sun Microsystems posted a $20 million loss for its fourth quarter ending June 1989. But this loss did not hurt Sun as much as the industry thought it might; Sun is still the industry leader. Meanwhile, competition from HP/Apollo and Digital is heating up. Sun no longer is leading by a comfortable margin and must pay serious attention to HP/Apollo and Digital.

In April 1989, Sun revamped its SPARC product line, decreasing prices and increasing performance. While Sun was emphasizing the SPARC product line, the 68XXX product line became the less desirable solution.

In November 1989, Sun announced a 486 upgrade package for the 386i product line. This announcement, coupled with the revamping of the SPARC line and the absence of a 68040 commitment, leads us to believe that Sun will drop the 68XXX product line, which we feel is a wise move. Supporting three architectures is a fine way to confuse the client base, and it can be expensive.

In December 1989, Sun announced two servers: the SPARCserver 1, targeting the low end of the market, and the SPARCserver 490, targeting the high end of the market. Now Sun's SPARC offerings span from $9,000 to $100,000. The advent of Sun's last two SPARC announcements changes the perception of Sun. It no longer is viewed as only a technical workstation vendor, but now also as a general-purpose computer vendor selling into both the commercial and the technical marketplaces. The question remains, does Sun offer enough commercial software applications to support its new strategy? More importantly, does the commercial marketplace view Sun as a viable solution since this environment is more concerned about reliability than performance?

While Sun is busy licensing its SPARC technology to various vendors, it must be careful not to lose sight of who its customers are and what market areas it wants to participate in.

HP/Apollo

Now here is an interesting story. In a click of a mouse, the coalition of Hewlett-Packard and Apollo Computer changed the map of the workstation industry. This merger places Sun in a more vulnerable position in terms of market share dominance and places Hewlett-Packard/Apollo in a more aggressive, stronger competitive situation. Buying out the competition is always a good way to increase market share. But, at the same time, it promotes friction within the unified company—friction such as laying off redundancies in the work force, East Coast-West Coast cultural differences, and potential job changes that entail moving employees from their resident states.

Hewlett-Packard/Apollo now faces two issues: integrating its midrange 68XXX product line and deciding which RISC architecture will prevail. In conjunction with these two issues, HP/Apollo must carefully monitor Apollo's installed customer base so the customers, especially those interested in 3-D graphics, will not start looking elsewhere for long-term solutions. On the other hand, Hewlett-Packard's customers, seeing the lower prices from Apollo, may now pressure Hewlett-Packard for lower equivalent prices.

Dataquest still believes that this coalition will be successful in the years to come and the acquisition will make Hewlett-Packard a better competitor. Following are a few factors that substantiate our beliefs:

- Hewlett-Packard has established an installed base outside the technical markets with its 3000 line. This base can be used as a springboard for success as nontechnical users begin to look toward UNIX and workstations.
- Hewlett-Packard products possess both high quality and reliability.
- Apollo has a large OEM installed base, such as Mentor Graphics, Nixdorf, and Siemens.
- Apollo's DN10000VS product is an excellent solution to 3-D graphics capabilities. This advantage comes with a downside; Hewlett-Packard now owns two different proprietary RISC architectures.

Because it has made a commitment to support the Motorola 68040 chip, Hewlett-Packard/Apollo can benefit from Sun's indecisiveness as to whether it should support this chip. Hewlett-Packard/Apollo can easily attract Sun's installed base of 68XXX customers.

Digital Equipment

Digital Equipment fell to third place in the lineup, mainly because of the HP/Apollo merger.

Historically slow to move to new technology, since the beginning of 1989 Digital Equipment has been taking a much more aggressive attitude toward adopting the latest technology. This change is evident with the announcement of the DEC 2100, a product whose price/performance rates just below Sun's SPARCstation 1. This rating is noteworthy, since Sun was historically the champion in price/performance.

Digital has proved its commitment to UNIX by introducing its RISC/ULTRIX product offerings. By announcing these products, Digital solved its product position problems. Before 1989, Digital's product line hovered around the 1- to 4-mips performance range, and the company did not offer a RISC-based solution. Now, not only does Digital have a full range of RISC offerings, but its product line, including the DECsystem 5820, ranges from 10 to 36 mips.

Even though Digital's new strategy will bring it new customers, it does have a disadvantage. Now that Digital has all these choices, (ULTRIX, VMS, and DOS), its customers are confused. One of Digital's successes in the 1980s was that all of its machines ran the same software, now they do not.

Although Digital has a broad offering in the RISC/ULTRIX product line, Digital still is predominantly a proprietary-based company. While the industry is screaming "standards!," most of Digital's sales still are VMS-based. This problem is hard to ignore, because VMS is Digital's bread-and-butter product line. Digital must keep its installed base happy, so when announcing new products it must balance between both VMS and ULTRIX users to defer any thoughts of favoritism toward one of the architectures.

Intergraph

Out of the coals and into the fire is the path that Intergraph has followed. The company decided that the CAD/CAM market alone was not going to

sustain the growth it desired; thus, it set its strategic sights on the general-purpose workstation market. The year 1988 was a very prosperous time for Intergraph with growth greater than the market growth. However, 1989 was not as generous. Intergraph grew 23.7 percent—much less than the overall market. Much of this slowdown is due to the fierce competition and price erosion in the workstation market.

Intergraph already has an impressive installed base in the CAD/CAM market and was the number-three CAD/CAM vendor in 1989. The revenue shown in Table 1 reflects Intergraph's general-purpose workstation revenue amount. The strengths that Intergraph has are also, in a sense, its weaknesses. As one of the top vendors in the CAD/CAM market, it is having difficulty expanding that image to be considered a general-purpose vendor. Its best customers are its loyal installed base, but this installed base is small—in the tens of thousands versus hundreds of thousands for Sun Microsystems.

Intergraph has attempted diligently to change this image. It announced the adoption of X Window and OSF as its application program interfaces (APIs) in order to move away from its proprietary windowing system. But in adopting these open standards, the company must be careful not to alienate its installed base.

If being a general-purpose workstation vendor is really how Intergraph wants to be perceived, the company must continue to port to its system software from areas other than CAD/CAM. We believe that the company also is lacking a competitive low-end product, which is the driving force in many markets. We estimate that, of the total 1989 workstation market, 25 percent can be attributed to the low end.

Silicon Graphics

In 1989, Silicon Graphics (SGI) leveraged off its reputation and success in the 3-D graphics market to enter new markets. At its $13,500 price tag, the Personal IRIS made 3-D graphics attractive to many typical 2-D users and opened the door for Silicon Graphics to penetrate a much larger low-end market. In contrast, the Power Series positioned the company to expand its system offerings toward the high end of the market. SGI has successfully sold the Power Series into its installed base. Focusing on the client/server model, Silicon Graphics is successfully selling into areas where Convex and Alliant are playing.

The acceptance of the Personal IRIS and the Power Series resulted in SGI's revenue growth of 75 percent in 1989, compared with an industry growth of 40 percent. These systems and supporting software have catapulted SGI into the top five of both the workstation and the supercomputering markets.

Silicon Graphics' strategy was to slowly move away from its niche-player position and into the broader technical computer marketplace. SGI has taken the first step by broadening its product line. It has gained market share in the low end and leaped ahead of the other contenders in the high-end workstation market. In fact, it showed such strength that Stellar and Ardent merged in order to better compete with SGI. To continue to be competitive, however, SGI will need to strengthen its application base. Currently, SGI has approximately 400 software packages, most of which are heavily oriented toward 3-D graphics, compared with more than 1,400 packages available on SPARC-based platforms and about 1,000 packages available on HP/Apollo RISC-based systems.

Today, SGI's 3-D graphics and binary compatibility across its product line are competitive advantages over most workstation vendors. SGI must continue to push 3-D graphics down the price curve and increase its software offering in order to capitalize on its advantage before it disappears.

SGI has an advantage over its competitors in the high end of the market. Silicon Graphics will benefit from the recent mergers by Ardent/Stellar (Stardent) and HP/Apollo. Silicon Graphics is the one stable firm in the midst of turmoil in this market. While both Stardent and HP/Apollo are trying to decide which architecture will succeed, customers may decide to go to Silicon Graphics.

ISSUES

The User Is King

Workstation users never had it so good. New workstations are being added to the abundance of products already available. Price/performance seems to drop dramatically with the advent of each new announcement. Although this trend is especially true in the entry-level segment of workstations, this is not the main issue for users. Users demand availability of applications, upgradeability and expandability, vendor credibility, service, support, and adherence to standards.

In short, the workstation market is beginning to display some traits of the traditional superminicomputer market. The workstation market is expanding into the commercial space, with applications such as finance and office automation.

The only certain winner is the user, who can look forward to ever-lower prices and a blizzard of new features. For the user, it is a win-win situation.

The Workstation of Tomorrow

What will the workstation of tomorrow look like? Following is a list that will give some insights into tomorrow's workstation:

- Mips will turn into bips.
- MB will turn into GB for memory configurations.
- GB will turn into TB for storage configurations.
- Users will have no idea what hardware is under the software.
- It will use a standard user interface.
- It will use a standard program interface.
- Mbps will turn into Gbps.
- It will use multimedia and full-motion video.
- It will integrate voice recognition.
- Computers will be used as human interfaces. (They will be like television; it will be hard to find a home without one.)
- UNIX will be a shrink-wrapped workstation software package.

It is inevitable that this list is the direction computers will be heading toward in the 1990s. The list does not apply just to workstations, but to the other classifications of computers as well.

In addition, all the numerous classifications of computers are giving the industry a headache, not to mention confusing the installed base. In the future, no one is going to give a hoot about the hardware, because software and networking will be the major issues of the 1990s. With this in mind, Dataquest believes that there will be only two classes of computers, single user and multiuser, regardless of the performance and price. Maybe this will be the Tylenol for the computing industry.

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Research Newsletter

1989 CAD/CAM/CAE PRELIMINARY MARKET REVIEW: A REPEAT OF 1988 AS VENDOR CONSOLIDATION ABOUNDS

INTRODUCTION

Continuing the consolidation trend of the late 1980s, albeit at a slower pace, 1989 saw 11 CAD/CAM/CAE-related mergers and acquisitions. Among the most notable was the purchase of Apollo Computer by the Hewlett-Packard Company (HP) and the IBM Corporation's recent buy of Lockheed Corporation's Cadam, Inc. The heightened flurry of merger and acquisition activity in the CAD/CAM/CAE industry (44 deals during the past three years) along with slowing revenue growth (12 percent in 1989) are clear signs that the CAD/CAM/CAE industry is entering market maturity. *As the industry approaches maturity, Dataquest believes that a number of destabilizing influences are operating—such as software unbundling, rapidly changing price/performance curves, and the move towards a systems integration business model—that will continue to cause the CAD/CAM market to behave in a volatile manner over the next several years.* This newsletter will review and examine the key happenings of 1989 by the major CAD/CAM business segments and what we expect to happen in 1990.

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CAD/CAM INDUSTRY OVERVIEW

1989 PRELIMINARY CAD/CAM/CAE MARKET SHARE

Table 1 lists the 1989 preliminary worldwide CAD/CAM/CAE market share ranking for the top 10 vendors, based on Dataquest's 1989 revised market growth estimate of 12 percent totaling $11.5 billion in end-user revenue. The first four market positions remain unchanged with IBM, Computervision Corporation, Intergraph, and Digital Equipment Corporation in places one through four, respectively. HP moved up one notch in 1989 by virtue of the Apollo acquisition.

The two big winners in this year's top 10 were Sun Microsystems, Inc., moving up four places to number seven, and Autodesk, vaulting 10 spots to number 10. The enormously positive acceptance of the Sun SPARC-based workstations in the CAD/CAM/CAE market was the principal driver moving Sun to the Dataquest top 10 for the first time. This 3 percent share does not include another $350 million in OEM revenue that Sun received by selling Sun workstations through turnkey suppliers such as Computervision and Valid Logic Systems, Inc.

The most impressive market share gain in 1989 was recorded by Autodesk. Remarkably, Autodesk rose from the number 20 to the number 10 position without adding major revenue acquisition to speak of (other than tiny Generic Software) and without receiving hardware revenue. Autodesk, with a profit margin of 20 percent after tax, has not only been one of the fastest growing CAD/CAM/CAE vendors, but also one of the most profitable.

1989'S BIGGEST SURPRISE: HP'S ACQUISITION OF APOLLO

The blockbuster deal of 1989 was HP's acquisition of Apollo; the acquisition took many people by surprise, given the rather conservative heritage of HP. The Apollo acquisition catapulted HP from a middle-of-the-pack participant to a clear second in the workstation industry, and it could seriously challenge Sun Microsystems, Inc., over the next several years to gain the industry's market share lead. In our view, HP integrated the Apollo organization well, but faces the much larger challenge of rationalizing the disparate and incompatible product lines. Moreover, HP was dealt a significant blow with Mentor Graphics' recent announcement that it will port its software to the Sun SPARCstation.

TABLE 1
1989 Preliminary Top 10 CAD/CAM/CAE Worldwide Market Share (Based on End-User Revenue, OEM Revenue Not Included)

Vendor	Percent	Share Rank	Share Rank
IBM	13.9%	1	1
Computervision	8.3%	2	2
Intergraph	7.4%	3	3
Digital	7.0%	4	4
HP/Apollo	4.3%	5	6
Mentor	3.4%	6	5
Sun	3.0%	7	11
Compaq	3.0%	8	8
McDonnell Douglas	2.0%	9	9
Autodesk	1.6%	10	20

Source: Dataquest
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1989'S BIGGEST DISAPPOINTMENT: FINANCIAL TROUBLE AT DAISY/CADNETIX

Daisy Systems Corporation looms perilously close to the brink of disaster, largely because of crippling financial obligations incurred during its hostile takeover of the Cadnetix Corporation just one year ago. Daisy's future now rests in the capable hands of Regent Pacific Management, a turnaround team specializing in high-technology financial disasters such as Daisy. However, even if the new team is able to eliminate the financial millstone hanging around Daisy's neck, the damage done to Daisy's customer installed base by preying competitors and management problems may be too severe to restore Daisy to the market power it once was.

1990 FEARLESS FORECASTS

Dataquest foresees the following developments in 1990:

- IBM's new RT workstation will not set the world on fire. This sluggishness is not because of a lack of technical features, but rather a result of IBM's organizational prejudice that continues to favor selling high-priced MVS and VM mainframes over inexpensive UNIX workstations. As a result, IBM will make a strong bid to buy Silicon Graphics, Inc., if Japanese companies (such as NEC Corporation or Sony Corporation) do not buy it first.
- The Sun-clone market will begin to take off in 1990.
- Sun will drop both the Motorola- and Intel-based architectures in 1990.
- Intergraph will port its CAD/CAM software to a workstation other than its own (e.g., HP, Sun).
- Digital Equipment Corporation will make a stronger attempt to become a turnkey CAD/CAM vendor through a series of software-related deals (with companies such as Applicon, Aries, or Matra).
- HP will announce the sale of its fledgling EDA software business to Mentor Graphics and, in return, Mentor will port to HP's entire line of workstations.
- Mentor acquired SCS on January 11, 1990. The former SCS's IC layout package is currently running on Sun. While the former Mentor's package will be ported onto Sun in 4Q'90.
- Daisy/Cadnetix will be sold to a Japanese vendor (e.g., Seiko) or file for reorganization, or both.

David Burdick

MECHANICAL CAD/CAM/CAE

1989: MCAE AND DISTRIBUTED PROCESSING FUEL GROWTH

The mechanical CAD/CAM/CAE market was dominated in 1989 by the strong and continued growth of the MCAE segment and the growth of vendors supplying technical workstations and personal computers.

The Dataquest 1989 forecast for mechanical CAD/CAM/CAE revenue is on track, with a total revenue figure for the worldwide market of more than $6.6 billion. An analysis of three-quarters of public company performance indicates an annual growth rate near 11 percent, matching our forecast. The higher 16 percent revenue growth expected for the European market may have been slightly conservative because of the strength of corporate investments in preparation for 1992. Major European corporations are making plant and equipment investments, positioning to gain market share as the trade barriers fall. Tax laws that encourage new research and development activity in France also are fueling growth in that market. Asian markets in general appear to be following the forecast of 11 percent growth. Japanese vendors are expected to continue to gain market share in the Japanese market.

Every major CAD/CAM/CAE vendor reported above average growth in the design and analysis application area. Users are investing in the current MCAE technology, finding the products refined and enhanced to a point of general productivity. Proponents extol the virtues of various user interfaces or modeling technologies, but the products primarily provide a reasonable tool for getting the job done.

For those people not satisfied with current products, several new technologies that promise many advantages are being integrated into MCAE products.

Parametric Programming

Parametric Technology was the first company to prove the viability of parametric programming in a product based on solid modeling. The company has enjoyed healthy growth and has developed a significant list of alliances and joint marketing agreements, proving the marketability of the concept.

Many other leading vendors are developing, or have recently introduced, a version of parametric or variational geometry. PDA Engineering and SDRC showed products at the recent Autofact show. Premise has developed a variational geometry-based system with an integrated free-form equation solver. The "what if" scenarios made practical by the two-directional geometry and equation-editing contribute greatly to the usefulness of parametric programming. This is enabling technology. *Dataquest expects every major successful MCAE product to have parametric features in the early 1990s.*

Knowledge-Based Engineering (KBE)

The world of knowledge-based or rule-based engineering design has been slow to evolve. The basic technology has grown from a few esoteric applications to today's more general-purpose solutions. ICAD and Wisdom, the leaders in this market niche, are rapidly adding new features and developing strategic alliances to ensure market acceptance.

The market potential for knowledge-based engineering is enormous. Every manufacturing enterprise can use this technology. Each company has standard procedures or methodology in its design process, proven over time. The exciting element of KBE arises from the ability to design something new using proven methods. The design process is captured with hundreds of rules or procedures; each of which is dependent on the previous step, calculation, or geometry construction. A complex design process can be captured and modified until it precisely deals with every design consideration. As more design constraints become known, these can be added to the process. A year or more can be used to fully implement a complex system. A more effective user interface is needed to drive the procedural, calculation, and geometric components of the process.

P-Method Analysis Tools

The P-method of finite element analysis is in its embryonic stage. Two pioneering companies, Noetic Technologies (owned by MacNeal-Schwendler Corporation) and Rasna, are the visible leaders in this area. The P-method has key advantages over the more common H-method. The setup required for the problem is simplified. With the P-method a user builds hundreds of elements, rather than several thousand, in a typical problem. The P-method process also provides reliable error checking, valuable to the novice user. Automatic generation and regeneration of elements has been an elusive dream for many finite element developers; this appears to be possible with the P-method. The next step of finite element analysis will allow the computer to work within a set of guidelines to generate an optimized geometry conforming to design constraints. *If the benefits of the P-method analysis are realized fully, this technology could be the most significant advancement in mechanical CAE in the 1990s.*

Each of the above companies contributed greatly to MCAE technology. Each has developed enabling technology that will influence the future direction of the industry.

SUPER STARS

Annual growth rates greater than 50 percent have become a distant memory for many companies in the CAD/CAM/CAE business. However, the super stars in 1989 exceeded this growth rate as shown in Table 2.

TABLE 2
Super Stars in Mechanical CAD/CAM/CAE (Estimated 1988 to 1989 Revenue Growth Rate and 1989 Worldwide Revenue)

	Growth Rate	Revenue ($M)
Silicon Graphics	80%	$100
Compaq	51%	$233
Sun Microsystems	50%	$113
Autodesk	50%	$ 77

Source: Dataquest January 1990

Silicon Graphics is expected to record more than $100 million in revenue, with an 80 percent growth rate over 1988. The great popularity of the Personal IRIS and the excellent third-party software vendor support are major factors contributing to success.

Compaq moved ahead several positions on the market share table, with an estimated 51 percent growth rate and $233 million in mechanical CAD/CAM/CAE-related sales. Aggressive marketing by Compaq combined with well-configured systems made the 386-based products the platform of choice for serious PC CAD/CAM/CAE users.

Sun also grew an estimated 50 percent in 1989, reaching more than $110 in mechanical sales. An effective sales effort, new products with improved price/performance ratios, and an aggressive third-party software campaign are supporting strong growth.

Autodesk, by far the fastest growing software vendor in the mechanical top 20 market share list, grew 50 percent and showed a revenue totaling $77 million. Significant product enhancements with the release of Revision 10, some acquisition activity, and a continued safe-buy status throughout the distribution channel accounted for Autodesk's growth.

Michael J. Seely

ELECTRONIC DESIGN AUTOMATION

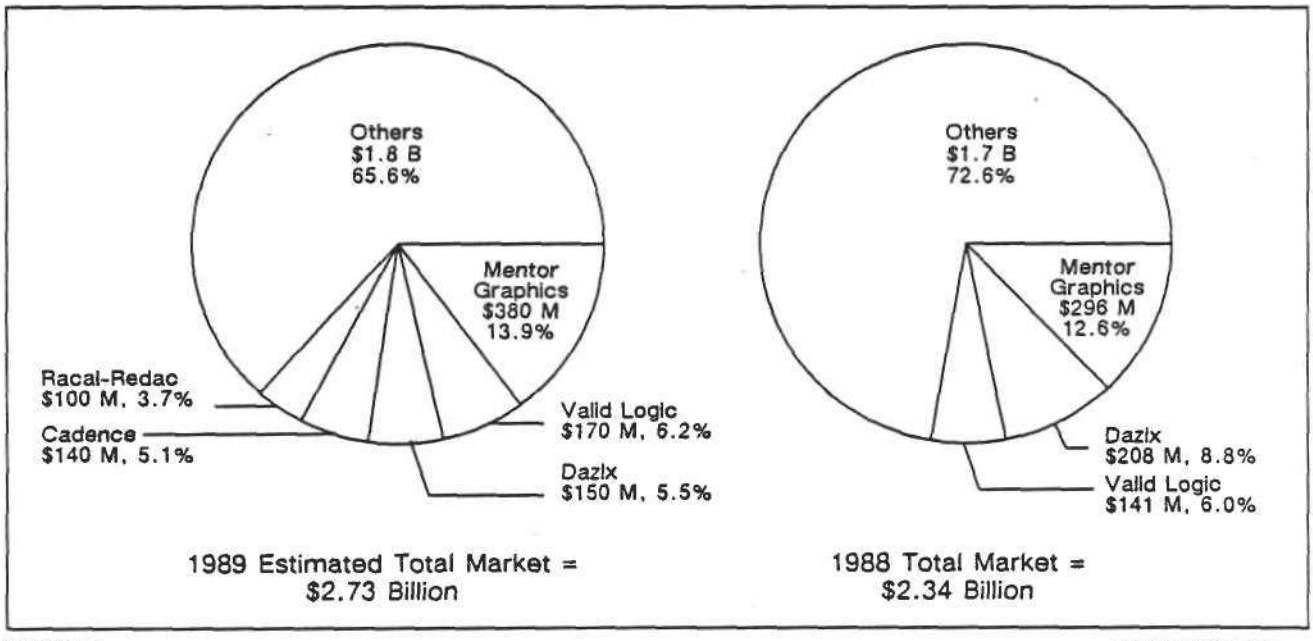
1989: A PIVOTAL TRANSITION PERIOD

Adapting to the rapidly changing competitive forces that shape the electronic design automation (EDA) industry while simultaneously sustaining growth and focusing on next-generation product development were the major challenges confronting vendors in 1989. It was a pivotal transition period. Vendors struggled to maintain equilibrium as they began to understand the new rules by which the EDA game will be played. The clear winners in 1989—Mentor and Cadence. Both companies increased market share significantly (see Figure 1). Yet, in 1990, each company faces challenges, which could impair future growth.

Valid Logic Systems continued showing signs of strength in 1989, surpassing Daisy/Cadnetix (Dazix) as the number two vendor behind Mentor Graphics. Racal-Redac, Inc., with its acquisition of HHB Systems, made a bid for a leadership position in the 1990s.

Dazix, however, experienced a traumatic year. The synergy between Daisy and Cadnetix, together with the strengths of each, were wholly offset by the financial difficulties stemming from the structure of their merger. As the industry moves into 1990, the former industry leader's future remains uncertain.

FIGURE 1
EDA Market Leaders—1988 and 1989 Revenue and Market Share (Millions of Dollars)



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Source: Dataquest January 1990

But Dazix is not alone. A myriad of other companies are inadequately positioned for the 1990s and face similar uncertainties. Many midsize companies will be challenged to compete aggressively against either the giants or the upcoming generation of start-up companies. If the term "industry consolidation" best describes the events of the late 1980s, Dataquest believes that "shakeout" is surely the word of the early 1990s.

Success in 1989 depended heavily on weathering the tremendous upheaval of the competitive forces driving the EDA business. For example, the three largest EDA workstation suppliers—Sun Microsystems, Digital Equipment, and Apollo Computer—experienced major changes in 1989. Both Sun and Digital had to manage severe product transition phases; and Apollo and HP worked on the integration challenges of the merger.

Furthermore, *Dataquest believes that the unabated merger and acquisition activity created a backlash in 1989, with the stability of individual companies, as well as the long-term viability of the EDA industry, being questioned.* The market was concerned about whether newly merged companies could focus effectively on next-generation product development while simultaneously confronting the challenges of merging product lines, distribution channels, development teams, and corporate cultures.

Yet the turbulence provided opportunities for some vendors. These vendors capitalized on the turmoil, using the uncertainties and perceived instability of the industry as weapons against competitors with uncertain futures.

Realignment of the Market Participants

Nearly all EDA vendors spent 1989 realigning and repositioning themselves in preparation for the market's increasing demands. For example, Mentor disclosed that it would open its system to allow competitors to integrate into the Mentor environment. In essence, Mentor is moving into the framework business. And the company was blessed with a stroke of luck when HP acquired Apollo. Apollo's newfound strength enabled Mentor to delay moving its software to the Sun platform until late 1990. Earlier this month, Mentor announced that it will offer all of its software on the Sun SPARCstation product line. The port is expected to be completed by December 1990.

Cadence continued to hold most of the IC CAD business, but the company spent much of the year setting the stage for its entry into the systems-design market. Cadence acquired Gateway Design Automation and formed a systems division in preparation. Cadence's framework provides an edge over competitors that are lacking such technology. But Cadence is entering the hotly contested systems market, currently occupied by several established companies. And convincing users to discard existing EDA systems in favor of the Cadence environment will be a major challenge, given the prohibitively high costs of switching.

Cadence also faces competition in the IC CAD arena, with several vendors preparing in 1989 for a full-scale battle in 1990. Competitors hoping to wrestle market share from Cadence include Seiko Instruments, Inc., Valid Logic, and Mentor Graphics, which acquired Silicon Compiler Systems earlier this month. Prior to the acquisition, Cadence's market share was more than twice that of its nearest competitor, Silicon Compiler Inc. However, the combination of Mentor and SCS puts Mentor right on the heels of Cadence. Cadence is also the first EDA vendor to prove the viability of a business model based on selling software only.

Valid continued to exploit its two primary advantages—running on the Digital and Sun platforms and offering a front-to-back EDA solution. Offsetting these advantages for Valid, however, were the product transition problems experienced by Digital and Sun, which caused a disruption in Valid's shipping schedules. In addition, Valid also was forced to dedicate precious resources to integrating product lines acquired from Analog Design Tools, Calma Company, and Integrated Measurement Systems.

Meanwhile, Dazix found itself embroiled in financial difficulties that have jeopardized the company. In short, the acquisition of Cadnetix bled the merged company of nearly all cash reserves and further exposed it to enormous debt. Exacerbating the company's problems was Sun's bumpy product transition period, as well as the uncertainty over Sun's commitment to its 80386/486 workstation line. By the end of 1989, Dazix's stock price had plummeted to less than $1 per share, and the company found itself without a helmsman, with both of its chief executives resigning after the merger.

THE CALM BEFORE THE OPEN SYSTEMS STORM

The year 1989 also saw ignition of the framework wildfire, with the CAD Framework Initiative (CFI) signalling the development of framework standards. The CFI set an aggressive schedule, with a demonstration of a procedural interface planned by June 1990. *Dataquest believes that, until standards are agreed upon by CFI's members, individual EDA vendors such as Cadence and Mentor will battle to establish their proprietary frameworks as de facto standards.* Indeed, Mentor continues to work to meet its framework-release deadline of mid-1990.

The events of 1989 have made it clear that success in the early 1990s demands that vendors provide open systems and support standards. And the myriad of standards that vendors will be forced to support continued to grow in 1989, with VHSIC hardware description language (VHDL) topping the list. Indeed, nearly every EDA vendor announced support for VHDL. However, only a handful of companies actually shipped VHDL-based products in 1989.

USHERING IN A NEW ERA

EDA users became more demanding in 1989, looking well beyond the marketing facade. Customers made it clear that they are looking to establish close relationships, or partnerships, with EDA vendors. This contrasts sharply with the somewhat distant relationships that have existed in the past. Buyers began evaluating vendors not only on their current product offerings, but also on their future product development plans, financial health, and corporate strategy. Dataquest believes that the market will become even more demanding in 1990, evaluating vendors on a range of other capabilities, including the quality of their framework, the openness of the system, the level of integration of the tools, and the number of third parties that are tightly integrated into the environment.

Ron Collett

AEC/MAPPING

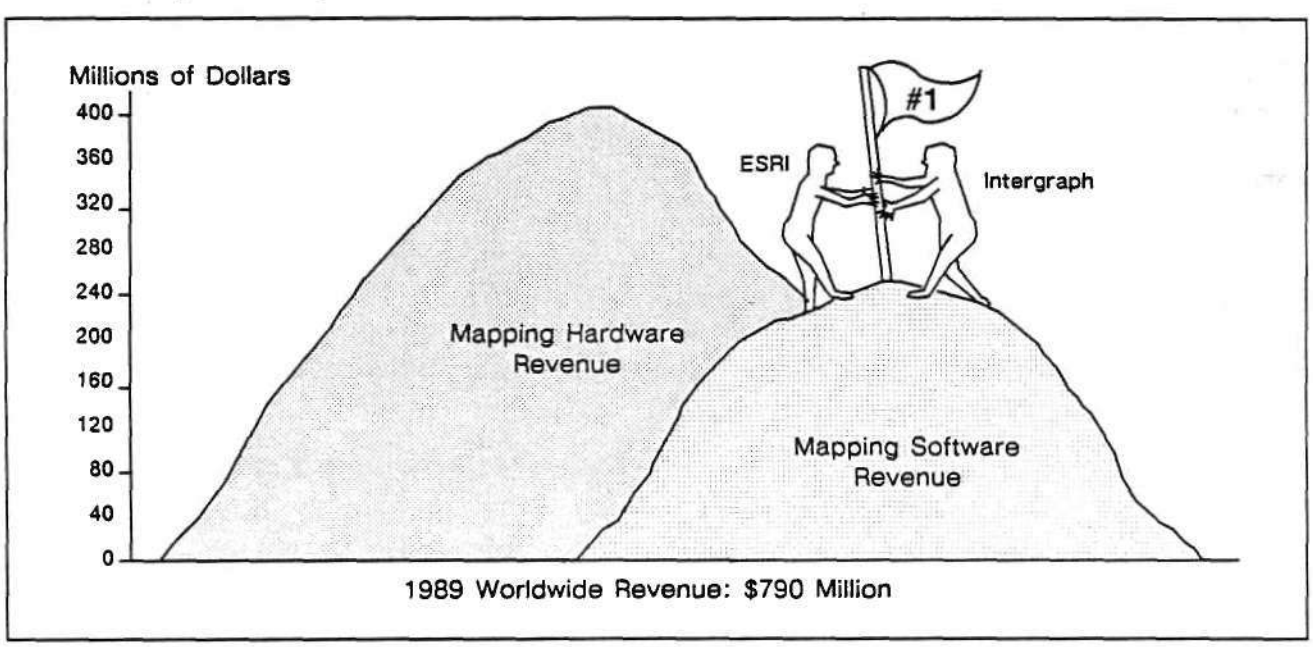
1989: AEC AND MAPPING CAD

In 1989, Intergraph retained its number one positions in both the mapping and AEC CAD markets (including hardware, software, and service). That outcome was almost preordained, given the company's initial distance from any competitor. The big story in 1989 is that ESRI's growth challenges Intergraph for the number one position in mapping software (see Figure 2).

ESRI finished 1989 with $40 million in factory revenue, including approximately $32 million in mapping software revenue—nearly on a par with Intergraph. Even these figures somewhat distort ESRI's influence among mapping buyers. In Europe, Intergraph receives full end-user revenue from its sales offices, while ESRI receives a smaller percentage of royalty revenue from dealers. In North America, ESRI has clearly outpaced Intergraph in mapping software revenue. *ESRI's growth is significant because we believe that market share in software revenue correlates with mind-share among users.*

The year 1989 was one of great media interest in mapping CAD, with articles in mainstream periodicals exploring all manner of futuristic mapping

FIGURE 2
ESRI Challenges the King



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Source: Dataquest January 1990

applications. Supplemented with a buzzword selling campaign by eager vendors, mapping CAD achieved a level of publicity surpassed only by the EDA market in the early 1980s.

AEC CAD: FINALLY COMING AROUND

Most architects are now aware of the inevitability of drawing with electronic tools, and nonusers know they will need to buy a system soon. They are driven by several forces.

Many architects are being pressured by their clients to deliver both an electronic and hard-copy drawing set. In addition, market-focused architects are creating a competitive edge by using CAD to demonstrate design options to clients. Non-CAD users have begun to see the marketing contribution that a computer can make in helping a client to understand (and buy into) a proposed design. Third, as renovation work captures an increasing percentage of a typical architect's business, computers offer better tools for merging existing drawings with new work.

1989'S BIGGEST SURPRISE: HARD COPY IS HOT

A/E/C Systems '89 was the beginning of a midyear flurry of plotter announcements, and, by the end of the year, it appears that a full-fledged price/performance war is on. Because AEC CAD is a major consumer of plotters, this new rate of product announcements makes AEC solutions more cost-effective.

1989'S BIGGEST DISAPPOINTMENT: TIGRIS IS LATE

Despite long expectations, Intergraph's full TIGRIS GIS is not shipping yet. The complex software problems are bound to be resolved during 1990, but the delay is costing the company market share.

WHAT TO WATCH FOR IN 1990

We foresee the following developments in 1990:

- Although greater numbers of architects finally will start buying computers for design, their purchases will demonstrate that the computer-resistant AEC designers gravitate toward safe (that is, brand name) buys.
- Lower cost to rasterize existing paper drawings makes CAD more appealing to design firms, which are increasingly finding the market for reworking of existing facilities better than the market for designing new buildings.
- Prices on plotters continue to drop—dramatically enough to cause growth in AEC, the most drawing-intensive CAD market.
- Following incubation in 1989, developers introduce new Autocad add-on products for mapping applications, using Release 10's entity-handle feature. At least one of these products is a strong success, and, bolstered by upcoming links to relational databases, Autocad gains mapping market share.

Kathryn Hale

PC CAD AND CAD RESELLERS

1989: PC CAD AND CAD RESELLERS

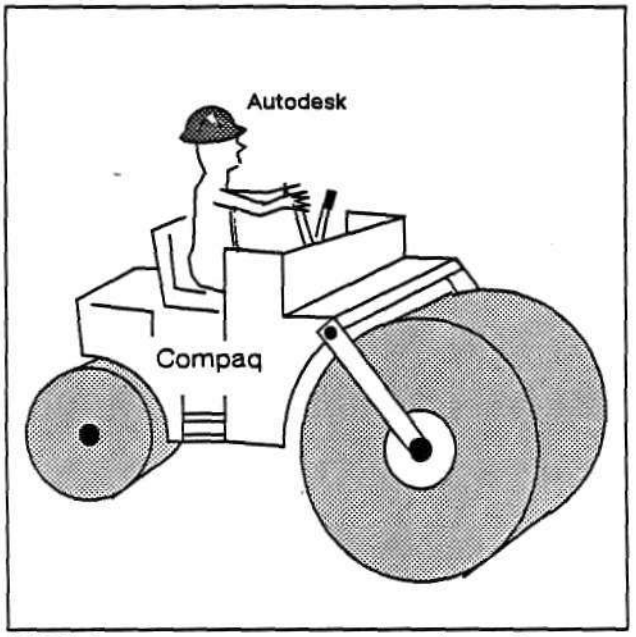
The top two companies in the PC CAD market, Compaq and Autodesk, continued their steamroller growth in 1989 (see Figure 3), with Compaq growing at a 40 percent rate and Autodesk at 55 percent (45 percent after excluding the new Generic Software acquisition). The 25 percent growth of Apple Computer, Inc., on the other hand, was somewhat disappointing. Preliminary estimates indicate that the entire PC CAD industry grew 17 percent, to a total revenue of $1.7 billion.

In 1989, it was business as usual in this buoyant market. Most of the growth was at the PC high end; average selling prices held steady; the hundreds of PC CAD software companies continued to survive and support an occasional interesting new entrant (such as Ashlar); and the usual 20 percent of dealers left the market.

CHANGE IS IN THE AIR

The year 1989 was the first year that technical workstations were sold in volume through dealers. Several large dealers shifted their sales to Sun's SPARCstation, often shipping the workstations with Autocad. By midyear, a few first-rate dealers had virtually dropped PC sales altogether in favor

FIGURE 3
Autodesk in the Driver's Seat



0005878-3 Source: Dataquest January 1990

of workstations in general and SPARCstations in particular. During 1989, UNIX-based versions of Autocad reached approximately 12 percent of total shipments, up from 5 percent in 1988 and 2.5 percent in 1987.

The key reason for a dealer to shift to workstation sales is the 40 percent profit margin, far higher than PCs. However, workstation volume requirements are demanding. *Only the most successful dealers have the resources to risk investing in workstation sales—and simply taking that risk ultimately encourages dealers to focus all resources on workstations.* As long as Sun can protect these dealers' margins, the dealers will continue to sell the product. This state of affairs should continue during most of 1990.

Another reason for a dealer to move to selling workstations is to avoid the hours consumed in building a high-end networked PC for CAD applications. Workstations are preconfigured with all the necessary items, at nearly the same final price as PCs, and still with better margins. This is not to say that overall PC sales suffered significantly. Compaq's continued excellent growth bears witness to continued strength in the PC market. Nonetheless, *PC manufacturers must be concerned about losing several of the most successful CAD dealers to workstation vendors.*

A 1989 SURPRISE

Last year offered few real surprises in the low-end CAD market. Most companies realized reasonable or outstanding revenue. Autodesk surprised some market analysts with its dramatic price cut on Autosolid, combined with the purchase of low-end Generic Software and the introduction of the Animator. Clearly, Autodesk has decided to remain in the mainstream software market, rather than pursue the high-end CAD market.

1989'S BIGGEST DISAPPOINTMENT: THE MAC STUMBLES

After much waiting, a wide variety of CAD products became available for the Mac . . . and met with limited user demand. Apparently, the engineers who buy and use Macs were not yet ready to spend more than $2,000 for a piece of software, as they are accustomed to the $200 variety. Although Claris CAD appeared to take off to a good start, a significant piece of Claris CAD growth appears to be at the expense of competing Innovative Data Design. No Mac software vendor seems pleased with first-year results.

Autodesk's limited endorsement of the Mac was no help to either company. Apple needs Autodesk more than vice versa, so the onus is on Apple to initiate a change in the status quo.

In 1990, it is also nearly mandatory for Apple to deliver a broader range of computers—either via more powerful, price-competitive Macs or possibly through delivering some integration with Digital Equipment products.

WHAT TO WATCH FOR IN 1990

We foresee the following developments in 1990:

- Sun's SPARCstation's inroads into the dealer channel meet competition from both new 486-based computers and other workstation vendors. Computer-vendor channel wars become obvious.
- DOS continues to be the principal operating system for low-end systems. No application appears to make OS/2 investments in CAD worthwhile, and the 70-megabyte UNIX appears monstrous in size to most PC CAD buyers. However, DOS applications running under Windows sell quite well.

- Successful CAD dealers increasingly operate from multiple locations within a region, taking market share from the hundreds of independent, single-site operations.
- The strongest PC CAD growth is in Europe.
- Autodesk's amazing growth continues. Autodesk's long-term viability and broad acceptance throughout many industries make Autocad an obviously safe buy. When the 386 version starts shipping in 1990, the performance boost will generate another revenue spurt.
- By the end of 1990, X-terminals with Autocad could start moving through CAD dealers, competing directly with Sun's product line.

Kathryn Hale

ASIAN CAD/CAM/CAE MARKET

SOFTWARE UNBUNDLING IS GAINING POWER IN JAPAN

Unbundled software in Asian CAD/CAM markets has gained popularity from 1988 to 1989 as indicated by Figure 4. Dataquest believes that this tendency will strengthen in 1990. In general, technical workstations and PCs are the preferred platforms for software unbundling. From an application perspective, EDA and MCAD are realizing the most gain from unbundling, rather than AEC and Mapping applications.

In this section, we will look closely at major software vendors marketing technical workstation-based products in both the EDA and MCAD market segments. We then will examine the changing strategy of non-Japanese vendors attempting to penetrate the Japanese CAD/CAM market.

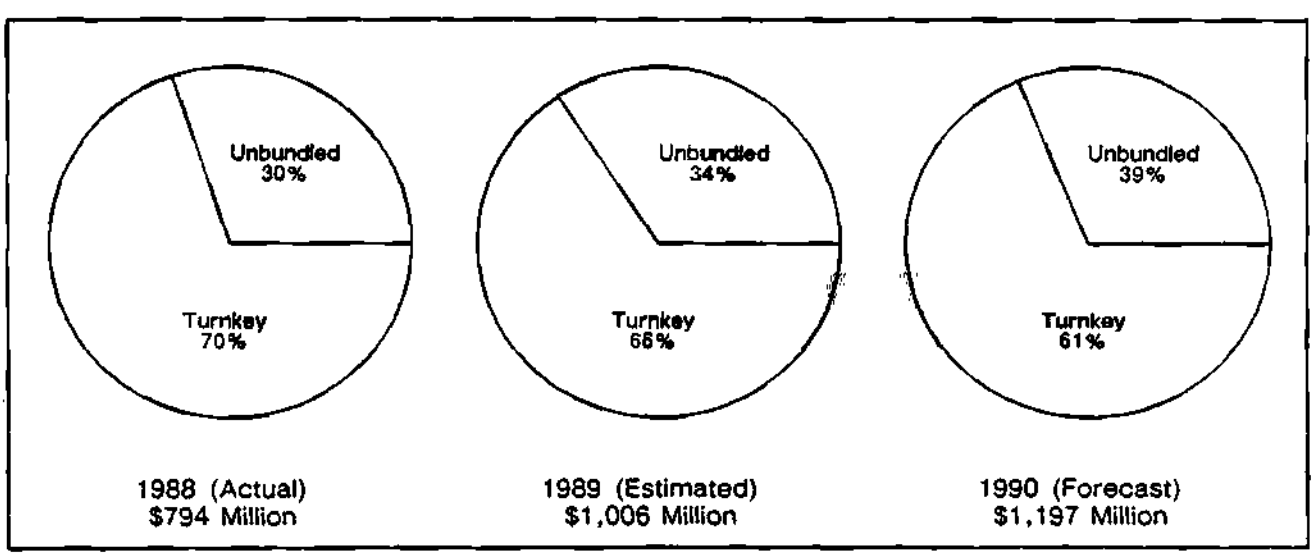
A Key To Success: Software Unbundling

Table 3 shows the current status matrix of software unbundling and turnkey sales for major software vendors and workstation vendors. The various strategies of key vendors regarding unbundling are discussed by application below.

EDA

The most enthusiastic vendor supporting software unbundling and multiple workstations support is undoubtedly Cadence Design Systems, which is marketing its CAE and IC layout software with the engineering-oriented trading company, Innotech, in Japan. Cadence traditionally has provided its software package unbundled. Currently, the package

FIGURE 4
Asian CAD/CAM Software Revenue: Turnkey Versus Unbundled (Millions of Dollars)



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Source: Dataquest January 1990

TABLE 3
Japanese Workstation and Software Matrix

Software Companies	Workstation Vendors: Sun	Digital	HP Yokogawa-HP	Apollo	SGI	IBM	NEC	Sony	Others
EDA									
Cadence	U	U	U	U	-	-	U	U	Solbourne
Valid Logic	U,T	U,T[1]	U,T[2]	U,T[2]	-	U,T[3]	-	-	Solbourne
Racal-Redac	U,T	U,T	-	T	-	-	U	-	-
Zuken	2Q'90	-	U,T	-	-	T[4]	U,T	-	Hitachi
Mentor Graphics	U[5]	-	1Q'90[6]	T	-	-	-	-	-
Seiko[7]	2Q'90	T	-	-	-	-	-	-	-
Dazix	U,T	-	-	-	-	-	-	-	-
MCAD									
PTC	U,T	U,T	U	U,T	U,T	-	U	-	Tek (XD88)
SDRC[8]	U,T	U,T	T[9]	U,T	U,T	T[10]	-	-	Tek (XD88)
Ricoh	U,T	-	U,T	-	U,T	-	-	U,T	Stardent
McDonnell Douglas	-	T	T	-	-	-	-	-	-
Hitachi Zogen	T	T	-	T	-	-	-	-	DG
Aries Technology	U,T	-	-	-	-	-	-	-	-
YHP	-	-	U,T	-	-	-	-	-	-
Mutoh[11]	-	-	T	-	-	-	1Q'90	-	-
CV (CADDS)	T	-	-	-	-	-	-	-	-

U = Supported by software unbundling.
T = Supported by bundled turnkey system.
(Specified date—Not supported currently, but will support after date specified)
[1]Does not support the former Calma's IC layout package.
[2]Only supports the former ADT's package.
[3]Only supports the former Valid's CAE package.
[4]Zuken's software package with IBM PCRT is marketed through IBM.
[5]Only supports the former SCS's package currently. The former Mentor's package will be supported in 4Q'90.
[6]HP is developing 68040-based workstation compatible to Apollo workstation.
[7]Does not include Dazix product.
[8]SDRC's software package with Sun, Apollo, Digital, and SGI workstations is marketed through Tokyo Electron.
[9]SDRC's software package with HP workstation is marketed through YHP (Yokogawa-HP).
[10]SDRC's software package with IBM PCRT is marketed through IBM.
[11]Does not include Intergraph's product.

Source: Dataquest
January 1990

is unbundled for all major workstations, except for IBM, in Japan. However, Cadence has acknowledged support for IBM's next workstation, if the workstation is popular among EDA users. We believe that the unbundling strategy of Cadence is attributable to the following:

- End users have various preferred platforms to run specific software; the set of preferred platforms varies by the user's environment. Therefore, it is critical that the vendor support the platforms optimal to a given environment, as does Cadence.
- If a software vendor offers a myriad of turnkey systems, the profit margins can deteriorate. This deterioration occurs because providing multiple turnkey systems forces software vendors to manage costly inventories of platforms while taking a risk of falling prices, as well as maintaining a staff of engineers dedicated to every platform.

- Because users of Cadence's product are mostly CAE- and IC-layout engineers, they usually are sophisticated enough to integrate vertical tools into a complete system.

Valid supports major U.S.-based workstations by both unbundling and bundling software. The porting status of Valid's software has been in the transition stage because of its acquisition of several niche vendors in the past two years. Valid is likely to support NEC and Sony workstations in the near future.

Zuken finally has decided to support Sun along with its current platforms—HP, IBM (OEM), and NEC. Although Zuken markets both turnkey and unbundled systems, the ratio of turnkey revenue is much larger at the present moment.

MCAD

Software unbundling in the MCAD market is driven by three MCAE vendors, Parametric Technology (PTC), Ricoh Corporation, and SDRC.

PTC's product is unbundled for major workstations—with the exceptions of IBM and Sony—through C. Itoh Techno-Science, Technodia, and Tokyo Electron. Fujitsu, an OEM of Sun workstations, markets the bundled system of SDRC and Sun. SDRC is likely to study porting its package onto Japanese workstations. McDonnell Douglas' package currently is bundled with Digital and HP workstations through Seiko Instruments.

Although several vendors still support one platform or multiple platforms by bundling, we believe that market requirements will demand unbundling in order to keep up with the fully open vendors.

CHANGING INTERNATIONAL STRATEGY OF OVERSEAS VENDORS

Japanese vendors are said to be protected by various barriers from overseas vendors. In the CAD/CAM arena, some of the major barriers are the difficulty in hiring a sizable number of trained engineers and salespeople, the laborious translation of documentations, the customization required to meet local users' desires, and the lengthy product evaluation cycle. Until the mid-1980s, many non-Japanese vendors had been struggling to market their products in Japan, ignoring these barriers. Recently, however, several vendors have recognized the characteristics of the barriers and taken effective actions to overcome them.

In the MCAD market, Silicon Graphics will open a technology center and a pilot plant for assembly in Kawasaki City and the Kanto area of Japan, respectively, in the third quarter of 1990. The engineers in the technology center will develop software for the local environment using the Japanese, Korean, and Chinese languages. Silicon Graphics also will port popular local software packages onto IRIS workstations. The pilot plant will be used to evaluate the merits and the feasibility of mass production in Japan.

We have indicated that Japanese (kanji) support is critical to penetrate the Japanese MCAD market. The required level of kanji support is different for conceptual design/analysis and for drafting. For conceptual design/analysis applications, engineers ask vendors to translate the documentation. However, for drafting applications, draftsmen require vendors to modify the original drafting package to be based upon Japanese Industry Standards (JIS), as well as to translate the documentation. If the drafting package does not support JIS, it cannot penetrate a large portion of the manufacturing industries. In light of this problem, Tokyo Electron, the distributor of SDRC, is modifying its GEODRAW drafting package to be based on JIS. With this effort, Tokyo Electron expects to expand SDRC related business from ¥4 billion in 1989 to ¥10 billion in 1992.

In the EDA market, vendors are allocating resources to Japanese distribution because of the high growth of this product in Japan. Cadence and SGI have joined Daisy, Mentor, and Valid in establishing Japanese subsidiaries.

Racal-Redac will open its research and development center in the Kyushu area of Japan in the first quarter of 1990; following Valid Logic Systems' opening of its research and development center in the fourth quarter of 1989. Racal reportedly will increase the number of resident research and development engineers from 30 in the first quarter of 1990 to between 50 and 80 by 1992. It seems Takahiro Katoh, president of Racal-Redac Japan, believes that the localization or fusion into local markets is predicated by such actions as establishing research and development centers, listing on the local stock exchange, owning its local headquarters building, and hiring local graduates every April and training them. Most of these actions have been taken by established overseas vendors such as Hewlett-Packard, IBM, NCR, and Unisys.

Distribution Strategy Is Critical

In the mid-1980s, when the North American CAD/CAM market dominated the global market (56 percent market share in 1985 and 37 percent growth from 1984 to 1985), the international strategies of U.S. vendors were often lukewarm. Recently, however, these strategies have become more sophisticated in order to penetrate the faster-growing international markets.

In general, the following three methods are used to enter the Japanese market:

- Establishing a fully owned subsidiary
- Establishing a joint-venture with a Japanese partner
- Finding a distributor

Currently, most of the overseas vendors evaluate each method and select the best method(s). In the last two methods, needless to say, the partner is the key to success.

Several overseas vendors understand the local users' desires more than Japanese vendors. For example, many non-Japanese software vendors are aggressively unbundling their packages. Cadence, PTC, and Racal ported their software packages to Japanese workstations before most Japanese vendors. Also, Cadence and Valid supported Solbourne for Matsushita's engineers. We believe that non-Japanese vendors can be more competitive by continuing to keep up with the demands of local users.

Japanese Companies Will Become More Aggressive in Mergers and Acquisitions

After Lockheed announced its intention to sell Cadam last April, several Japanese companies negotiated with Lockheed for Cadam. Although Cadam was acquired by IBM, *Dataquest expects Japanese companies hereafter to be more aggressive in mergers and acquisitions, including taking an equity position in the CAD/CAM arena*, because of the following reasons:

- Even if a Japanese company targets the domestic market with unique technology or product provided by its non-Japanese partner, the Japanese company might lose its market if the non-Japanese partner is acquired by a hostile buyer. The best way to avoid this situation is acquisition or major equity positioning.
- If a Japanese company targets the global market, the company should study the feasibility of partnering with an optimum local company, including the acquisition, equity-taking, or establishment of a fully owned subsidiary.

Although Japanese CAD/CAM and computer vendors are still cautious, Dataquest believes that friendly acquisitions and equity-taking will be prevalent in the Japan CAD/CAM market in the 1990s.

Yu Uemura

EUROPEAN CAD/CAM/CAE MARKET

EUROPE 1989

The technical workstation is the key hardware platform for Europe. There are significant advances in workstation technology today and forecasts of speeds of 100 mips on the desktop during 1990 are being claimed. Growth in workstation technology has not been complemented by a significant growth in software technology. The recurring theme at the December 1989 European Computer Conference in Geneva, Switzerland, was a significant lack of software developed for the PC workstation platform or, indeed, for more traditional technical workstation platforms. The technical workstation market was in transition during the last year. Although the statistics superficially are similar to those of the two previous years, clear signs of competition from new companies and products appeared. In particular, in the PC workstation area, new CPU technology has emerged and the applications have broadened. In addition, the power struggle between OSF and UNIX International has injected some urgency into the UNIX battlefield. These trends continued all year. The market has become even more competitive; the HP/Apollo takeover, for example, predicted the first-time loss for Sun. The product introduction of the first Sun clone from Solbourne is another good example. With the emergence of the 386 and 486, Dataquest predicts that the PC workstation will have significant impact in the traditional workstation sector.

CASE Technology plays a significant role in redressing the software balance for the workstation. During 1989, we have seen the commitment to CASE by major EDA vendors. There were significant moves, particularly with ICAD, to bring CASE into the mechanical sector. Dataquest

believes that CASE will be increasingly important in developing applications for the workstation and personal workstation marketplace.

The 1992 bandwagon is very much rolling today. Companies are gearing up their marketing strategies to exploit the wonders of a unified Europe in 1993. And in the CASE area, significant opportunities exist in Re-engineering software products to accommodate the 1993 changes. Internal borders will disappear between the 12 countries of the EC in 1993. Separate systems currently exist in each country to accomplish similar jobs. Post-1992, these systems must be integrated. The only way this can be achieved effectively is with the use of sophisticated CASE tools. The blurring of the boundaries between CAD and CASE means that these significant opportunities also are available to CAD vendors.

Perhaps the most important opportunity for CAD/CAM vendors in Europe occurred with the breaching of the Berlin Wall in November. For sometime Western European CAD/CAM vendors have been able to exploit Eastern European markets because the Europeans do not operate under the same constraints imposed by the U.S. Department of Commerce on U.S. vendors. With today's more liberal attitude on behalf of the U.S.S.R., significant opportunities now exist in East Germany, Czechoslovakia, Poland, and Hungary. This new market potentially could change the face of the CAD/CAM industry in Europe. Eastern Europe still is impoverished, relatively speaking. Therefore, even at today's eroded prices, CAD/CAM technology still is expensive for Eastern Europe. However, the demand for the technology is there. Potentially, this demand can be satisfied by low-end systems and by recycling used CAD/CAM equipment in Eastern Europe, thus fueling a significant replacement market in Western Europe.

Significant progress has been made in the workstation and personal computer area in the implementation of superior graphics processor technology. Products based on the new Intel i860 and parallel transputer-based machines will challenge existing superworkstations and graphics workstations at a fraction of the cost. However, the success of these machines will depend on the emergence of parallel algorithms and software.

SURPRISES DURING 1989

Spain was a surprising growth area during 1989—the Spanish market has come of age and will warrant a separate study during 1990. The growth in revenue in the Spanish market is approximately 33 percent, which is second only to Germany in the European marketplace. Spain is a significant market to watch next year.

In a surprising move, McDonnell Douglas announced its intention to move a significant portion of its CAD research and development to McDonnell Information Systems International, based in Hemel Hempstead, United Kingdom. Following on the heels of the acquisition by McDonnell Douglas of Shape Data, a Cambridge-based company, this relocation endorses the commitment to Parasolids as a key part of the McDonnell Douglas Unigraphic System.

DISAPPOINTMENTS FOR 1989

The year 1989 has seen the arrival and departure of the little-known MAI Basic Four Company, headed by Bennett Le Bow, into the European CAD/CAM consciousness. In its hostile takeover bid for Prime Computer, this company and the chairman wreaked significant havoc throughout the Prime organization and its share of the market. The industry at large wished the hostile takeover to fail. With the rival bid from J.H. Whitney, the future of Prime Computer is assured; however, not without significant penalties to Prime. This action has affected Prime's earnings and will have consequent ramifications for the whole Prime work force. However, Prime, and certainly its star company Computervision, have recovered from situations like this in the past.

WORTH WATCHING IN 1990

Alternative distribution channels are key in the CAD/CAM marketplace of the 1990s. *Dataquest believes that companies that master the complex distribution channel issues in Europe will enjoy a significant competitive advantage.* This is a major challenge for Europe because even though 1992 is just around the corner, the alternative distribution channels of the 12 EC countries are different. Understanding these differences is key to success in the European CAD/CAM market.

Emerging application areas include computer graphics animation, the general computer-aided styling market, and computer automation in the fashion industry. These are areas that have stimulated significant interest during 1989 and promise rewards for entrepreneural CAD companies into the 1990s.

Charles Clarke

Dataquest
a company of The Dun & Bradstreet Corporation

Research Newsletter

IBM SEEKS TO CONTROL DESTINY, BUYS CADAM; OTHER CAD/CAM ACQUISITIONS EXPECTED

INTRODUCTION

In a much anticipated move precipitated by Lockheed's desire to divest itself of its information systems business units, IBM announced on November 9, 1989, that it will acquire CADAM, Inc., a major information systems subsidiary of Lockheed Corporation and a major CAD/CAM software supplier to IBM (both internally and commercially). The deal is still subject to final approval by the U.S. government but is expected to be finalized within 60 days. Because of the pending government review, official details from both IBM and CADAM are sketchy. However, the companies announced that CADAM will operate as a wholly owned IBM subsidiary and will remain in CADAM's Burbank, California, headquarters. CADAM employees will not be transferred to IBM.

Dataquest believes that the net effect of this buyout is mostly positive from IBM's standpoint, principally because IBM now has gained greater control in managing its future CAD/CAM solution strategy. On the downside, this buyout poses some risk for potentially alienating IBM's other key CAD/CAM solution providers (most notably, Dassault and SDRC). Additionally, the buyout may limit the willingness of future mechanical CAD third-party software suppliers to port badly needed application software to the new RT workstation due out early next year.

We further believe that more equity-related deals from IBM in the CAD/CAM/CIM area are likely to be announced over the next several quarters, including a substantial relationship involving Dassault's CATIA group.

The remainder of this newsletter will examine the impact of the CADAM acquisition from a number of viewpoints.

IBM'S ACQUISITION MOTIVATION—A DEFENSIVE MANEUVER

Although IBM has become increasingly aggressive over the past several years in pursuing equity relationships with key software partners, we believe that the CADAM acquisition was mostly a defensive maneuver designed to achieve the following:

- Prevent a potentially hostile competitor (e.g., Fujitsu) from buying CADAM and creating havoc and confusion in IBM's installed base
- Protect IBM's internal mechanical design automation investment, which numbers more than 3,000 CADAM seats

Despite both the defensive nature of the acquisition and the fact that IBM has favored CATIA over CADAM as supplier of its principal software platform over the past several years, Dataquest believes that this is a good business deal for IBM because of the following reasons:

- It gives IBM much greater control in dictating its future CAD/CAM strategic direction.
- IBM regains access to GM-EDS, because CADAM is one of the preferred suppliers.
- It gives IBM greater bargaining leverage in negotiating with Dassault for a better deal in its existing OEM relationship or for an expanded equity relationship.

In essence, IBM bought an option with the CADAM acquisition. It can choose either to take the best functional pieces from CADAM and integrate them along with CATIA and CAEDS (from SDRC) into a new system (perhaps built around its newly announced CIM architecture) or to maintain the status quo by pushing CATIA (which sells more

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hardware) and de-emphasizing CADAM. The arm's length positioning of CADAM as a wholly owned subsidiary reporting to IBM's Industrial Systems Sector in parallel with IBM's own CAD/CAM/CIM marketing group leads us to believe that IBM intends to maintain the status quo, at least for now.

FUJITSU—OUT ON A LIMB

Perhaps the company most negatively affected by the acquisition is Japan's second largest CAD/CAM supplier, Fujitsu, because it relies on CADAM software as its principal solution platform. Although IBM indicated that CADAM would continue "to meet its contractual obligations," the writing is certainly on the wall that Fujitsu must find a suitable replacement for CADAM. A good replacement candidate might be Adra Systems with its CADAM look-alike software.

THE FATE OF IBM'S OTHER TWO MCAD PARTNERS—DASSAULT AND SDRC

At the outset of the process to acquire CADAM, IBM was careful to keep its other key CAD/CAM solution partners (most notably Dassault and SDRC) advised of its intentions and strategic positioning. Our feedback from both Dassault and SDRC leads us to believe that, on the surface, the CADAM acquisition is not viewed as a competitive threat. Realistically, however, some underlying concerns must exist, if for no other reason than that IBM now has gained an additional piece of negotiating leverage at contract renewal time. In any case, the issue of potential favoritism toward CADAM will become a moot point if and when IBM takes an equity stake in the CATIA and/or CAEDS product lines.

CADAM'S GM-EDS AND COMPETITIVE UNIX PLATFORM RELATIONSHIPS

With respect to the acquisition, CADAM's recently announced support for hardware platforms other than IBM's (e.g., from Apollo Computer, Digital Equipment Corporation, Hewlett-Packard Company, and Sun Microsystems, Inc.) comes into question, particularly as it relates to CADAM's status as a preferred supplier to GM-EDS. IBM currently is not an approved platform supplier in the GM-EDS C4 program, while CADAM has been selected and approved but only on non-IBM UNIX workstation platforms. Indications are of a major conflict here, resolvable only by the following actions:

- GM-EDS including IBM's new RT workstation as an approved platform
- GM-EDS favoring its other CAD/CAM software supplier McDonnell Douglas, which has no conflict in running on any brand of UNIX workstation hardware

In any event, running CADAM on platforms other than IBM appears to be a risky situation, in that IBM will most likely offer only lukewarm support for CADAM running on competing platforms.

LITTLE OR NO IMPACT FORESEEN FOR OTHER CAD/CAM TURNKEY VENDORS

Dataquest does not believe that the CADAM acquisition will have any material effect on the other large turnkey CAD/CAM companies, such as Computervision, Intergraph, or McDonnell Douglas, largely because most of IBM's CAD/CAM business is virtually no-bid, IBM-only business that most other competitors never even see. McDonnell Douglas potentially could receive a mild uptick in business resulting from GM-EDS CADAM switchovers to its Unigraphics system.

DATAQUEST CONCLUSIONS

Dataquest believes that the CADAM acquisition represents a defensive but sound business move on the part of IBM to ensure a more stable future and help retain its position as the world's leading CAD/CAM supplier. At a minimum, the acquisition will help IBM maintain the status quo by preventing an unfriendly competitor from buying CADAM and stealing the potentially lucrative CADAM upgrade business. At best, IBM will begin to focus its vast resources on developing the CAD/CAM software side of its business (as opposed to just hardware) and use CADAM as the beginning of a larger strategy that combines the best features of CADAM, CATIA, CAEDS, and Valisys into a more integrated, cohesive system.

David Burdick
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Research Newsletter

GRAPHICAL USER INTERFACE: WHAT IS BEHIND ALL THE FUROR?

EXECUTIVE SUMMARY

In spite of all the informative and technical material that has been published over the issues of graphical user interface (GUI), confusion remains in the UNIX industry over which user interface will be adopted as an official standard. Uncertainty exists over what X/Open is doing to establish a GUI standard, and many people are wondering why any of this is important to the end user or commercial markets.

Currently, four major GUIs are being implemented: Open Look, Motif, Presentation Manager, and NeXT Step. In addition, several computer companies are implementing their own proprietary GUIs, such as Apple Computer and Xerox, and some companies are designing a better mousetrap. For example, Visix has reengineered Motif to obtain a GUI with improved speed and performance while maintaining full compliance with the specifications.

This newsletter discusses the following issues:

- The importance of the GUI issue to the developers, ISVs, and end users
- A review of GUI vendors' claims of increased productivity
- The significant issues of standardization GUIs

Dataquest believes that UNIX GUIs have not been around long enough for applications developers to know all the problems associated with each one. We conclude that multiple GUIs should exist to spur both competition and innovation in products. Proponents of Motif or of Open Look are unlikely to abandon their products easily. Consequently, government standards agencies or large-volume UNIX purchasers, such as the U.S. Navy or General Motors, must pressure the UNIX hardware manufacturers to adopt a common application programming interface (API). Such an agreement would ease the programmer's burden of having to support multiple interfaces, while letting each of the hardware manufacturers sell GUIs with their own added competitive features.

OVERVIEW

If Apple Computer had licensed the GUI technology that many major computer companies are trying to imitate, we would not be embroiled in the current confusion over which graphical user interface (GUI) has superior features, or which one will triumph. As the feuding continues among the different technical managers, software developers, and engineering staffs that support the variety of available GUIs, many business and MIS managers are asking themselves what the furor is all about. More importantly, they are asking also what the GUIs will provide to their companies in terms of increased productivity and future sales.

DOES IT REALLY MATTER WHICH GUI IS RUNNING ON YOUR SYSTEM?

The answer is probably no if you are using a GUI to make computing easier. The very nature and appearance of a GUI allows one product to be used as easily as any other. Once someone has been trained on one GUI, it will not take that person very long to learn how to use another GUI. For example, on most GUIs, to delete a file you move the file icon into a trashcan icon. Trashcan icons are recognizable whether they are depicted as the 32-gallon containers in your garage or as the little round receptacle under your desk.

The answer is also probably no if you are a UNIX programmer. These individuals are

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conversant in shell scripts, C Language, and other UNIX tools. They have learned to work with the X Window technology without the need for the GUI sitting on top of X Window. The GUI adds convenience only in certain instances.

The answer is yes if you are a software developer, ISV, or programmer trying to implement the GUI on your computer, or if you are trying to write an application that must interface to a specific GUI. Differentiation exists because applications take advantage of APIs, and APIs are different for each window system. The differences between GUIs exist at the toolkit level—C libraries that interact with the operating system and hardware. Although it is possible to write applications to several kinds of APIs, supporting two or more APIs in terms of software engineering, maintenance, service, and customer support is expensive.

The answer is also yes if you are a hardware vendor or ISV competing for market share. If you support the "wrong" GUI you cannot attract buyers for your systems. What may be even worse is that if you support one GUI to the exclusion of another, you may not be able to run the application packages that your customers want to use.

DOES A GUI INFLUENCE PRODUCTIVITY?

As workstations move out of the hands of engineers and into the world of business and commercial applications, a need to make UNIX more accessible to the business community has become apparent. Many people buying UNIX are not programmers but accountants, doctors, dentists, attorneys, stockbrokers, and other noncomputer professionals. These people are used to handling files on their own systems or working with predefined data-entry fields. They are baffled by UNIX's terse command language. After these individuals log in and issue their passwords, they are faced with a prompt and no knowledge of how to access their files. Their files may be resident in any one of a multitude of directories. If their computers are tied into a network, their files may be spread across any number of systems on a network. These users want a common, easy-to-learn interface that will allow them to move easily through directories to access their files.

Companies that have to deal with large numbers of users who are not UNIX initiates realize that there is a need for a GUI to make some sense out of the apparent chaos of such UNIX features as shell scripts, complex path names, sockets, streams, and cryptic commands such as grep, awk, nroff, and others. These companies are discovering that it is less expensive and less time consuming to train someone on an icon-based system then on a character-based system. Mouses, menus, windows, and dialog boxes replace the command languages. Icons simplify concepts of files and commands. Using a mouse to point to a file is easier and faster than typing in lengthy commands or trying to remember.

The intuitive approach of a GUI invites experimentation with commands, instead of guessing at exhaustive passwords and possible command combinations. People using GUIs are more willing than others to experiment with these tools to figure out what to do next in order to access their word processor or to bring up a spreadsheet. If they try, they will often succeed.

GUIs also facilitate moving employees from single-user, dedicated PCs to networked environments with access to shared resources, data bases and applications. For many companies, this move results in savings in software license fees and gives employees the ability to share resources. Multiuser, multitasking networks allow many tasks to run in parallel, resulting in increased productivity.

WHERE'S THE STANDARD?

As commercial users and ISVs evaluate the benefits of GUIs, they are demanding a standard GUI that guarantees application portability and a minimum of user retraining costs. They are asking for one common GUI across various hardware platforms that is exactly the same or so similar as to be negligent.

These standards can be established only by official standards organizations such as ANSI and ISO rather than through the efforts of the Open Software Foundation (OSF) and UNIX International (UI). The GUI argument centers around which organization will prevail in the standards war—UI or OSF? UI and OSF do not create standards; they only implement the standards set by standards bodies. The only standards bodies that will be deciding the future of GUIs are ANSI and ISO; IEEE operates with the sanction of ANSI to establish a user interface standard. The major obstacle of waiting for this to occur is the time involved.

Although X/Open is thought to be the deciding standard mediator, X/Open's stated charter is to

create the procurement specs to be used by large purchasers of open systems such as the European Community, the U.S. government, and commercial enterprises. X/Open specifies the interface definitions, not specific products. Developers then take the specifications and create competing products, which are developed to those specifications.

UI has taken an official position to support multiple GUIs, believing that this stand is as essential to the future of UNIX as the support of multiple data bases. Just as UI will not decide if UNIFY or Oracle or Informix or Ingress should be the only sanctioned UNIX data base product, the organization will not specify either Open Look or Motif to the exclusion of the other product.

DATAQUEST ANALYSIS

The GUIs are leading us to a time in the not-so-distant future when we will turn on our computer and find a wonderful assortment of goodies popping up in windows on our terminal, including multimedia applications, extremely high-resolution graphic images, and video displays. Dataquest anticipates a host of new methods for interacting with data through the development of intelligent interfaces that both automate frequently repeated tasks and anticipate human actions in order to increase productivity. However, long before this type of development can occur, we need to resolve the issues of a standard interface.

On one hand, the establishment of a standard GUI is necessary if UNIX is to successfully penetrate the commercial market. Currently, software developers and ISVs are reluctant to commit to one GUI over another. They fear the financial impact if the majority of the industry selects some other GUI. Hardware manufacturers and OSF (the developers of Motif, Open Look, Next Step, and others) are not willing to give up the competitive edge derived from having a unique GUI.

ISVs want a standard established in order to reduce their costs of bringing a product to market. No one wants to do the same job two or three times if they can do it once. Companies find it expensive to support multiple products of similar characteristics.

On the other hand, selecting Motif, Open Look, Next Step, or Presentation Manager as a standard based upon the product's technical superiority is not the solution. Certainly, superior technology does not always win the standards game. If you doubt this is true, look at the video cassette market. VHS was not as good as Beta, but how many Beta tapes can be rented at video stores these days?

We believe that a more desirable solution to the GUI problem exists. A common API for the two leading UNIX interfaces, Motif and Open Look, *is* possible, and nothing is technically wrong with this approach. In theory, this API could also easily be designed to support multiple "look-and-feel" options. Although UI has presented this proposal to OSF, OSF is not willing to discuss this solution at this time.

If the problems of different toolkits and their multiple APIs can be resolved by a common API, software developers will not have to write multiple versions of each application. Having one common interface would also include the benefits of application portability, interoperability of applications, and a protected software investment because the ISV is not locked into a single hardware manufacturer's system.

It is time to send a message to the government standards bodies and tell them to focus on the needs of the UNIX industry and market as a whole. Instead of adopting one GUI product as a standard, Dataquest prefers that these standards bodies adopt one common API and allow multiple GUIs to exist and compete with each other. Until programmers have worked sufficiently with existing GUIs, implemented applications on them, and used the interfaces for several years, they will not be able to determine the best GUI product for the requirements of applications developers, users, and vendors.

Dataquest believes that the GUI developers should be allowed to add whatever features that they think they absolutely need to be competitive. Two or more GUI products can coexist as long as one standard API exists. UNIX's legacy has been the promotion of creativity and innovation. More advanced technical work has been done on UNIX than on any other operating system. Competition is healthy and promotes diversity and an explosion of ideas. Two or more GUIs would only enhance this innovation through competition.

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Research Newsletter

VIRTUAL REALITY: THE NEXT USER INTERFACE

"Reality is the thing on the other side of your sense organs."
Jaron Lanier, VPL Systems, Inc.

SUMMARY

Computer technology is at the threshold of being able to produce realistic, computer-generated input for each of our major senses: sight, hearing, and touch. By applying these technologies, we will be able to experience any environment we can imagine. This report surveys the equipment, applications, participants, and opportunities in the new and rapidly developing virtual reality (VR) industry. Dataquest believes that VR is a mainstream development, not just laboratory curiosity. The following recent events and market trends support this position:

- Computer users are moving from the one-dimensional text string interface to graphical, two-dimensional user interfaces. The next step along this evolutionary path is the three-dimensional interface. Our electronic workplace metaphors will evolve from notepad to desktop to office.
- The microcomputer software industry's growth is closely coupled with the shift toward emphasizing products with high graphical content. The fastest-growing ones are those that emphasize graphics most in their product line.
- Computer graphics are nearing realism.
- Megapixel displays provide resolution and palettes eclipsing those of television and approaching 35mm film.
- Entertainment systems with 3-D displays have been available for some time, but this fall will be the first time 3-D control equipment will become available to the consumer market. Broderbund and Mattel will offer systems supporting the Nintendo game unit.

EQUIPMENT

The equipment used to produce VR is somewhat different from that normally included in a personal computer system. Because our visual sense is our major source of information, most effort has been directed to developing displays. Developers are working on the other senses as well.

Displays

The basic piece of VR equipment is a 3-D head-mounted display as shown in Figure 1. To produce the illusion/reality, the display must span nearly the 180-degree-wide and 150-degree-high human range of vision. Furthermore, to produce the 3-D effect, separate displays are required for each eye. The now-standard approach to accomplishing this is essentially to place a Sony Watchman immediately in front of each eye with some special optics to permit the wearer to view the screens comfortably.

This display system isn't quite sufficient. To produce an effective VR, the images must reflect movement of the head. With this capability, the display wearer becomes a traveler through VR. When the traveler turns his head around, he must see what is behind him in the VR. Similarly, the system must accommodate looking up, moving, and tilting the head to the side. To accomplish this, a six-degrees-of-freedom motion-tracking system is mounted on the traveler's head.

Some human engineering requirements are imposed by the coupling of the display and position

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FIGURE 1
Virtual Reality Traveler

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Source: Dataquest
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tracker. The system must update the displays about every 30 milliseconds to produce a smooth image for the wearer; updating only every 100 milliseconds creates enough wearer disorientation to produce nausea. These considerations determine the complexity of the VR scene a given computer system can render. The complexity is usually measured in polygons.

Sound

Sound generation is now a fairly mature technology. The additional requirement VR imposes is that the sound cues reflect the tilting and rotation of our heads. Stereo headsets, with sophisticated tone-generating equipment, are used with the head-position tracker mentioned above.

Touch

The obvious problem in VR is relating the individual to the VR space created. For instance, VR travelers should be constrained from walking through walls or passing their hands through solid objects. Without a computer-controlled exoskeleton capable of resisting the strength of its wearer, this level of reality is unachievable; we are not aware of its being pursued anywhere now.

The area of tactile cues is tractable enough to allow some progress. The leaders in this area are using tactile generators. The piezoelectric units can be flexed under computer control well enough to suggest different surface characteristics to the VR traveler. Other technologies are being considered also.

Control

Once we have created the VR environment, we need to interact with the created reality and to control it. Requiring the traveler to communicate with his 3-D space through a 1-D keyboard or 2-D mouse is inadequate. Earlier systems used separate knobs on a control panel to control each degree of freedom. The desired six degrees of freedom are attainable with the hand-held motion-tracking unit described earlier. More popular is a glove attached to the motion tracker and further instrumented to reflect the articulation of the finger joints.

(Developers have extended the glove technology to produce an entire body suit.) The traveler's hand now can be materialized in the VR. It can grasp objects in VR and, through gestures, initiate control activities including menu selection and flight. To date, making menu selections in this way is quite clumsy. Several pioneers are working to replace gestures with voice control. Voice recognition technology currently is more than adequate for making selections from menus.

Support

Creating VR environments can be very time consuming. Often the desired environment is one that exists in reality. To capture information from reality for use in VR requires a 3-D analog of a 2-D page scanner. Several people are working on spatial data-capture systems that scan an environment optically.

VR SYSTEM COST

Impressive complete systems have been constructed for less than $40,000. The rapidly diminishing subsystem costs could reasonably make these a consumer item within five years.

APPLICATION AREAS

VR technology offers promise in architectural and mechanical design. Following is a sampling of VR possibilities related to design.

Architecture

A client could move through a building before he begins construction. Inconsistencies in a set of plans would become clear immediately. Recognizing view-blocking beams would be trivial. The architect could explore the building as a person three feet tall or seven feet tall and check for any adverse effects. The impact of sun angles could be examined conveniently.

Control Centers

In VR, the environment is completely flexible. Flat panel displays can float in midair without trailing cables.

Consider the NASA Mission Control Center in Houston. For each space flight, each flight-controller's station panels are recabled. Each panel has a quite-limited area for information display. Using VR, the controllers could each have their own ideal station. Information panels could appear floating in air above and around them. Others could appear as a stack of paper before them. Controllers could leaf through the pages of real-time graphic displays and hang those of interest before them in midair. This could become the ideal financial analyst environment by just changing the type of information displayed. The technique easily extends to manufacturing and business-control applications.

Illustration

Imagine an automobile manufacturer wanting to determine the appearance of a range of fabrics in a car. The cost of creating and fitting the fabric would easily exceed the cost of creating the code to generate and project the fabric onto the seats of the car in VR. It would even be easier to check the effects of light angles and intensities on the fabric in VR.

Interior decorators could use VR in a similar way. They could let clients examine the finished rooms before they are done. Jewelers could create the art work for their catalogs without having to construct the catalog models from real gold and diamonds. Currently, jewelers melt one model down to make the next model rather than tying up gold in inventory.

Manufacturing

After a complex system is designed, it is not always apparent whether the system is manufacturable or not. VR would allow the developers to attempt assembling a product from its parts before parts fabrication begins.

Presentation Graphics

A conspicuous movement to simulate 3-D exists today in the personal computer presentation graphics market. Drop shadows, perspective bar charts, and surface charts are all attempts to provide the illusion of 3-D. Why not just enter VR and have a 3-D chart?

PARTICIPANTS

The following paragraphs list some of the major participants in the development of VR technology.

Academic Institutions

Boston University

VR work is being performed at Boston University in the field of biomedical engineering in conjunction with MIT.

Carnegie Mellon University

Carnegie Mellon University (CMU) is doing creative work in VR input devices and computer music. It transformed humans into musical instruments through VR. CMU also developed the Sensor Frame, which locates objects within a 3-D space.

Media Lab

The Media Lab has worked on developing the user interface for VR. The Media Lab is experimenting with using gestures, such as flicks of the wrist, to control menus.

The University of North Carolina

The University of North Carolina (UNC) at Chapel Hill is active in head-mounted displays, force displays, and true 3-D displays. One display system, the Pixel-Planes, first built in 1986, uses a separate processor for each pixel. It provides high-quality, real-time motion displays by processing more than 1,000 polygon scenes 30 times per second. UNC constructed a 24,000-polygon model of a building. Its radiosity model can process the 4,000 polygons and 30,000 patches, making up the lobby one time per second.

Government

Air Force

Wright Patterson Air Force Base (WPAFB) has been working on user interfaces for pilots for a long time. It is spending roughly $10 million per year on R&D in this area. It sponsored the development of the God's Eye View display. In this configuration, the pilot sees his plane and the enemies' as through the eyes of a third party on high—an essential ability in jet fighter combat because the targets are commonly maneuvering beyond the range of human vision.

NASA

A team of scientists at NASA's Ames Research Laboratory pioneered modern VR. This team began work five years ago. Its focus has been on developing telepresence and virtual workstations. The NASA team supports extensive research in menu design and position sensor performance.

The team has applied VR to a wide range of applications. Activities in computational fluid dynamics have helped engineers visualize complex fluid flows and other multidimensional data sets.

Private Industry

Abrams/Gentile Entertainment

Abrams/Gentile Entertainment (AGE) is bringing the DataGlove to the mass market. It has licensed the VPL design and reengineered it for use with the Nintendo game system. This fall it will be available from Mattel at retail stores as the Power Glove and will cost about $80. Broderbund's competing U-Force Controller is the subject of a lawsuit by Mattel and AGE. AGE is developing other VR-related entertainment systems and additional AGE technology applications.

Ascension

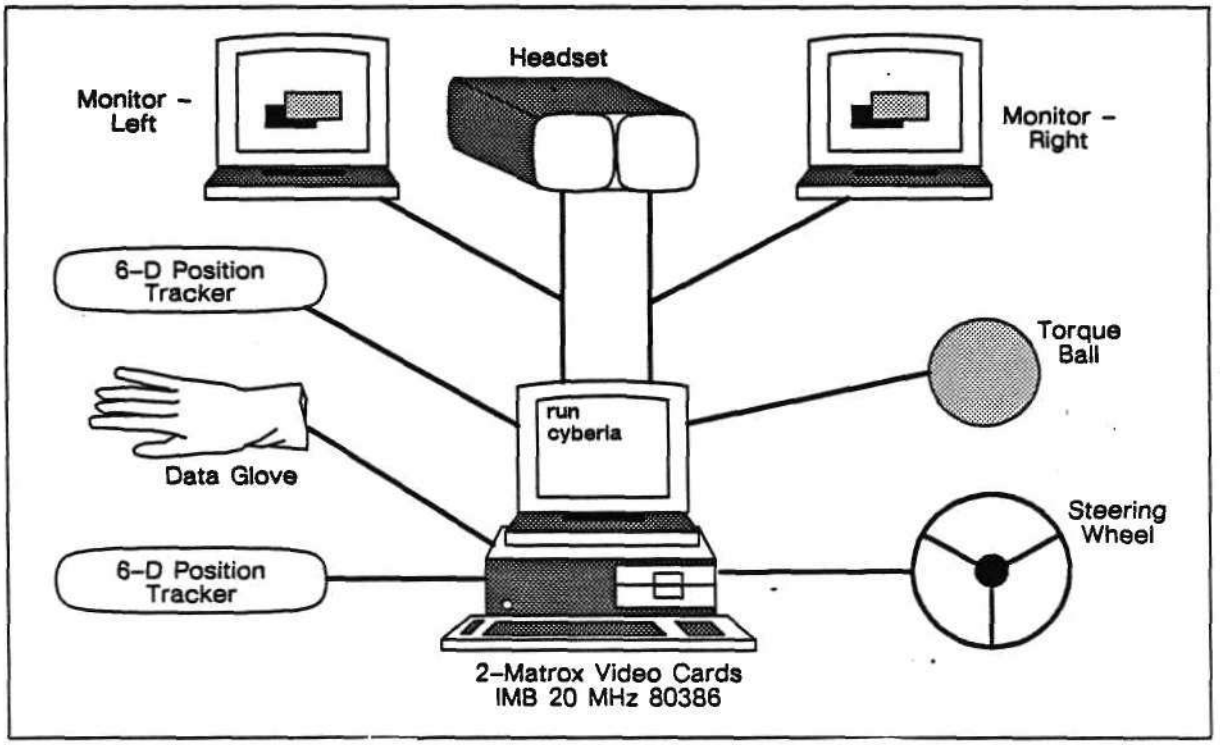
The start-up company Ascension is developing a six-degrees-of-freedom sensor. The company expects the sensor to overcome many of the performance and applicability limitations of current systems. The product is scheduled for introduction in the third quarter of 1989.

AutoDesk

The AutoDesk CyberSpace best illustrates how close VR can come to being a significant commercial product. AutoDesk, the developer and publisher of AutoCAD, has committed to producing products in the virtual reality area.

Figure 2 illustrates a CyberSpace configuration. Whereas the VPL system shows how much can be accomplished with available technology, the CyberSpace system shows how little the hardware can cost to create a VR system. On June 7, the same day that VPL debuted in San Francisco,

FIGURE 2
Cyber Configuration Autodesk Cyberspace



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Source: Dataquest
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California, the CyberSpace system was introduced at the A/E/C Systems Conference in Anaheim, California.

CyberSpace uses the VPL EyePhone and DataGlove. Each eye is assigned a Matrox video control board to generate the video images. A pair of 19-inch monitors shows the computer operator what the VR traveler is seeing with each eye. Except as noted, the remaining components connect through serial ports to a 1MB, 20-MHz 80386 PC that provides the computing platform. The EyePhones and DataGlove each contain Polhemus position trackers. The computer operator uses a CiS TorqueBall to position the traveler coarsely in VR. The traveler may use gestures with the DataGlove to control movement through CyberSpace or use a steering wheel to control flight through VR. This wheel, bought as a game part at Fry's Electronics for $79, connects to the computer through a PC game port.

The CyberSpace team developed the software using Zortech's C++ compiler ($149). The team developed about 3,000 lines of C++ code running under DOS to create its VR. It wants to provide its programs to other VR explorers at some point to encourage development. Future development plans include connecting CyberSpaces over a network, adding MIDI sound support, and adding to the powers of the VR traveler.

The applicability of VR to AutoDesk's mainline product development is clear. Dataquest expects to see 3-D snap grids and other engineering drawing facilities added to CyberSpace. Although Dataquest does not expect AutoDesk to announce a commercial version of CyberSpace in the next six months, AutoDesk's commitment to 3-D is clear from its current product line. The current CyberSpace Development Kit pricing is listed in Table 1.

Broderbund

This fall, Broderbund will be marketing its U-Force controller for use with Nintendo games. This system detects the position of objects such as hands within a frame. The technology is derived from that used with the Theraman. The Theraman is an electronic musical instrument on which the position of the musician's hands around the unit controls the pitch. It is probably best known for the

TABLE 1
CyberSpace Development Kit

Item	Price per Unit	Quantity	Extension
80386 PC w/1MB	$2,200	1	$ 2,200
Matrox video board	$8,000	2	$16,000
VPL EyePhone	$9,400	1	$ 9,400
VPL DataGlove	$8,800	1	$ 8,800
19-inch monitor	$ 700	2	$ 1,400
CIS TorqueBall	$3,300	1	$ 3,300
Game steering wheel	$ 75	1	$ 75
Dual serial port	$ 75	2	$ 150
Game port	$ 35	1	$ 35
Total Kit Cost			$39,360

Source: Dataquest
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sound that presaged a monster's appearance in the film *Revenge of the Killer Tomatoes.*

Pixar

Pixar is best known for its extremely high-quality computer graphics renderings. One of its productions, *Tin Toy,* won an Academy Award—the first film to win such an award where the subjects of the film were not filmed from reality. Pixar produced the film almost a year ago on computers of its own design. Each megapixel frame required almost an hour of computer time to generate. The renderings are more realistic than "claymation" and include the application of sophisticated self-shading to enhance the realism.

Pixar demonstrated its systems at Spring Comdex in a section of the IBM booth devoted to exhibiting the potential of the Intel i860 chip. There Pixar generated quarter megapixel frames in 5 or 10 seconds, resulting in an image slightly better than that of a very good television set.

The company has been a leader in the development of the RenderMan specification. The specification essentially does for 3-D color what the PostScript specification does for 2-D black and white. The standard provides for textures and focus as well as the expected object, shadowing, and light-source specifications. Renderman produces textures through procedures called shaders that specify the characteristics of a surface—perhaps a fabric or a hammered metal surface. Pixar intends to market a library of shaders, in addition to its current services, when RenderMan platforms become widely available. We expect RenderMan to be implemented in a VR system.

Polhemus

Kaiser Aerospace and Electronics Company purchased the Polhemus Navigation Sciences Division of McDonnell Douglas in September 1988. Its six-degrees-of-freedom position sensor, which has become synonymous with its name, is the standard for VR developers. The systems it currently offers consist of sensor units attached to control boxes that connect to computers through RS-232 interfaces. Dataquest believes that future units will move the control box onto a PC expansion card to reduce prices.

Most of today's VR systems include one Polhemus unit in the headset and one in the DataGlove. These units can be used for other VR data-capture applications. Sensors mounted in a stylus can be slid over the surface of an object to digitize it for exporting to VR. The simplest use of the sensor is as a 3-D mouse. SimGraphics'systems allow the sensor to associate with an object in VR: subsequent manipulations of the sensor act as manipulations of the associated object.

Pop-Optix Labs

Pop-Optix Labs produces the optical elements used in essentially all VR head-mounted displays. With this system, the VR traveler comfortably views a pair of television screens about two inches in front of the eyes.

SimGraphics Engineering

SimGraphics Engineering develops both general-purpose and custom VR applications. It

provides drivers and utilities for using the DataGlove in UNIX environments. SimGraphics is developing VR Workbench, which is a platform supporting multiple DataGloves and other VR components and technologies. It promises to provide easy access to VR capabilities. SimGraphics is working with Northrup on the Automated Airframe Assembly Program (AAAP) to develop a commercial product using the DataGlove in VR. With it, components are manipulated with a 3-D mouse (DataGlove/Polhemus unit) to test the ability to assemble a system before the system is manufactured. The 3-D mouse becomes identified with an object that is subsequently manipulated through the 3-D mouse. SimGraphics is also developing plans and technology for interactive, networked, simulator-based entertainment systems.

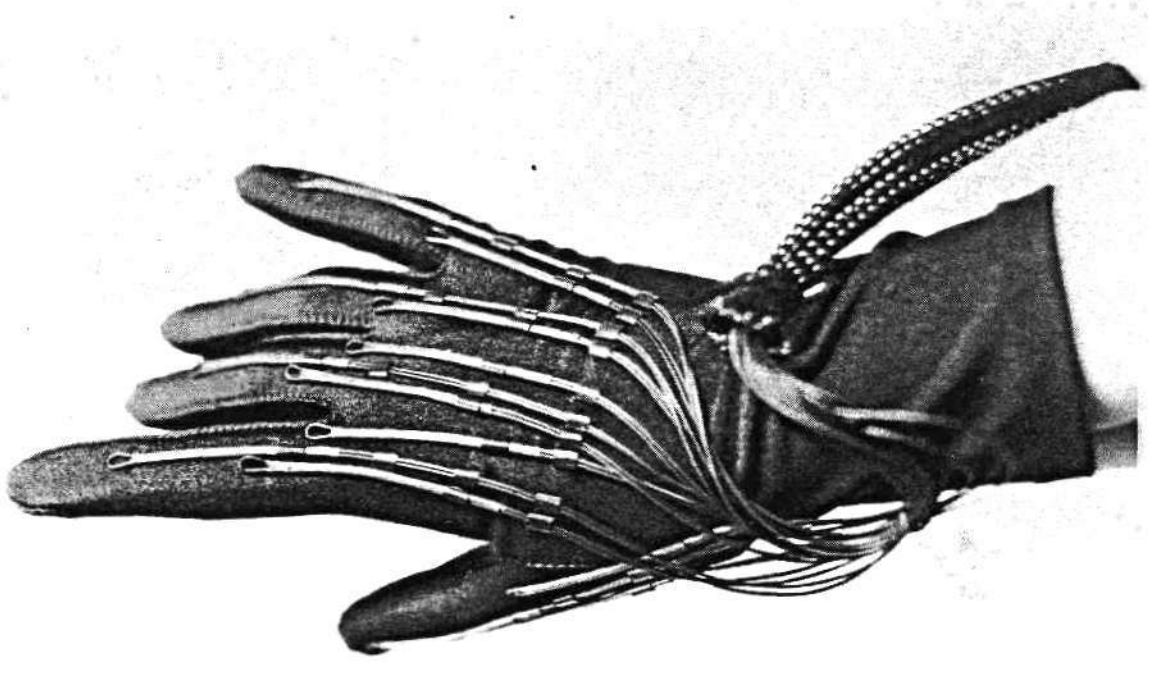
VPL Research, Inc.

VPL stands for Virtual Programming Languages. VPL Research, Inc., was founded with the intent of developing virtual reality hardware and related software development tools. The first product it marketed, however, was the DataGlove, shown in Figure 3. Just as the mouse pointer serves as the proxy for the fingertip on the electronic desktop of 2-D user interfaces, the DataGlove stands in for the hand in the 3-D environment of VR. By providing an entire hand rather than a fingertip in 3-D, the user has a more powerful and familiar surrogate to use in these new electronic surroundings.

The DataGlove has become the leading VR interface device among developers. The elastic glove is fitted with fiber-optic sensors that measure the articulation of the finger joints. The glove includes a Polhemus sensor to position the glove with six degrees of freedom. VPL lists the DataGlove at $8,800. Approximately 100 of them have been sold so far.

VPL recently added the EyePhone to its product line. The EyePhone is a headset that combines Sony color LCDs with lenses from Pop-Optix and a Polhemus positioning unit. The displays provide 84,000 pixels per eye using an NTSC video signal. This unit's price is $9,400 and very likely will be the VR standard.

FIGURE 3
VPL's DataGlove



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Source: Dataquest
September 1989

VPL exhibited its RB2 VR system in San Francisco, California, and at SIGGRAPH in Boston, Massachusetts. The two people using the system together looked like graduates from the Marcel Marceau School of Engineering as they controlled with gestures, finger-walked through, and interacted in the electronic environment. Reality Built for 2 (RB2), is a high-end environment that uses a Silicon Graphics IRIS system for each eye supported. A 33-MHz Macintosh II coordinates their activities. The complete VR development package, excluding the IRISs, is priced at $70,000 for the two-person system. The environments are much more complex than those of any other system. Gourand shaded surfaces provide rounded objects. Doors are constrained to move on hinges. The ceiling fan is controlled by a switch on the wall in the VR. The capability for end users to create environments easily, without programming, will be available soon.

VPL has one software product, Swivel 3-D, in general distribution now. It is being marketed by Paracomp and distributed and promoted by Softsel. Swivel 3-D is used with RB2 to define shapes through rotation, extrusion, and other methods. VPL's Body Electric software defines the behavior of VR objects. ISAAC is a real-time hierarchical rendering program that produces the shaded images seen in RB2.

MARKET NEEDS AND OPPORTUNITIES

Several areas need to be significantly improved in order to accelerate the development of the VR market. Cost reduction is important but will be provided by expansion of the VR market and developments in digital electronics. Product developments in several areas are needed to support general VR technology.

Applications

Presentation graphics, VR development tools, real-time rendering software, anthropomorphic agents operating in VR, and all of the other applications that will end up making VR worthwhile are waiting to be created.

Chips

VR needs video chips that are significantly more powerful to render more-complex scenes at the 30-frame-per-second rate desired for smooth motion. Higher-performance computer chips are needed to track the motions of objects in the scene.

Construction Equipment

VR developers need software tools to construct VRs. None of the systems encountered supported the construction of objects within VR.

Data Scanners

No products are offered for capturing data from reality into VR. This capability would enable many applications. Imagine an interior decorator scanning your living room into VR. The decorator could then outfit and paint your VR room and let you experience it before ordering the materials for redecoration. A similar procedure could be followed in designing and creating appliances to be fitted to in-place equipment.

Displays

Current 3-D displays are uncomfortable to look at for extended periods of time because of the fixed focus distance of the images. Because the eyes are always focused on the horizon, the tendons controlling focus are not flexed; their motion causes irritation of the eye. This is the phenomenon that makes people want to rub their eyes after watching a movie (especially from the front row) or staring through a microscope for a long time. Optical and/or holographic mechanisms are needed to correlate focusing with proper stereopsis.

Hard Copy

Holographic printers/cameras are needed to capture the VR environment for display to people outside of VR. 3-D Manufacturing in Sylmar, California, currently provides a unit with the basic capabilities, but a wider range of media and price performance is needed.

Position Sensors

Faster position sensors are needed. The lag time between a position change and the time the related data is received by the computer is sufficient to make it difficult for objects in VR to stand

still as you move around them. Current sensors have a range of about five feet.

DATAQUEST CONCLUSIONS

VR has the look of the wave of the future. The technologies that drive VR are progressing rapidly. The cost of computation is rapidly decreasing while the available power is rapidly increasing. The most recent crop of microcomputers incorporates multiprocessing capabilities in its designs. VR is well suited to take advantage of current multiprocessor, multiprogramming capabilities.

The quality standards for video images have evolved through CGA, EGA, and VGA in less than 10 years. Texas Instruments' video processor shows the direction of development for the high-performance, low-cost, video image-generation support that VR needs. HDTV will be providing the higher-quality image and the higher bandwidths needed to make VR an effective communications medium.

The development of VR as a significant marketplace will be controlled by the development of standards, equipment, and software tools to create and support VR travelers. The number of identified potential applications is already adequate.

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CAD/CAM INDUSTRY FLOURISHING DESPITE CONSOLIDATION TURMOIL

SUMMARY

Dataquest recently completed its comprehensive CAD/CAM market review and forecast (see Tables 1 through 7 at the end of this newsletter). Our research shows that although the industry is undergoing a very turbulent period, it has shown amazing resiliency, growing a very respectable 19.7 percent (15.1 percent when currency is adjusted) from 1987 to 1988. Against a backdrop of record vendor consolidations (18 CAD/CAM-related mergers and acquisitions, as shown in Table 8), some remarkable CAD/CAM success stories occurred during 1988 as depicted in Figure 1. These 1988 successes included the following:

- An explosive growth of desktop systems, particularly workstations
- A tremendous rebound of the Electronic Design Automation application market
- The continuing rapid growth of international markets

There were also some very big disappointments in 1988, including:

- The sluggishness of the North American CAD/CAM market
- The continuing demise of host-based CAD/CAM systems

This newsletter discusses the high-level issues affecting what occurred in the CAD/CAM market during 1988 as well as the direction in which we see the industry heading over the next five years.

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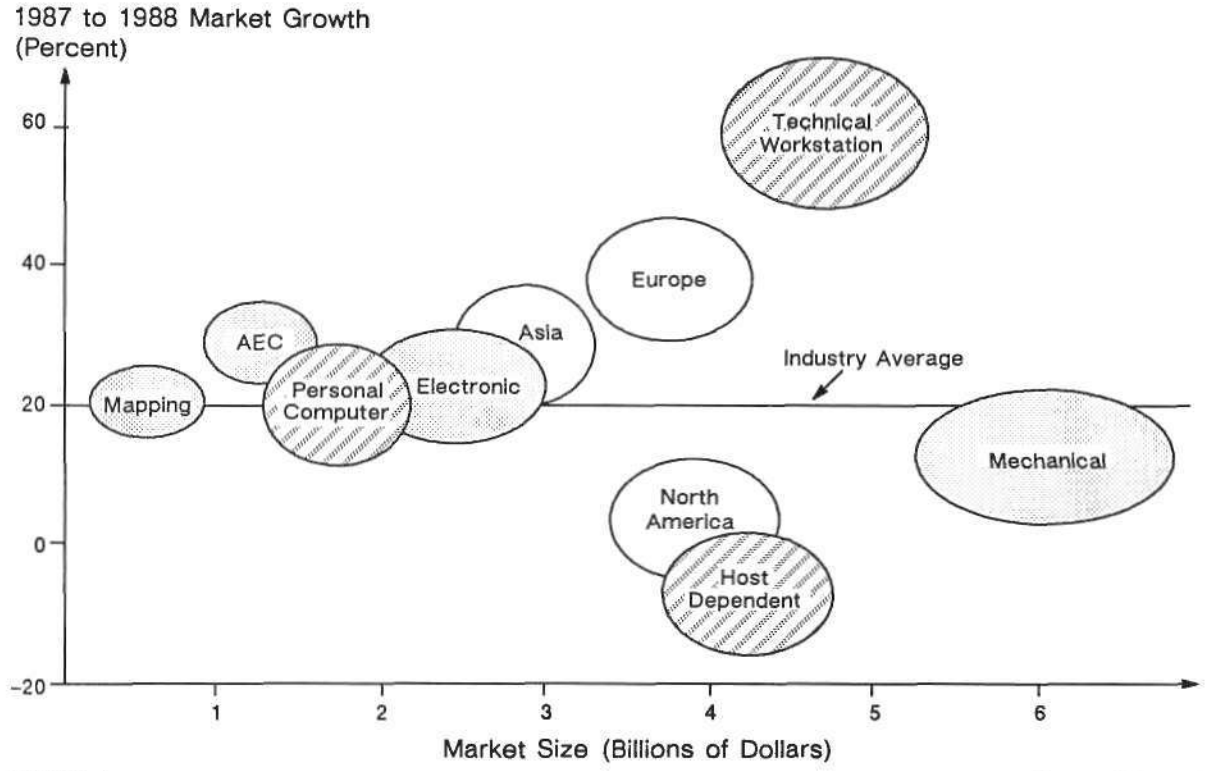
Figure 1

Worldwide CAD/CAM Industry Market Portfolio



CURRENT INDUSTRY TRENDS

During 1988 and continuing through 1989, a number of important, underlying trends are affecting the performance of the worldwide industry as a whole, ranked in order of importance as follows:

- Consolidation
- Rapid growth of international markets
- Rapid growth of workstation-based systems
- Performance explosion

Consolidation

The CAD/CAM market is currently undergoing a period of vendor consolidation driven by a combination of three factors:

- The rapid CAD/CAM workstation price erosion (25.0 percent per year over the last several years), caused by the introduction of lower-priced workstations and personal computers, has created considerable margin pressures and organizational dislocations, particularly among older, turnkey CAD/CAM vendors that are accustomed to selling expensive, host-based systems.

- End-user penetration rates are much higher (30.0 to 40.0 percent by seats and greater than 75.0 percent by sites), making it more difficult for newer vendors to build and establish a sizeable installed base.

- There is an oversupply of vendors offering products with little or no differentiation (i.e., approximately 200 vendors worldwide are offering PC-based drafting). Consequently, we now have a situation of too many vendors chasing too few dollars.

Rapid Growth of International Markets

International markets (e.g., European, 36.0 percent; Asian, 24.0 percent) are growing much faster than the North American market (7.0 percent). This is because international markets have been penetrated only about half as much as the U.S. market) and have not experienced the same level of price erosion. Consequently, vendor competition is much less severe in the international market, and there is a greater willingness to buy more expensive turnkey systems as opposed to cheaper unbundled systems.

Currency fluctuations also played a part in inflating the actual international revenue growth numbers, although this was much less a factor than in previous years. The 1988 European figures were inflated by an average of 3.2 percent, while Japan's were inflated 11.3 percent. This translates to currency adjusted figures of 32.0 percent for Europe and 11.0 percent for Asia.

Rapid Growth of Workstation-Based Systems

Workstation-based CAD/CAM systems, particularly those from Sun, Digital, Hewlett-Packard, Apollo, Intergraph, and Silicon Graphics, are growing rapidly (more than 60.0 percent) at the expense of host-based systems, whose growth rate declined during 1988.

Performance Explosion

Workstation performance continues to increase at an incredible rate. Since 1984, workstation CPU and graphics performance have double every year, while prices have either remained constant or declined. We expect this trend to continue to the point where

in 1990, a state-of-the-art, $70,000 workstation will have CPU performance of 50 mips, feature 10 Mflops, and be capable of drawing several million vectors and 500,000 polygons per second. This incredible explosion in workstation performance will inherently challenge the software suppliers to keep pace with the hardware manufacturers by taking advantage of the extra performance features. In our opinion, software is currently 12 to 24 months behind the lead of the hardware vendors, which leaves room for smaller start-up companies to enter and take advantage of this performance window.

MARKET SHARE

Top Ten

Table 1 lists the worldwide CAD/CAM vendor market share of the leading vendors ranked by revenue. With respect to the change in the top ten market share positions in 1988 versus 1987, five vendors moved up, including:

- Prime moved from eighth to second place by virtue of its acquisition of Calma and Computervision.
- Hewlett-Packard moved from ninth to sixth place.
- Fujitsu moved from tenth to seventh place.
- Two vendors that make their first appearance ever on the Dataquest top 10 list are Compaq, which moved from twelfth to eighth place, and NEC, which moved from sixteenth to tenth.

Three vendors in the top 10—IBM, Intergraph, and Mentor—stayed in the same position as they were in 1987, while Digital and McDonnell Douglas fell two and three places, respectively.

U.S. Vendors Dominate, but Japanese Vendors Are Catching Up

As Table 9 indicates, U.S.-based vendors continue to dominate the worldwide market for CAD/CAM systems. CAD/CAM represents one of the few high-technology markets in which U.S. vendors still enjoy a sizeable lead. This is because the United States still leads the world in software and workstation technology, although the Japanese are catching up quickly. For example, the Japanese vendor share of the Japan CAD/CAM market climbed in 1988, eclipsing the share of U.S. vendors.

Dataquest expects that in the future, non-U.S-based vendors will become more competitive, particularly in their local markets. Additionally, to become more competitive, U.S. vendors will have to increasingly improve the local content and support of their products overseas. The importance of being perceived as a local vendor with strong support capabilities will increase as differences in technologies diminish.

Today, only a handful of U.S. vendors—IBM, Digital, and Hewlett-Packard—are perceived as being local suppliers in the European and Asian markets.

IBM

As Table 1 indicates, once again IBM leads the pack with a 13.9 percent share of the worldwide CAD/CAM market. IBM's continuing leadership in this market grew wider in 1988 and is now almost twice the size of the next largest competitor. What is truly amazing about IBM's growth in CAD/CAM is that it does not yet have a competitive workstation offering. Indeed, almost 85.0 percent of IBM's 1988 CAD/CAM revenue was derived from sales of host-based systems that are almost extinct in the non-IBM segment of the market. Dataquest believes that although Sun and Apollo will make some inroads into the IBM installed base (as they have done very successfully in Digital's VMS base), most IBM users will wait until IBM delivers a competitive workstation of its own before they decide to switch to this more powerful, cost-effective style of computing.

In 1988, IBM struggled in the PC hardware area, which, until recently, was one of its strongholds. The introduction of MCA PCs with OS/2 has not fared nearly as well as the older PC-Bus MS-DOS versions that were the de facto industry standard in years past. Compaq and Apple now sell more PCs for CAD/CAM than does IBM.

Also in 1988, IBM continued to favor Dassault's Catia CAD/CAM software and de-emphasize its longstanding Lockheed CADAM software. This once amicable but now strained relationship has prompted Lockheed to announce that it has ported CADAM to competing Apollo and Sun workstations. Now that CADAM is publicly up for sale, IBM will probably continue to push Catia at the expense of CADAM.

Dataquest expects that during 1989, IBM will do the following:

- Make a bigger play in the CIM market via its recent alliance with Santa Clara start-up Valisys

- Attempt to create the foundations of a successful workstation strategy, which may include introducing new RT-based systems or buying Silicon Graphics. The major challenge for IBM here is not technology, but trying to motivate and re-align its monster-sized mainframe organization and culture toward selling inexpensive but powerful workstations. This is a formidable challenge when one considers the sales quotas carried by an IBM salesperson.

Prime Computer

Nineteen-eighty-eight was a whirlwind year for Prime, which vaulted 6 places and 5.5 percent in market share to become the number two CAD/CAM vendor in the industry. Prime's acquisitions of Computervision and Calma have transformed the company from a middle-of-the-road participant to a CAD/CAM powerhouse that owns 20 to 25.0 percent of the world's installed base of mechanical CAD/CAM seats.

Prime has done a good job in integrating its new acquisitions. However, the recent unfriendly takeover battle with MAI Basic Four has defocused many of Prime's resources and has somewhat stalled the success of its CAD/CAM group. While Prime has done a good job of melding the organizations together, it still faces a much larger challenge of integrating and paring down its disparate product offerings.

Intergraph

Intergraph was one of 1988's major success stories. After weathering a tough product transition during 1987 that netted only a flat 6.0 percent in revenue growth, the company rebounded with an astounding 25.0 percent growth last year, which vaulted it into the number three position worldwide and the number one position in North America. Much of Intergraph's success was due to the growth and acceptance of its Clipper-based Interpro workstations. Although most of these workstations were sold to existing Intergraph customers who have Intergraph software, the company has placed increasing emphasis on establishing itself as a general-purpose workstation supplier outside of its traditional base. Indeed, based on Dataquest's general-purpose technical workstation market share figures, Intergraph's $275 million in workstation hardware revenue is good for a 6.7 percent share and fifth place in the fast-growing $4.1 billion workstation market.

Intergraph, like many CAD/CAM vendors, had an exceptional year in Europe where it recorded revenue growth of more than 63.0 percent in 1988. One order from British Telecom alone netted Intergraph $35 million in mapping and utility CAD systems last year.

During the first quarter of 1989, Intergraph announced that its outlook for 1989 would be much softer than most Wall Street analysts had been predicting because of the continuing trend toward lower system prices and the unanticipated delays in new product shipments. However, Dataquest believes that whatever slowdown Intergraph might be feeling now will be short lived. The company has tremendous upgrade potential in its installed base with its new TIGRIS mapping products and is making major inroads in the mechanical CAD/CAM market with its well-received I/EMS software.

Digital Equipment

Although 1988 was a record year for Digital in terms of revenue derived from technical workstations, overall it was a down year for the company in CAD/CAM, with revenue off 18.0 percent. Total system unit (host systems plus technical workstations) sales were up more than 270.0 percent. However, because most of Digital's sales were in the inexpensive workstation area as opposed to its traditional mix favoring more expensive host-based systems, it experienced an erosion of overall revenue. Digital's $780 million in 1988 CAD/CAM revenue does not include another $500 million or so of revenue derived from OEM sales to turnkey system companies such as Computervision and Intergraph.

During 1988, Digital announced an important new program—the Distributed Cooperative Marketing Partners (DCMP) program—whereby Digital essentially becomes a turnkey vendor taking full responsibility for the sale, service, and support of CAD/CAM hardware and software. Its first turnkey solution (announced at last years' Autofact show) was a Matra Datavision Euclid solution. Others are currently being negotiated. Dataquest believes that Digital, like IBM, recognizes that software is where the future growth and opportunity lies in the CAD/CAM market. We expect Digital to become increasingly aggressive in pursuing its own private-label software solutions.

One of the major challenges we see for Digital during 1989 and beyond is to weather the transition from a host-based vendor to an aggressive workstation supplier. Earlier this year, Digital unveiled some very impressive products including its first RISC-based machine, the DECStation 3100. One important aspect of this announcement was that its RISC machine would not support Digital's popular VMS operating system. This could create a significant opportunity for competing UNIX workstations vendors such as Sun and Apollo to make further inroads into Digital's installed base, since Digital users now have to move to a UNIX platform to gain access to high-performance workstation technology.

Mentor Graphics

Over the past five years, Mentor Graphics has been the fastest-growing and most dominant vendor in the Electronic Design Automation application segment. In 1988, the company grew an astonishing 43.0 percent without the benefit of any significant revenue-adding acquisitions. It made great inroads in expanding its share of the PCB market growing 238.0 percent and moving from tenth place to third place in PCB market share.

One of the most consistent rumors bandied about during 1988 centered on which platform, besides Apollo, Mentor would eventually support. Because of increasing concerns about Apollo's long-term viability, speculation continued to mount that Mentor would indeed announce another platform until Hewlett-Packard's recent purchase of Apollo. Now, it appears that Mentor will stick with Apollo, since its viability is no longer in question. Dataquest believes that Mentor may also port its applications to HP workstation hardware in exchange for HP's CAE business (both external and internal).

MARKET OUTLOOK—GENERAL TRENDS AND ISSUES

Increased Market Verticalization/Specialization

Dataquest believes that the CAD/CAM market is now in its third stage of industry evolution. The first stage was characterized by vendors supplying general purpose graphics capabilities across a wide variety of disciplines (e.g., Applicon and Computervision). Stage two saw the introduction of vendors that built systems tailored for a specific discipline (e.g. Daisy, Mentor, and Valid, which built systems specifically

for Electronics Engineering). The third stage is characterized by vendors that supply tools to fill missing functional gaps in older-generation systems (e.g., data base management or framework tools) or that provide significant enhancements to improve the productivity of certain classes of jobs or problems an engineer may wish to solve (e.g., logic synthesis or integrated MCAE). The major challenge of this third stage is to develop and market products that are compatible with older-generation systems.

Continued Vendor Consolidation

As the CAD/CAM market increases in size and complexity, Dataquest believes that companies will engage in more strategic partnering activities in order to accomplish the following goals:

- Enter new market segments
- Gain access to more capital
- Gain access to key technologies
- Satisfy purchasing requirements for large contracts
- Gain market consensus by endorsing certain standards

The Fallacy of Penetration—Don't Forget the Aftermarket

Even though end-user penetration rate measures by seats (30.0 to 40.0 percent) or sites (75.0 percent) are relatively high, a sizeable opportunity remains for selling aftermarket products (e.g., additional software, peripherals) and new technology to old customers, sometimes called "technology refreshment." The combination of selling aftermarket products and technology refreshment accounts for approximately one-third of today's market. Dataquest believes that over the next five years, this segment will grow to two-thirds or more of the entire CAD/CAM market. This scenario tends to favor companies with large installed bases or products that are compatible with existing technologies.

Distribution—The Challenge of the 1990s

As prices continue to fall, there looms a major challenge to be able to profitably sell low-priced systems. Although today, most CAD systems are sold through a direct sales force, in the future, dealers and distributors will play a bigger role in getting CAD products to the market. However, this channel is in its infancy and needs lots of development. The CAD vendors that have the best-developed low- and high-end distribution channels are likely to emerge as the most successful vendors in the long term.

MARKET OUTLOOK

Emerging Opportunities

We expect the following major growth opportunities in the CAD/CAM market over the next five years:

- Engineering data base management systems
- Object-oriented environments
- More powerful desktop MCAE systems that incorporate feature-based modeling techniques and true 3-D graphics
- Engineering workstations
- Desktop geographic information systems
- Logic synthesis tools
- Electronic design tools supporting the VHSIC hardware description language (VHDL)
- Mixed analog/digital simulation
- Apple Macintosh PC-CAD products

Regional Forecast

Dataquest expects that the international markets—Europe and Japan in particular—will continue to grow faster than the North American market over the next five years although the gap will not be as disparate as in previous years. Nevertheless, CAD/CAM vendors that are not receiving more than 50.0 percent of their revenue from international markets are likely to lose market share over the next several years.

Platform Forecast

As our forecasts indicate, Dataquest believes that technical workstations will dominate the CAD/CAM market over the next five years. Last year, technical workstation revenue surpassed host-based systems revenue to become the leading CAD/CAM platform in the market. Vendors such as Sun, HP/Apollo, Digital, Intergraph, and Silicon Graphics will be major benefactors of the rapid growth in CAD/CAM workstations.

Apple and Compaq should also experience high growth rates in the personal computer/workstation area over the next several years. Apple's Macintosh has really taken off as a viable CAD/CAM platform, and Compaq's 386 machines are now outselling IBM in the CAD/CAM market.

Although our forecast shows personal computers declining over time, this trend is a bit misleading. We believe that personal computer functionality will eventually match that of workstations. Therefore, personal computers as we know them today will essentially be made obsolete by a new class of low-end workstations. In the future, we may do away with the term personal computer altogether and further segment our workstation forecast.

Average Selling Prices

We expect CAD/CAM workstation selling prices to continue to decline, dropping an average of 8.2 percent over the next five years. Most of this expected drop is due to a changing product mix that will favor lower-cost systems as opposed to real drops in the price of hardware or software.

Revenue Source Forecast

We continue to believe that CAD/CAM software and service will grow much faster than hardware. Software comprised 28.0 percent of total market revenue in 1988. Dataquest forecasts that software will grow to 38.0 percent of the market in 1993.

We also believe that while total personal computer revenue will tail off substantially over the next five years, there will be a sizeable CAD/CAM software aftermarket for PCs long after workstations have replaced this architecture.

Distribution Class Outlook

One of the most important trends we will be watching over the next several years is the change in the way CAD/CAM systems are distributed. Today, turnkey systems still account for the lion's share of the market, approximately 56.0 percent. Dataquest predicts that by 1993, turnkey system sales will fall to 39.0 percent of the market with the balance comprising unbundled sales and sales through dealers and distributors. We strongly believe that the most successful vendors in the future will be those that have solved the low-end distribution puzzle by successfully managing a multitiered strategy that encompasses all three forms of distribution—turnkey, unbundled, and dealer/distributor.

David Burdick

Table 1

CAD/CAM 1988 Worldwide Market Share

	Revenue	Units	Revenue Share	Units Share
IBM	1,510.0	42,002	14.6%	11.6%
Prime Computer	874.0	8,185	8.4%	2.3%
Intergraph	801.6	8,780	7.7%	2.4%
Digital	780.0	9,834	7.5%	2.7%
Mentor Graphics	300.8	4,162	2.9%	1.2%
Hewlett-Packard	276.9	15,353	2.7%	4.3%
Fujitsu	269.0	2,975	2.6%	.8%
Compaq	250.0	48,000	2.4%	13.3%
McDonnell Douglas	231.0	3,081	2.2%	.9%
NEC	226.4	11,400	2.2%	3.2%
Sun	215.3	10,244	2.1%	2.8%
Daisy Systems	205.2	2,005	2.0%	.6%
Apollo	196.0	10,201	1.9%	2.8%
Control Data	170.0	1,893	1.6%	.5%
Hitachi	154.0	1,500	1.5%	.4%
Apple Computer	150.0	35,000	1.4%	9.7%
Valid	141.0	1,277	1.4%	.4%
Schlumberger (Applicon)	140.0	1,911	1.4%	.5%
Nihon Unisys	138.5	700	1.3%	.2%
Autodesk	117.3	0	1.1%	.0%
Other	3,200.2	142,341	30.9%	39.4%
All Companies	10,347.2	360,842	100.0%	100.0%
All U.S.-Based Companies	8,179.9	322,919	79.1%	89.5%
All Asian-Based Companies	1,441.3	25,817	13.9%	7.2%
All European-Based Companies	726.1	12,107	7.0%	3.4%
All Hardware Companies	2,630.2	271,976	25.4%	75.4%
All Turnkey & SW Companies	7,717.0	88,866	74.6%	24.6%

Source: Dataquest
April 1989

Table 2

CAD/CAM Worldwide Forecast by Application

	1988	1989	1990	1991	1992	1993	CAGR
All Applications							
Revenue	10,347	11,824	13,223	14,180	15,446	16,805	10.2%
Systems	328,369	407,470	484,580	552,540	616,010	672,840	15.4%
Workstations	360,842	436,070	509,750	572,460	634,520	689,630	13.8%
Mechanical							
Revenue	5,950	6,645	7,271	7,483	8,070	8,604	7.7%
Systems	188,159	227,970	263,860	296,490	324,350	346,300	13.0%
Workstations	213,046	249,760	283,410	312,050	339,550	360,580	11.1%
Facilities Design							
Revenue	1,408	1,660	1,845	1,965	2,047	2,177	9.1%
Systems	71,903	96,420	120,200	140,120	157,540	174,630	19.4%
Workstations	75,498	99,710	122,840	142,090	158,980	175,690	18.4%
Mapping							
Revenue	645	787	932	1,071	1,203	1,380	16.4%
Systems	9,708	13,280	17,120	20,340	23,370	26,750	22.5%
Workstations	11,975	15,460	19,140	22,090	24,820	27,920	18.4%
Electronic CAE							
Revenue	1,127	1,307	1,525	1,760	1,959	2,169	14.0%
Systems	31,590	37,120	45,570	53,140	62,210	69,920	17.2%
Workstations	31,851	37,290	45,690	53,230	62,290	70,020	17.1%
IC Layout							
Revenue	334	420	505	581	652	740	17.3%
Systems	4,152	5,670	7,240	8,510	9,800	11,460	22.5%
Workstations	4,314	5,790	7,320	8,560	9,830	11,480	21.6%
PCB Layout							
Revenue	884	1,004	1,144	1,321	1,515	1,736	14.4%
Systems	22,856	27,010	30,580	33,940	38,740	43,770	13.9%
Workstations	24,158	28,060	31,350	34,440	39,040	43,950	12.7%

Source: Dataquest
April 1989

Table 3

CAD/CAM Worldwide Forecast by Region

	1988	1989	1990	1991	1992	1993	CAGR
Worldwide							
Revenue	10,347	11,824	13,223	14,180	15,446	16,805	10.2%
Systems	328,369	407,470	484,580	552,540	616,010	672,840	15.4%
Workstations	360,842	436,070	509,750	572,460	634,520	689,630	13.8%
North America							
Revenue	3,984	4,333	4,759	5,100	5,585	6,108	8.9%
Systems	175,846	211,260	242,600	270,010	297,230	318,890	12.6%
Workstations	188,074	220,970	250,900	276,560	303,410	324,610	11.5%
Europe							
Revenue	3,387	3,987	4,497	4,853	5,288	5,766	11.2%
Systems	90,895	115,880	140,600	162,330	182,630	200,850	17.2%
Workstations	102,281	126,350	149,800	169,530	189,120	206,630	15.1%
Far East							
Revenue	2,760	3,222	3,637	3,861	4,158	4,475	10.1%
Systems	55,580	73,070	91,960	108,090	121,770	135,610	19.5%
Workstations	63,413	80,290	98,530	113,310	126,590	140,010	17.2%
Rest of World							
Revenue	216	282	330	366	415	456	16.1%
Systems	6,048	7,270	9,420	12,110	14,380	17,500	23.7%
Workstations	7,074	8,470	10,530	13,050	15,400	18,380	21.0%

Source: Dataquest
April 1989

Table 4

CAD/CAM Worldwide Forecast by Platform

	1988	1989	1990	1991	1992	1993	CAGR
All Platforms							
Revenue	10,347	11,824	13,223	14,180	15,446	16,805	10.2%
Systems	328,369	407,470	484,580	552,540	616,010	672,840	15.4%
Workstations	360,842	436,070	509,750	572,460	634,520	689,630	13.8%
Technical Workstation							
Revenue	4,409	5,847	7,476	9,015	10,473	12,025	22.2%
Systems	74,984	107,290	148,790	194,340	243,770	293,280	31.4%
Workstations	74,986	107,290	148,790	194,340	243,770	293,280	31.4%
Host-Dependent							
Revenue	4,156	3,906	3,488	2,832	2,666	2,488	-9.8%
Systems	11,348	11,540	11,180	9,890	10,050	10,170	-2.2%
Workstations	43,820	40,130	36,360	29,810	28,550	26,960	-9.3%
Personal Computer							
Revenue	1,782	2,071	2,259	2,334	2,308	2,292	5.2%
Systems	242,037	288,650	324,610	348,300	362,200	369,390	8.8%
Workstations	242,037	288,650	324,610	348,300	362,200	369,390	8.8%

Source: Dataquest
April 1989

Table 5

CAD/CAM Worldwide Average Price per Seat Forecast by Platform

	1988	1989	1990	1991	1992	1993	CAGR
Turnkey & Hardware-Only							
Technical Workstation	40.1	35.8	31.9	28.4	25.3	23.4	-10.2%
Host-Dependent	285.3	255.6	233.9	212.5	195.2	177.8	-9.0%
Personal Computer	5.3	5.1	4.8	4.5	4.1	3.9	-6.0%
All Platforms	22.9	20.3	18.4	16.6	15.6	15.0	-8.1%
Turnkey							
Technical Workstation	56.2	53.0	49.8	46.8	44.5	43.9	-4.8%
Host-Dependent	393.9	370.1	346.3	322.8	302.9	284.9	-6.3%
Personal Computer	18.5	18.8	17.3	16.1	15.1	13.7	-5.8%
All Platforms	77.4	70.2	63.2	55.3	51.4	49.3	-8.6%
Hardware-Only							
Technical Workstation	19.3	17.8	16.2	14.6	13.4	12.7	-8.0%
Host-Dependent	167.8	146.9	135.6	127.5	122.6	116.0	-7.1%
Personal Computer	4.3	4.4	4.3	4.1	3.8	3.6	-3.5%
All Platforms	9.6	9.0	8.7	8.2	8.1	8.1	-3.3%

Source: Dataquest
April 1989

Table 6

CAD/CAM Worldwide Revenue Sources Forecast by Platform

	1988	1989	1990	1991	1992	1993	CAGR
All Platforms							
Hardware	6,105	6,627	7,169	7,382	7,732	8,129	5.9%
Software	2,820	3,507	4,157	4,750	5,458	6,198	17.1%
Service	1,500	1,690	1,896	2,048	2,256	2,477	10.6%
Total	10,347	11,824	13,223	14,180	15,446	16,805	10.2%
Technical Workstation							
Hardware	2,314	2,940	3,641	4,239	4,756	5,326	18.1%
Software	1,313	1,893	2,549	3,234	3,934	4,661	28.8%
Service	770	1,013	1,287	1,542	1,783	2,038	21.5%
Total	4,409	5,847	7,476	9,015	10,473	12,025	22.2%
Host-Dependent							
Hardware	2,577	2,341	2,077	1,677	1,576	1,465	-10.7%
Software	973	960	875	723	689	654	-7.6%
Service	663	605	537	432	400	368	-11.1%
Total	4,156	3,906	3,488	2,832	2,666	2,488	-9.8%
Personal Computer							
Hardware	1,214	1,346	1,451	1,466	1,400	1,337	1.9%
Software	534	654	734	794	835	883	10.6%
Service	67	71	73	74	73	72	1.5%
Total	1,782	2,071	2,259	2,334	2,308	2,292	5.2%

Source: Dataquest
April 1989

Table 7

CAD/CAM Worldwide Forecast by Distribution Class

	1988	1989	1990	1991	1992	1993	CAGR
Total Hardware and Software Revenue							
Turnkey	4,963	5,399	5,647	5,650	5,745	5,845	3.3%
Unbundled	3,962	4,735	5,680	6,482	7,445	8,482	16.4%
Total	8,925	10,134	11,327	12,132	13,190	14,327	9.9%
Hardware Revenue							
Turnkey	3,592	3,768	3,892	3,841	3,860	3,880	1.6%
Unbundled	2,513	2,859	3,278	3,541	3,871	4,249	11.1%
Total	6,105	6,627	7,169	7,382	7,732	8,129	5.9%
Software Revenue							
Turnkey	1,372	1,631	1,755	1,809	1,885	1,965	7.5%
Unbundled	1,449	1,876	2,402	2,941	3,573	4,234	23.9%
Total	2,820	3,507	4,157	4,750	5,458	6,198	17.1%
Workstation Shipments							
Turnkey	88,866	96,390	105,210	112,790	119,890	123,920	6.9%
Unbundled	271,976	339,670	404,540	459,660	514,620	565,700	15.8%
Total	360,842	436,070	509,750	572,460	634,520	689,630	13.8%

Source: Dataquest
April 1989

Table 8

1988 CAD/CAM-Related Mergers and Acquisitions

Date	Activity	Valuation ($Millions)
01/88	Prime Computer, Inc., merges with Computervision Corp.	$500.0
02/88	ECAD, Inc., and SDA merge, forming Cadence	$ 67.0
03/88	Mentor Graphics Corp. acquires Tektronix CAE Systems Division	$ 5.0
03/88	Control Data acquires a 20.0 percent stake in Silicon Graphics Computer Systems, Inc.	$ 68.9
04/88	Autodesk, Inc., acquires 80.0 percent of Xanadu	N/D
04/88	Valid Logic Systems, Inc., acquires GE Calma's Electronic CAD group	$ 4.0
05/88	Mentor Graphics acquires Contour Design Systems	$ 2.25
08/88	Intergraph Corp. acquires ANA Tech Corp.	N/D
10/88	Silicon Compiler Systems, Inc., acquires CAECO, Inc.	N/D
10/88	McDonnell Douglas acquires Shape Data, Ltd., a subsidiary of Evans & Sutherland	N/D
10/88	Prime Computer, Inc., acquires the Mechanical and AEC groups of GE Calma	N/D
10/88	Valid Logic Systems, Inc., acquires Integrated Measurement Systems, Inc.	$ 17.5
11/88	Cadnetix Corp. completes acquisition of SimuCAD	$ 6.0
11/88	Cadnetix Corp. completes acquisition of HHB Systems, Inc.	$ 60.0
11/88	Valid Logic Systems, Inc., acquires Analog Design Tools	$ 35.0
11/88	Daisy Systems, Inc., acquires Cadnetix Corp.	$ 95.0
12/88	Cadence acquires Tangent Systems from Intergraph Corp., which in turn takes a 10.0 percent equity stake in Cadence	$ 14.0
12/88	Cadam, Inc., acquires Personal CAD Systems, Inc.	N/D

N/D = Not Disclosed

Source: Dataquest
April 1989

Table 9

CAD/CAM Worldwide Market Share by Vendor Country Origin

	1985	1986	1987	1988
Worldwide				
U.S. Vendors	86.5%	83.5%	81.1%	79.9%
Japanese Vendors	9.8%	10.6%	11.9%	13.6%
European Vendors	3.7%	5.9%	7.0%	6.5%
Total	100.0%	100.0%	100.0%	100.0%
North America				
U.S. Vendors	98.8%	99.2%	98.9%	99.2%
Japanese Vendors	0.0%	0.0%	0.0%	0.0%
European Vendors	1.2%	0.8%	1.1%	0.8%
Total	100.0%	100.0%	100.0%	100.0%
Asia				
U.S. Vendors	49.1%	54.1%	51.6%	47.6%
Japanese Vendors	50.5%	45.5%	47.6%	51.7%
European Vendors	0.4%	0.4%	0.8%	0.7%
Total	100.0%	100.0%	100.0%	100.0%
Europe				
U.S. Vendors	86.7%	80.4%	79.5%	82.4%
Japanese Vendors	0.0%	0.0%	0.0%	0.0%
European Vendors	13.3%	19.6%	20.5%	17.6%
Total	100.0%	100.0%	100.0%	100.0%

Source: Dataquest
April 1989

Dataquest

Conference Schedule

1989

Semiconductor User/ Semiconductor Application Markets	February 27–28	Le Meridien Hotel San Francisco, California
Japanese Components	April 20–21	Tokyo Bay Hilton International Tokyo, Japan
Computer Storage	April 26–28	The Doubletree Hotel Santa Clara, California
Document Processing	May 16–18	Monterey Sheraton Hotel Monterey, California
Copiers	May 16–17	
Printers	May 16–17	
Electronic Publishing	May 18	
Imaging Supplies	May 18	
Color	May 18	
SEMICON/West Seminar	May 24	The Dunfey Hotel San Mateo, California
Telecommunications	June 5–7	Silverado Country Club Napa, California
European Components	June 7–9	Park Hilton Munich, West Germany
Asian Semiconductor and Electronics Technology Seminar	June 28	Radisson Hotel San Jose, California
Financial Services	August 22–23	The Doubletree Hotel Santa Clara, California
Technical Computing and Applications	September 11–13	The Doubletree Hotel Santa Clara, California
European Copying and Duplicating	September 18–19	Majestic Hotel Cannes, France
Western European Printer	September 20–22	Majestic Hotel Cannes, France
Taiwan Conference	September 25–26	Grand Hotel Taipei, Taiwan
Distributed Processing	September 26–28	The Doubletree Hotel Santa Clara, California
SIA/Dataquest Joint Conference	September 27	Santa Clara Marriott Santa Clara, California
Information Systems	October 2–6	Tokyo American Club Tokyo, Japan
Semiconductor	October 16–18	Monterey Sheraton Hotel Monterey, California
Asian Semiconductor and Electronics Technology	November 2–3	Kunlun Hotel Beijing, China
European Telecommunications	November 8–10	Grand Hotel Paris, France
European Personal Computer	December 6–8	Athens, Greece

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Research *Bulletin*

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HEWLETT-PACKARD BUYS APOLLO— VAULTS INTO WORKSTATION MARKET LEAD

On April 12, 1989, Hewlett-Packard and Apollo Computer jointly announced a friendly, definitive agreement by which Hewlett-Packard will acquire Apollo in a deal valued at more than $475 million. Based on Dataquest's 1988 year-end market share numbers, the combined venture has 30.4 percent of the burgeoning workstation market, which is slightly larger than the 28.3 percent share enjoyed by the previous number one, Sun Microsystems. This bulletin examines the implications of this blockbuster agreement.

PLUSES

In Dataquest's view, Hewlett-Packard brings the following positives to the venture:

- Financial stability, which will help allay growing fears about Apollo's viability
- A stable, experienced management team with a well-developed corporate infrastructure, particularly in the area of sales and support
- Strong, high-quality manufacturing capabilities
- A broad line of complementary products ranging from PCs and corporate minicomputers to printers, plotters, and storage devices

In Dataquest's view, Apollo brings the following positives to the venture:

- A large workstation installed base
- Important, big-name software
- Mentor Graphics and a greater presence in CAD/CAM/CAE
- Its status as the approved vendor in many major accounts including GM/EDS
- Leadership in networking technology

MINUSES

Possible negative features of the venture are the following:

- Highly overlapping product lines
- Sizable conflict with HP's CAD/CAM/CAE software business (We believe, however, that HP might de-emphasize or drop segments of its present software offerings, perhaps even selling its electronic CAE business to Mentor.)

FINAL ANALYSIS

Both companies have a significant challenge ahead of them in merging their highly overlapping product lines. Dataquest believes that Hewlett-Packard currently has a stronger midrange line of workstations, whereas Apollo's strength lies at the low- and high-end ranges of the price/performance curve. Over time in the newly combined company, HP will likely become the provider of low-end and midrange workstations based on the Motorola 680xx technology, while Apollo's Prism architecture will most likely reign supreme over HP's Precision Architecture for RISC-based workstation offerings.

Dataquest believes that this is a very positive marriage for both companies, on the whole. Combining Hewlett-Packard's three Ms—Money, Management, and Manufacturing—with Apollo's large installed base, breadth and depth of software, and CAD/CAM/CAE presence makes the merged companies a formidable force in the workstation market and a significant competitive threat, particularly to Sun and Digital Equipment.

David Burdick
Carl Flock
Mike Tyler

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Research Newsletter

CCIS Code: General Newsletters
1989-2
0003025

WORKSTATION SUPERBOWL 1988

EXECUTIVE SUMMARY

As each workstation vendor files onto the January playing field, Dataquest pauses to assess 1988's scorecard and describe the year's key events. The 1989 season promises to be marked both by accelerating performance curves on the high end and equally spectacular price points on the low end. This newsletter also analyzes the "portfolio" of the workstation industry, including company market share and growth rates. (See Table 1 and Figure 1.)

Table 1

Estimated Worldwide Workstation Revenue and Market Share
(Millions of Dollars)
1988

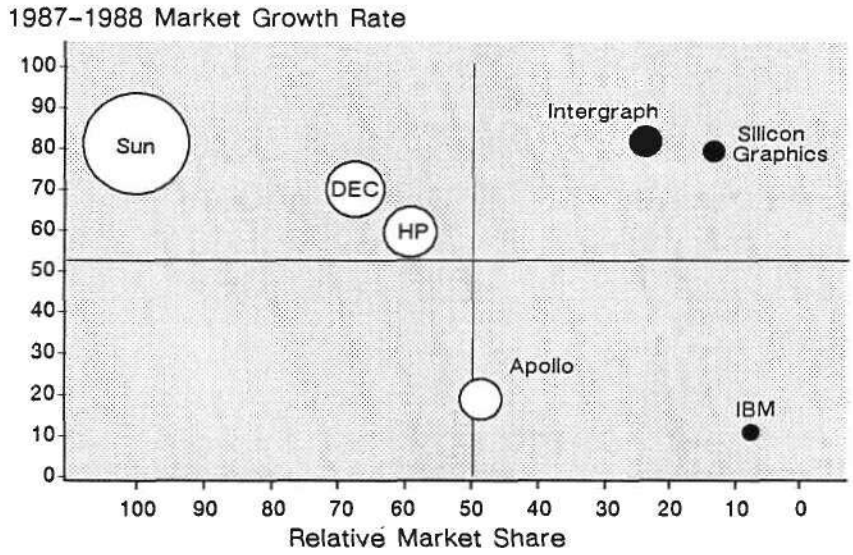
Company	1988 Revenue	Market Share	Point Change	1987-1988 Growth
Sun Microsystems	$1,165	28.3%	+4.2	80.6%
Digital	765	18.6	+1.8	70.8%
Hewlett-Packard	695	16.9	+0.7	59.8%
Apollo	555	13.5	-4.0	18.1%
Intergraph	275	6.7	NR	83.3%
Silicon Graphics	180	4.4	+0.7	81.8%
IBM	105	2.6	-1.1	10.5%
Others	370	9.0	-3.5	10.4%
Total	$4,110	100.0%		53.0%

NR = Not reported last year

Source: Company Quarterly Reports
Dataquest
February 1989

Figure 1

BCG Matrix for the 1988 Workstation Industry



Note: Market growth rate (Y axis) is taken directly from Table 1, reflecting the 1987 to 1988 workstation revenue gain/loss. Relative market share for 1988 normalizes each company's market share with respect to the leader's market share. The size of each circle is roughly proportional to the company's 1988 workstation sales revenue.

0003025-1

Source: Dataquest
February 1989

The rules of the workstation game are clearly changing. Sun still shows fast reflexes, but is growing; Digital and Hewlett-Packard now are building highly competitive workstations; and Apollo is slipping away from the front.

Dataquest believes that the workstation industry is still principally technology-driven. The key challenge in 1989, as in previous years, is the management of rapid technological advances in workstations (e.g., faster computing and graphics capabilities and lower prices) by balancing aggressive product development against a profitable migration of products over time.

However, there are signs that the customer is wresting control. These signs include an increasing demand for the support of standards and customers' expectations that vendors provide a full range of compatible workstation solutions—from an entry-level, 4-mips solution for technical publishing to a high-level, graphics-intensive, 15-mips solution for engineering. We conclude this newsletter with the 1989 product challenges for each major workstation vendor from the customer's point of view.

THE 1988 WORKSTATION INDUSTRY

The workstation market, continuing to exhibit remarkably robust growth, increased from $2,680 million in 1987 to $4,110 million in 1988, reflecting annual revenue growth of 53 percent. The primary factors contributing to this sustained growth are as follows:

- Workstation penetration still remains relatively low, in terms of the total available market. We estimate that 20 percent of the worldwide engineering community and less than 5 percent of the emerging office, university, and financial markets have workstations.
- The average price per workstation has been dropping precipitously at a 20 percent annual rate, further fueling buying activity.
- Megabuyers like General Motors, Lockheed, and Ford have standardized on a select set of hardware vendors and are now purchasing workstations in volume.
- Workstations, competitive in terms of both price and features (built-in networking and graphics), provide a natural replacement market for the weakening minicomputer market.

The Scorecard

Table 1 shows the 1988 scorecard in terms of sales revenue, annual revenue growth, and market share for the prominent workstation vendors. Not surprisingly, Sun Microsystems is still the star quarterback, gaining an impressive 4.2 points in worldwide market share in 1988. And while Digital made considerable headway in 1988, there is still a considerable spread between that company's workstation revenue and Sun's workstation revenue.

Close at Digital's heels is Hewlett-Packard (HP), a company whose late 1988 offerings have yet to be counted. Apollo, just behind HP, fell to fourth place in market share—the culmination of a year of product transition problems.

Emerging in the fifth place slot is Intergraph, a major player in the CAD/CAM market for more than a decade. After formally entering the general-purpose workstation market last year, Intergraph grew an impressive 83 percent in 1988, principally through its engineering sales into the oil exploration; plant design; utilities; and federal, state, and municipal government sectors.

In sixth place, Silicon Graphics Inc. (SGI) grew a remarkable 82 percent in 1988, although its market share stayed constant. This type of growth pattern reflects SGI's dominance of the 3-D workstation niche, where its growth occurs without cutting into the market share of the dominant 2-D workstation suppliers.

Finally, IBM has still not fully recovered from its late entrance and failure to attract third-party software developers, and actually lost market share in 1988.

Figure 1 shows how the workstation players are positioned as we enter 1989. Digital trails Sun, and there is a considerable gap in relative market share. However, Digital's aggressive pricing on the recently announced DECStation 3100 will undoubtedly help relieve this gap. Although Hewlett-Packard's 1988 performance was a good notch above the industry average, it is clear that the company must concentrate on gaining market penetration.

Intergraph and Silicon Graphics lead with the highest growth rates in the workstation industry. While SGI's market share is low due to its niche product offerings, we anticipate that the company will push into a more aggressive position based on the very price-competitive Personal Iris it announced in October.

Finally, it is clear that both Apollo and IBM, which have slipped in market share and growth rate, must engage in strategic redirection—with regard to product offerings and organization—in order to rejoin the game.

Also, note that the size of each company's circle in Figure 1 is roughly proportional to its 1988 workstation sales revenue. If we had used a linear scale, Sun's revenue circle would be nearly 100 times larger than that of IBM or Silicon Graphics!

Nonetheless, the relative size of the companies' revenue circles faithfully represents the following:

- The vast revenue margin between Sun and its nearest competitors
- The cluster of 1988 revenue performance by Digital, Hewlett-Packard, and Apollo
- Apollo's continued strength in terms of installed base

COMPETITIVE ANALYSIS

Sun Microsystems Inc.

Sun Microsystems remained the premier workstation company in 1988, ranking number one in market share and number three in revenue growth. Much of its success can be attributed not only to continuing demand for the company's staple (and still backlogged) Sun 3 product line, but the ramping up of the Sun 4 RISC line, now accounting for 25 percent of the company's annual revenue.

In addition, 1988 saw increased internationalization, marked most prominently by Sun's penetration into Japan via a blanketing of distribution channels, including C. Itoh Techno-Science Company, Ltd., and OEM arrangements with Nippon Steel, Tokyo Electron (TEL), Toshiba, and, more recently, Fujitsu.

In terms of product marketing strategy, Sun's principal drive in 1988 penetrated beyond the realm of its traditional CAD/CAM and CASE users. The two main vehicles were, at the low end, the Sun 386i and, at the high end, the Sun 4 RISC line. The Sun 386i, which supports both UNIX and DOS, was clearly aimed at the broader needs of the commercial environment, and passed through a growing base of value-added resellers.

At the high end, the Sun 4 made inroads into Wall Street and the financial community. The success of both high- and low-end systems demonstrated amply that Sun could be as innovative in marketing as it is in technical matters.

Sun's marketing force in both product entry and product transition strategy has provided a guideline for other workstation vendors. In terms of product entry, Sun rewrote the rules by aggressively underselling the competition with its entry-level diskless node configuration. This strategy provides customers with not only a lower-cost alternative for accessing workstation power, but also empowers customers to buy more nodes per site and upgrade memory requirements at their own pace.

A good example of Sun's successful product transition strategy is its introduction of a server configuration for a new high-performance model prior to providing a truly interactive workstation version. This effectively lengthens the life cycle of the older workstation models: the lower-power models essentially siphon off the computing power of a server on a network. In turn, the installed base of low-power machines creates pent-up demand for higher computation, thus driving up sales of the new server.

A great deal of Sun's future success depends on its scalable RISC line. Based on its near-blinding success, Sun and AT&T attracted a bevy of SPARC licensees. Recently, these licensees formed a consortium, including the semiconductor firms of Bipolar Integrated Technology, Fujitsu Microelectronics, LSI Logic Corp., Texas Instruments, and Ross Technology (a subsidiary of Cypress). These vendors recognize that, by cooperating on compatibility, testing, and verification procedures for SPARC, they will facilitate growth in each of their separate niche markets. And, if the SPARC Applications Binary Interface (ABI) becomes a reality—with SPARC proliferating via the financial muscle of AT&T—Sun could indeed "seize the industry by the binaries." (The catalyst for this may well depend on the success of Sun's much-anticipated, low-end SPARC platform.)

Nonetheless, Sun faces several challenges. For instance, financial analysts worry about the toll of Sun's extremely fast growth and if the company can mature organizationally without losing the flexibility needed in a field characterized by aggressive "time-to-market" tactics. Burdened with three hardware platforms and multiple accelerator options, Sun's product release cycle is approaching a gargantuan level of complexity. The question is not whether Sun can meet the technical challenges of 1989, but whether the company can learn to manage its organization faster than Digital and HP can introduce leading-edge workstations.

Also, it is uncertain whether Sun will provide its large installed base of Sun 3 (68000-based) customers with a migration path in a timely manner. Finally, there is some concern about Sun's ability to provide state-of-the-art 3-D graphics performance.

Digital Equipment Corporation

Digital's robust growth in 1988 principally reflected the success of its VAXStation 2000 sales coupled with the marketing muscle of Don McGuiness's relatively new Engineering Systems Division. While still moving primarily VMS-based products into the market, Digital's workstation sales in 1988 were driven by the company's greatest strength: the immense installed base of VMS users. Dataquest estimates that, at least in the CAD/CAM market, Digital's VMS operating system still owns approximately 18 percent of the installed seats. Digital's existing customers are "captive" in the sense that they already have considerable design investment in VMS.

Why then isn't Digital number one? Dataquest attributes Digital's 1988 "number two" performance to the following factors:

- UNIX dominated 1988 workstations sales; for example, the yearly run rate for UNIX in the engineering community almost doubled that of VMS.
- Until December 1988, Digital's product offerings hovered around 1 to 4 mips, whereas most vendors were already offering 10-mips systems.
- Until January 1989, Digital did not offer RISC, the rallying cry of the technical performance push.

With these recent announcements, Dataquest believes that Digital has woken up. Except for Hewlett-Packard, most of the giant computer companies have had trouble adopting the swift and nimble characteristics of the smaller workstation companies. Several factors indicate that Digital is now a very serious player, including the 1987 formation of a specific workstation group, the focus of increased development efforts on ULTRIX, and, most notably, the acquisition of critical workstation technology components. Digital's alliance with MIPS Computer, its leveraging of the X-Windows technology from M.I.T., and the licensing of Apollo's Network Computing System (NCS) also indicate that Digital now has an aggressive game plan.

Hewlett-Packard Company

As a relatively late entrant to the technical workstation market, Hewlett-Packard continued its rapid catch-up pace in 1988, growing close to 60 percent, or 7 percentage points over the workstation industry average. However, in one sense, these estimates are conservative. When Hewlett-Packard's multiuser systems, which are connected to its superminicomputer series (many of which are effectively used as workstations) are included with the HP300 and 800 series, Hewlett-Packard claims that its growth in UNIX-based systems is approximately 125 percent, significant considering the industry average of 32 percent. Taking the industry by surprise, HP has silently evolved a wide array of price/performance offerings. These offerings range from the HP 340M, focused on 2-D, monochrome applications, to the HP 935 Turbo SRX, which addresses the 3-D, high-graphics performance necessary for highly realistic visual simulation.

In contrast to Digital, HP marked 1988 with more than six workstation product introductions, ranging from the low-end, 2-D, 68000-based workstations to a RISC-based, 3-D graphics superworkstation.

Dataquest sees the following strengths in the HP workstation line:

- Provides high reliability and quality in manufacturing
- Complemented by a leading peripherals business
- Installed in a wide range of vertical target markets
- Selected as an approved supplier to General Motors/EDS

First and foremost, the name Hewlett-Packard is almost synonymous with world-class manufacturing quality and reliability. This may well prove to be Hewlett-Packard's chief asset in high-volume, low-end workstation production. Ultimately, a manufacturing advantage translates into decreased support costs over a product's life cycle and, most important, increased customer satisfaction (fewer DOAs and downstream equipment failures).

Second, Hewlett-Packard's leading position in the plotter and printer industry provides a total solution package and, undoubtedly, more latitude in pricing for workstation/hardcopy device configuration.

Third, although Hewlett-Packard has not been considered a forerunner among workstation industry pundits focusing on performance ratings, in actuality, the company is a household word among its large installed base of engineering, manufacturing, and even HP 3000-based office end users. Not surprisingly, HP has leveraged the nontraditional workstation markets, targeting members of its RISC workstation line for the office and, through companies like Gerber Systems, into the factory sector.

Fourth, because each chip-defined product series has been scaled, an inexpensive upgrade path exists for a workstation series, thus protecting the customer's investment.

Entering 1989, Hewlett-Packard's workstation business faces the following challenges:

- Few third-party software products with major market share
- Proprietary RISC technology

Despite the fact that more than 750 applications run on HP-UX, few industry-standard, third-party software vendors to date have adopted HP as their main platform. However, HP's recent approval as a preferred workstation supplier to General Motors/EDS helped it bring mechanical CAD software giants CADAM and McDonnell-Douglas into its camp.

In contrast to the Sun and Digital RISC workstations, HP's captive-chip technology, Hewlett-Packard Precision Architecture (HPPA), could limit the potential volume of new RISC-based software development.

Apollo Computer Systems

Objectively, Apollo was a major disappointment in 1988, sliding from a market ranking of number two to number four. Apollo's problems arose from several different sources, including the following:

- Financial vulnerability associated with relying on certain OEM accounts
- Difficult product transitions
- Related to the above, consequent major organizational realignments
- Increasing buyer recognition that the Apollo AEGIS operating system is not a standard UNIX.

Historically, one of Apollo's greatest strengths has been its solid foundation of OEM customers such as Mentor, Calma, Auto-trol, and Siemens. During 1988, however, purchasing fluctuations among its major OEMs (particularly overseas) caught Apollo off guard, resulting in major operating losses during the second quarter.

Product line transition also plagued Apollo in 1988. For instance, with the introduction of the DN 3500, Apollo correspondingly discounted the DN 4000 line—but not in time for the balance sheet to show the rewards in sales volume. Most notably, in early 1988, Apollo announced the RISC-based DN 10000 but did not ship until the third quarter. This was tantamount to showing your hand at the poker table: Three quarters left plenty of time for Apollo's competitors to respond, and they did.

Intergraph Inc.

Since the heyday of CAD/CAM, Intergraph has been a major presence in the CAD/CAM industry. Recognizing the slowing growth in the CAD/CAM industry (16 percent growth in the 1987-1988 period), Intergraph reorganized its workstation division as a separate business unit late last year—primarily to seize the opportunity in the still-burgeoning workstation industry.

As a general-purpose workstation vendor, Intergraph has the following strengths:

- A large existing installed base in engineering applications established during more than 20 years
- A full line of 2- and 3-D workstation solutions
- A fully vertically integrated solution

Intergraph already has a large installed base in CAD/CAM, being the number three CAD/CAM revenue leader with $800 million in revenue during 1988. Dataquest estimates that 34 percent of this total revenue was attributable to UNIX-based workstation sales.

Intergraph provides its own system components (central processing unit, floating-point unit, and memory management unit, and cache) as well as system software, much like the now-legendary Japanese "vertical integration" formula. The company claims, with some justification, to have the largest installed based of RISC workstations, based on its Clipper architecture purchased from Fairchild in 1986. Whether the Clipper architecture is scalable to the heights of the SPARC and MIPS processors remains an open issue: The C300 RISC pushes at 50 MHz to get 14-mips performance.

Clearly, Intergraph has several challenges ahead of it, namely:

- To improve its market perception as a general-purpose workstation vendor
- To increase the number and range of available third-party software

- As a late entrant, to accelerate its technical and marketing efforts to survive the fast growth rates in this industry
- To avoid potential channel conflicts with the CAD-based workstation sales channel

At UniForum '89, Dataquest anticipates that Intergraph will make good its promise to be a price/performance leader. The Company plans to introduce a highly aggressive workstation, signaling to the existing players that the company is to be taken very seriously.

Silicon Graphics Inc.

Unlike other workstation vendors, Silicon Graphics Inc. (SGI) uniquely meets the high-performance graphics workstation requirements for select target markets, principally high-end mechanical engineering, medical imaging, visual simulation, product styling, and computer-aided entertainment.

There are several signs that SGI intends to aggressively protect its current market position in 3-D graphics. In late 1988, it announced the entry-level Personal Iris and, at the high end, the Power Series. While the Power Series maintains SGI's position as the premier supplier of 3-D graphics systems, the highly price-competitive Personal Iris promises to bring in a much wider customer base. The 25 percent price reduction for its midrange products underscores the price competitiveness of the SGI workstation line.

On the low end, the new Personal Iris appears to be a direct attack on the Sun 3/160CXP, Sun's most popular product. In essence, the Personal Iris offers Sun 3/260 and Sun 4/150 performance for a Sun 3/160 price. A major challenge for SGI is to let the marketplace know that its machines are no longer just for the sophisticated user with deep pockets.

On the high end, the 4-D Power Series seems pitted against the Stellar workstation, offering comparable graphics performance for approximately $10,000 less.

As another indicator of future success, SGI focused on attracting third-party software suppliers. In the last half of 1988, SGI doubled the number of its solution suppliers and, most significantly, added several major players in mechanical engineering, including Manufacturing Consulting Services (MCS), PDA Engineering, and SDRC.

Even so, Dataquest sees some vulnerability in SGI's maintenance of a niche graphics position, as other vendors develop 3-D graphics savvy. However, we see greatly expanded opportunities for SGI in picking up a share of the 2-D workstation market, thereby serving the more general-purpose graphics needs of its installed base. Dataquest estimates that 70 percent of the total 1988 graphics workstation market sales were associated with 2-D graphics platforms.

IBM

Like other large computer companies, IBM has had trouble developing the flexor muscles required to keep pace with the competition in the workstation market. For instance, despite the fact that IBM was the first to develop RISC technology (the Model 810), its first workstation, the IBM PC/RT, was introduced late in 1986 but was not competitive with respect to price or performance. As a result, within a year of introduction, IBM was forced to retrench, dramatically reducing the RT price by 25 percent.

This ill-fated beginning was sustained in 1988 by the following related negative marketing factors:

- Failure to stand up to competitive technical performance repelled a critical mass of software developers, delaying the availability of applications.
- It has been an uphill battle to sell UNIX in the office, the dominant sector IBM has targeted the RT. (We estimate that 50 percent of all RTs sold were shipped into the office environment.)
- For the engineering community, the RT can run full versions of the industry-leading CATIA mechanical analysis software. However, the RT CATIA cannot bridge to CADAM, the most popular design package.

Recently, IBM has shown some signs of awakening. These signs include the following events in 1988:

- 1988 performance enhancements now make the RT competitive. Furthermore, Dataquest anticipates that IBM will announce a higher-performance system in the 15 to 20-mips range in second quarter to third quarter timeframe.
- IBM has moved toward an "Open Systems" philosophy. In third quarter 1988, it announced the licensing of Silicon Graphics' 3-D graphics library, the de facto industry standard. And along a more strategic vein, the AIX operating system has been accepted as the Open Systems Foundation (OSF) standard.
- Following in the steps of Digital, in late 1988 IBM announced the formation of the Advanced Workstations Division. This product certainly will provide the vehicle to allow IBM to focus on the unique marketing demands of its workstation strategy.

Overall, the lesson of the RT has been twofold. First, for IBM's immense installed engineering base, the workstation does not provide an effective bridge between its highly popular PC and mainframe lines. This undoubtedly relates to the diverse and noncompatible operating systems (DOS, AIX, and VS).

Second, as a point-source solution, a single IBM workstation model cannot compete against other vendors' graded range of workstation performance classes, from systems for simple nontechnical applications (e.g., 1-mips solutions for publishing) to more complex engineering applications (e.g., 10-mips, floating-point-intensive solutions for mechanical analysis and imaging).

DATAQUEST ANALYSIS

The Sun Challenge

To most industry watchers, Sun's competitive achievement provides hard evidence ($1.1 billion worth, to be precise) that a successful strategy involves the relentless introduction of leading-edge, price/performance products, and tireless promotion to and education of the marketplace. After three painful years of losing ground to Sun, Apollo, Digital, and Hewlett-Packard have learned their lessons. UNIX, Open Systems Architecture, Networks, fiercely aggressive pricing, and, above all, swift time to market must be top priorities.

As a guide to action, Sun's strategy is clear and compelling. As a measure of performance, it is unambiguous. It is also wrong.

Reacting to Sun will always place a vendor safely in second place. And in the 1988 workstation market, that meant giving away a nontrivial $1.1 billion of business. More important, a company in fifth place gave away nearly $5 billion in business.

For Sun, which redefined the industry standard in "time to market," the challenge is to decrease the drag coefficient imposed by supporting three hardware platforms. However, given Sun's previous record of "zero wait state" business solutions, we anticipate continuing efforts to streamline the product release cycle.

The Rest of the Players

For Digital, the challenge is not only to catch up, but to reestablish itself as a performance and technology leader by extending UNIX (DECWindows is an excellent first step) and being first to market with a leading-edge workstation.

Hewlett-Packard must continue to attract major software vendors in order to entice customers to its platforms. Given the quality of Hewlett-Packard's product line, perhaps a little more marketing flamboyance and bravado would be the right tactic to attract industry attention.

For Apollo, the challenges in 1989 are somewhat greater than for the major players. Broadening its large account base beyond the control of any single account will increase financial stability. But, the lesson of the DN 10000 should be heeded: Don't let the cat out of the bag too early.

For Intergraph, the chief challenge is to firmly establish itself as a truly general-purpose workstation vendor. In the short term, this means providing a fertile software development environment and/or porting strategy to lure high-quality third-party software suppliers. As a relatively late entrant, Intergraph's best chances probably lie in the fairly unpenetrated sectors where it already has an established presence—the financial and office environments associated with the Intergraph CAD/CAM installed base.

For Silicon Graphics, it is clear that unless the company wishes to keep its 3–D niche player status, it will soon have to diversify into 2–D workstation platforms to compete effectively against Hewlett–Packard in engineering environments.

Finally, for IBM, the challenge is straightforward: To compete in the workstation market more effectively, it must provide a larger family of price–competitive workstation solutions.

Lisa Thorell
Kathleen Hurley

(The authors would like to acknowledge the contributions of several colleagues in discussing, reviewing, and producing this newsletter: Dave Burdick, vice president and director of the CAD/CAM Industry Service; Carl Flock, associate director of the Technical Computer Industry Service; and Michael Seely, associate director of the CAD/CAM Industry Service.)

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HEWLETT-PACKARD'S ANSWER TO THE PERSONAL IRIS: ROCK SOLID GRAPHICS

Joining the flurry of January workstation announcements, Hewlett-Packard (HP) revealed the HP 9000 340 SRX, a low-end 3-D workstation complementing its growing bounty of low-end 2-D and high-end 3-D workstation products. While much less powerful in terms of mips and floating-point performance, it is clear that the 340 SRX is competing head-to-head with the Silicon Graphics Personal Iris in graphics power (see Table 1).

Clearly, Silicon Graphics is the vendor of choice for computationally intensive, purely 3-D applications. However, HP now provides a full-line solution for customers that require high-performance 2-D workstations and 3-D workstations. The need for both forms of graphics is most obvious for printed circuit board design. However, it also better describes the requirements for most real-world manufactured parts, which increasingly consist of an electronic component (2-D design) in addition to a mechanical form factor (3-D design).

Even so, as any real workstation user can attest, mips, NURBS, and vectors tell only part of the story. These technical indicators belie HP's true hidden strengths, namely:

- Excellent manufacturing reliability
  - HP's high-quality manufacturing imperative allows the company to charge only 3 percent for a typical service contract, compared with the industry standard of nearly 12 percent.
- A generous VAR policy
  - HP has provided up to 10 percent compensation for VAR-mediated sales.
- A global sales distribution network
  - According to its 1987 annual reports, HP's geographical distribution of revenue was 51 percent—North America, 33 percent—Europe, and 18 percent—Asia. In contrast, Silicon Graphics' global sales revenue was much more skewed: 83 percent—North America, 10 percent—Europe, and 7 percent—Asia.

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It is apparent that the workstation wars have evolved beyond pure specmanship: A full binary-compatible product line, an easy path for hardware upgrades, and a means for communicating with other vendors' machines are equally important to the customer. Fully armed with these elements and the aggressive business strategy outlined above, HP is now clearly a well-muscled workstation contender.

Lisa Thorell
Dave Burdick
Kathleen Hurley

Table 1

Comparison of System Architecture and Performance 9000 340 SRX and Personal Iris

Feature	9000 340 SRX	Personal Iris
Microprocessor	Motorola 68030 16 MHz	MIPS R2000 12.5 MHz
Floating-Point Linpack (Single-Precision Kflops)	Motorola 68882 200	MIPS R2010 (Optional) 2,120
Mips (Published)	4.0	10.0
Memory	4 to 16MB	8 to 16MB
Expansion Bus	HP-IB	SCSI
Minimum Disk Storage	152MB	170MB
Graphics		
Color	16" 1,280 x 1,024	19" 1,280 x 1,024
Color Planes	8 to 24 + 4 overlays	8 to 24 + 4 overlays
3-D Vectors/Sec.	70,000	80,000
4-Sided Poly/Sec. Z-Buffer Gouraud	4,000	5,800
Soft Z Buffer	Yes	Yes
Depth Cueing	Yes	No
Dithering	Hardware	Software
NURBS	Hardware	Software
Diskless Price	$14,900	$15,990
Price with Disk	$18,900	$19,990
Price: Disk + FPU	$18,900	$21,990

Source: Dataquest January 1989

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Research Newsletter

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1988 CAD/CAM MARKET REVIEW AND 1989 OUTLOOK: INDUSTRY CONSOLIDATION ABOUNDS, DESKTOP SYSTEMS FLOURISH

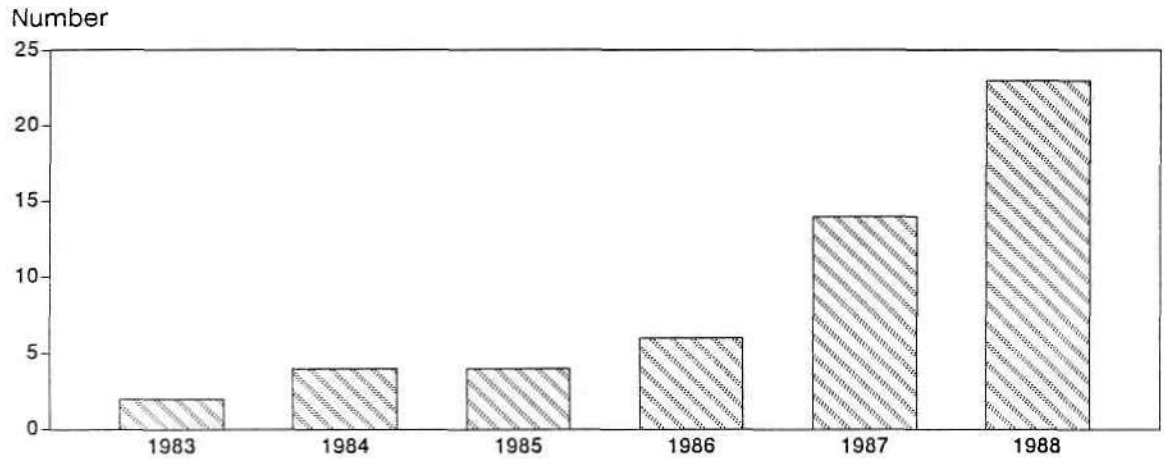
Dataquest's preliminary CAD/CAM market assessment indicates that 1988 worldwide revenue growth will come in very close to our forecast 16 percent, totaling nearly $10 billion. However, the complexion of the market changed dramatically during 1988, driven by more than 20 major CAD/CAM mergers and acquisitions (see Figure 1) and by continued explosive growth in desktop workstations and PC-based CAD systems.

This newsletter provides insights into Dataquest's preliminary 1988 market analysis and gives our views of the key 1989 trends and issues. The segments appear in the following order:

Industry Overview—David Burdick
Mechanical CAD/CAM—Michael J. Seely
Facilities Design and Mapping—Lisa G. Thorell
Electronic Design Automation—Tony Spadarella
PC CAD—Kathryn Hale
Asian CAD—Yu Uemura
European CAD—Charles Clarke

Figure 1

CAD/CAM-Related Mergers and Acquisitions



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January 1989

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INDUSTRY OVERVIEW

1988: MARKET SHARE LEADERS SHOW DRAMATIC CHANGE

As Table 1 indicates, there was a major reshuffling of the top 10 CAD/CAM market share positions when 1988 results are compared with 1987 results. Note the number of vendors appearing in the top 10 list for the first time: Compaq, Daisy, Sun, and Apollo. By virtue of its acquisition of PCB giant Cadnetix, Daisy vaulted from number 18 in 1987 to number 8 in 1988. Compaq, Sun, and Apollo entered the top 10 in 1988 due to the rapid growth and acceptance of more powerful desktop workstations and personal computers.

Table 1

1988 Estimated Top 10 CAD/CAM Worldwide Market Share
(Based on Total End-User Revenue)

Vendor	Market Share (Percent)	1988 Market Share Rank	1987 Market Share Rank
IBM	15.3%	1	1
Prime*	8.5%	2	8
Intergraph	8.1%	3	3
Digital**	8.0%	4	2
Mentor Graphics	3.0%	5	5
Compaq**	2.5%	6	12
McDonnell Douglas	2.1%	7	6
Daisy#	2.0%	8	18
Sun Microsystems**	2.0%	9	17
Apollo Computer**	1.9%	10	11

*Includes Prime, Computervision, Calma, and Versacad
**Reflects revenue from hardware sold directly to end users; does not include revenue from OEM and VAR channels
#Includes Daisy and Cadnetix

Source: Dataquest
January 1989

Prime's acquisitions of Computervision and Calma boosted its market share position from number 8 to number 2. Despite Prime's flurry of acquisitions, however, it still ranks a distant second behind IBM, which has almost twice Prime's market share.

Digital Equipment Corporation dropped two positions in 1988, surpassed by both Prime and Intergraph. Digital experienced a difficult 1988 due to continued inroads made by workstation vendors. Apollo, Hewlett-Packard, Silicon Graphics, and Sun penetrated Digital's installed base and revealed Digital's seeming inability to develop and deliver competitive midrange and high-performance workstations. Digital's recent agreement with Mips is expected to yield new products that should help narrow its price/performance gap in workstations during 1989.

Most Significant Trend in 1988: Consolidation

Without a doubt, the outstanding issue of 1988 was the firestorm of CAD/CAM–related mergers and acquisitions. We view this as a clear sign that the CAD/CAM industry is now entering the market maturity stage.

Dataquest believes that two major forces are driving the consolidation trend. The first is a matter of simple economics: Too many companies are chasing too few dollars. Since 1984, the growth rate of new companies entering the market has outstripped the slowing rate of revenue growth in the industry. The CAD/CAM revenue pie is just not growing as fast as the number of vendors lining up for slices. Therefore, a vendor must either settle for a smaller piece of the pie or combine with another vendor or vendors.

Second, most of the remaining CAD/CAM market potential lies with selling additional CAD/CAM products (workstations, software, and services) to current CAD/CAM users who want to spread CAD/CAM usage more widely across their site, or who want to migrate to newer, more–advanced, performance systems. This market scenario favors vendors with larger installed bases. Usually, an incumbent vendor is the favored choice when users decide to add more CAD/CAM capacity because of the system and data compatibility requirements. Therefore, in order to penetrate the installed base of a competing incumbent vendor, companies must either build and sell compatible systems, or buy customers through strategic acquisition as Prime, Valid, and Daisy have done.

1988's Biggest Surprise: Prime's Acquisition of Computervision

In what started out as a bitterly contested action, Prime landed the largest CAD/CAM jewel of 1988 with its acquisition of Computervision. Several surprising elements surrounded this deal, including the unfriendly, highly resistive nature of the initial offer and the high degree of functional overlap among product lines. Nevertheless, Prime has done an excellent job in melding the two companies together and has completed integration of the sales force and marketing and administration staff. However, Prime still faces the much larger challenge of integrating and paring down its disparate product offerings and absorbing newly acquired Calma.

1988's Biggest Disappointment: The Postponed Navy Buy

One positive factor that we strongly expected to occur, but which never materialized, was the $1 billion Navy CAD–II procurement. The bureaucratic bungling and political maneuvering that caused the postponement (perhaps indefinitely) of the buy, left many CAD/CAM companies reeling from the unfulfilled opportunity and associated drain of company resources in preparing for the bid.

In assessing the aftermath of the botched CAD–II procurement, one positive note was a new willingness and openness on the part of competing vendors to find ways to work with one another to satisfy requirements of the bid. We believe that the Navy buy acted as a major influence in fueling the strong trend in the CAD/CAM marketplace toward strategic partnering.

1989: KEY TRENDS AND ISSUES

On the Comeback Trail: Workstation Vendors Apollo, Digital, and IBM

Workstations and the ensuing battle for the engineer's desk will continue to be a major theme in 1989. Dataquest believes that workstations will dominate the computer market of the 1990s. Recognizing this trend, it is likely that Digital and IBM will reassert themselves by more vigorously addressing this market through new product introductions, and that Apollo will attempt to define a leadership position through market repositioning.

Digital is expected to break from its seamless VMS strategy by introducing a UNIX–only workstation based on the Mips CPU early this year. This product is expected to perform at 10 to 20 mips, but initially will lack a high–performance graphics architecture.

IBM, on the other hand, is expected to unveil new workstations incorporating higher–performance graphics via its technology licensing arrangement with Silicon Graphics. Even with newer, high–performance workstations, IBM faces a formidable challenge in trying to persuade software developers to port badly needed application software to the machine.

Apollo Computer, the pioneer and once dominant force in technical workstations, faces the difficult task of trying to stop or slow its market share erosion. In fairness to Apollo, the company really had nowhere to go but down from a market share standpoint since it virtually owned the market several years ago. Fortunately, Apollo does not have to play catch up in terms of workstation technology and products. Its DN 10000 and 3500/4500 series of workstations are highly competitive from a price/performance standpoint. In our view, Apollo's major challenge is to improve its image and marketing capabilities in order to combat the onslaught of publicity generated by Sun.

1989's Hot Boxes: Apple, Compaq, and Silicon Graphics' Personal Iris

Dataquest expects that Apple, Compaq, and Silicon Graphics will be major CAD/CAM platform winners in 1989. After receiving the endorsement of Autodesk with its new Apple version, and the blessing of Digital via a strategic technology relationship, Apple is poised to become a major new desktop platform. We believe that during 1989 many CAD/CAM vendors will port software to the Apple Macintosh line.

Compaq is also expected to continue riding a strong growth wave in 1989 due to the popularity of its 80386–based systems in CAD/CAM applications. Based upon projections of its current growth rate, Compaq could overtake IBM in PC CAD hardware revenue in 1989.

The new, powerful, but affordable 3–D Personal Iris workstation from Silicon Graphics, is also expected to be a popular CAD/CAM platform during 1989. The Personal Iris generated a great deal of interest at the recent Autofact conference, particularly in relation to its use as a 3–D MCAE workstation.

Operating System Wars

An interesting situation to watch in 1989 will be the continuing drama surrounding UNIX and the new Presentation Manager–based, OS/2 CAD/CAM applications. Although most major companies in the hardware and software arena have committed to either the AT&T/Sun (Archer Group) or the OSF version of UNIX, it is still unclear which of these two standards will emerge as the undisputed winner. Our guess is that 1989 will be a year of political intrigues and maneuverings with respect to UNIX, and that very little in the way of UNIX standardization will occur with respect to truly portable applications.

We expect to see a number of new OS/2 CAD/CAM applications introduced during 1989 that incorporate the new Presentation Manager. Dataquest will be watching market acceptance of these applications very closely because the multitasking, multiwindow capabilities of Presentation Manager could adversely affect growth in the low–end, desktop UNIX market.

Managing the Merger and Acquisition Aftermath: Perception Is Everything

Dataquest believes that 1989 will be a watershed year in terms of assessing the effects of all the merger and acquisition activity that has occurred in the CAD/CAM market over the past two years. While a strong case for withholding judgment until several years have passed could be made, the honeymoon periods will have elapsed for many of the newly merged companies (e.g., Prime/Computervision, ECAD/SDA, Daisy/Cadnetix). By the end of 1989, a more concise analysis of merger and acquisition activity with respect to revenue growth, profitability, and new product development can be made.

In any event, success in the CAD/CAM market over the long term hinges upon how well the marketplace perceives a company is performing over the near term. In other words, it is extremely important that newly combined companies show positive wins and results early in order to build customer confidence over the long term.

David Burdick

1988: A YEAR OF COOPERATION AND GROWTH

A record number of joint product developments, sales agreements, and OEM relationships were announced in 1988. At the November Autofact show, no less than 100 such announcements were made by industry leaders such as IBM, Digital, and McDonnell Douglas. The marketing agreements and amendments made by the leading mechanical CAD/CAM vendors in 1988 are as follows:

- IBM with:
  - Apollo
  - Cadam
  - CAD/CAM Technologies
  - Dassault Systems
  - SDRC
  - Silicon Graphics Inc.
- Digital with:
  - Matra Datavision
- Computervision with:
  - Prime
  - Versacad
- McDonnell Douglas with:
  - Apollo
  - EDS
  - ICAD
  - PDA Engineering
  - Shape Data
- Hewlett-Packard with:
  - CimTellegence
  - CimLinc
  - McDonnell Douglas
- Control Data Corporation with:
  - Silicon Graphics
  - Parametric Technology
- Prime with:
  - Calma
  - Computervision
  - Versacad
- Schlumberger with:
  - Apple
- Intergraph with:
  - Template Graphics Software
  - Tangent Systems

The following factors contributed to this trend:

- Users are demanding more integration between applications.
- Many vendors discovered the benefit of leveraging distribution channels established by other vendors.
- Some of the weaker vendors with good technology, development capability, or large installed bases are being viewed as attractive investments by others with cash reserves.
- Many new and enhanced products are providing enhanced user interfaces, new applications, or enhanced modeling tools. These new products are being used to create synergy among older programs both in existing product lines and between different vendor products.

A surprising additional factor may be the U.S. Navy. Although the well-publicized CAD-II buy did not make it to the request-for-proposal stage, many vendors found themselves talking to competitors and considering strategic alliances that would allow the team to meet the diverse technical requirements of the specification. With the door of communication forced open, many vendors found talented and hard-working allies with whom to do business.

Another tactic for growth, and one very popular in the electronic CAD industry, is through merger and acquisition. Perhaps the ultimate strategic alliance, a company acquisition goes well beyond a joint licensing or marketing agreement. Prime has perfected this technique, growing its market share and adding software for new platforms and new application areas. In the last 12 months, it has acquired Versacad, Computervision, and, most recently, GE Calma.

Revenue Growth above Forecast

Our 1988 forecast for mechanical CAD/CAM revenue looks a little conservative. All the obvious market indicators of the publicly traded companies suggest that the 1988 mechanical CAD/CAM market performed better than expected. The PC and technical workstation platforms continue with high forecast growth, and the European and Asian markets appear strong. We now expect the actual worldwide revenue numbers for 1988 to come in a bit above the 18 percent growth rate in the forecast.

MCAE: A Market Growing in Segments

The less-than-stellar growth of two-dimensional MCAE tools such as Cognition, Iconnex, and others testifies to rule number one in the low-end mechanical CAD market: If it is slow, hard-to-use, does not run on standard hardware, or does not make drawings, it better be cheap.

The three-dimensional MCAE tools need to consider rule number one but the added value of a 3-D or solid data base can justify a higher price tag, due to advantages in enhanced complex design, integrated analysis, and downstream benefits.

We expect MCAE to continue to be a growth area across the board. New low-end products will make the less-complex tasks more productive, thus attracting new users to MCAE technology. New high-end tools will supply the first high-performance mechanical simulation design environment that combines dynamic modeling and analysis.

WHAT TO WATCH FOR IN 1989

- More integrated design and analysis products—The target market is design optimization. As more analysis tools are developed in the manufacturing environment, the issues of design for quality or design for manufacturability will become feasible objectives. We expect leading MCAE vendors to develop tools that support the designer in making trade-off decisions concerning quality, manufacturability, cost, assembly, performance, and maintainability.

- Integrated design and documentation tools—The target market here is mainstream manufacturing, the people who manufacture and maintain what they design. The paperless factory is still on the drawing board, but the cost of access for everyone in an organization is down low enough that it should be taken as a serious option. X-Window terminals and multiuser PCs are removing the price barrier, allowing everyone access to the corporate engineering data base.

- High-end fringe applications—The following products in particular are pushing back all the barriers to complex high-performance design and analysis:

  - Parallel processing
  - Computational fluid dynamics
  - Knowledge-based programming
  - Crash simulation
  - Real-time thermal and stress analysis
  - Mechanism analysis

  The developers' increased knowledge as they work with these tools and applications will be applied to known problems in other application areas. The things that work will filter down, making the high-end market fresh, exciting, and fast growing. It will also cause a rapid increase in user perception by defining adequate system performance and functionality.

Michael J. Seely

1988: THE COMMERCIALIZATION OF THE MAPPING MARKET BEGINS

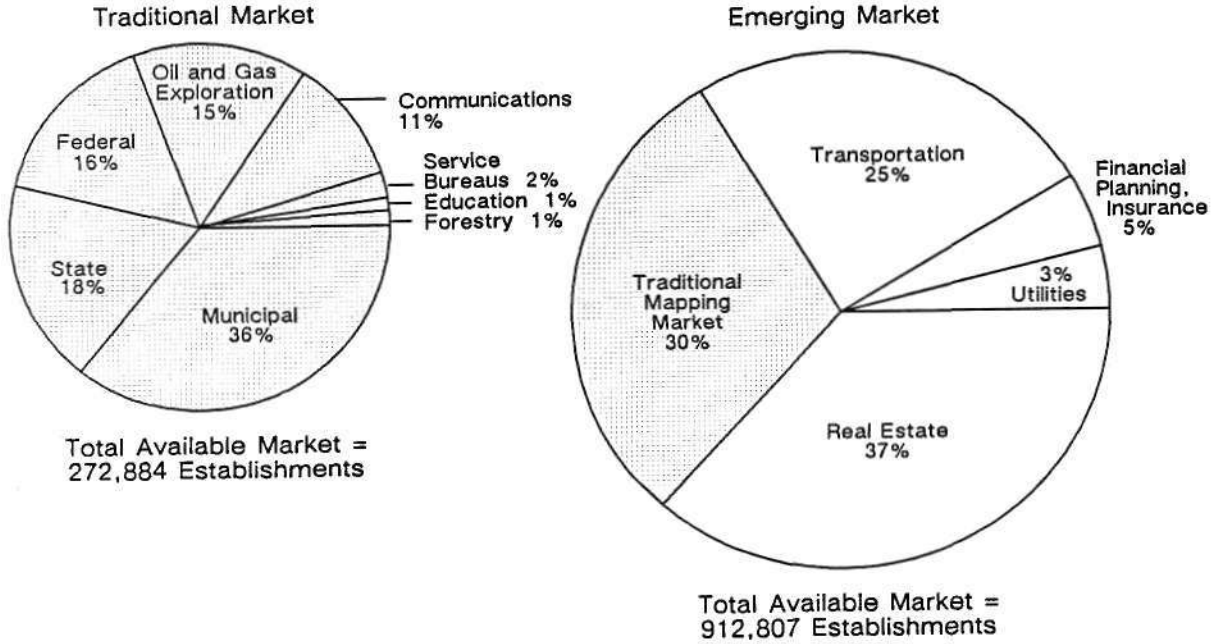
Often considered the black sheep of the CAD/CAM world, the mapping market really came into its own in 1988. Compared with its larger and slower growing mechanical and electronic brethren, the mapping industry emerged as the clear growth leader. From 1987's $495 million revenue base, the industry grew 28 percent to $635 million in 1988. Indeed, all the excitement is now at the low end, where PC mapping systems grew from $35 million in 1987 to $57 million in 1988, a huge 65 percent growth rate. Vendor products like Environmental Systems Research Institute's PC/ArcInfo, Autodesk's Autocad, and IBM's GFIS are pushing the front of this wave.

An Emerging New User Market

Traditional mapping end users include government agencies, utilities, and land resource design and management (e.g., landscape architecture, forestry, and agriculture). In the past, the participation of many nonprofit agencies has placed a ceiling on the mapping industry as a whole. More recently, however, the industry has witnessed a growing number of nontraditional and, most important, very profit-motivated users, including real estate, financial planning, transportation, market research, and strategic sales departments. Figure 1 captures what all the excitement is about: the promise of a massively large pool of users whose motivations to buy are based on hard-nosed business decisions.

Figure 1

Total Available Market for Mapping Software: Past and Future



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Source: Dataquest January 1989

True geographical information systems (GISs) have complex data base manipulation capabilities. Quite distinct from this are the desktop mapping products, most of which are simple presentation graphics tools, that map a data set (e.g., warehouse locations) to some geographical layer such as a map of U.S. states, census regions, or land parcel tracts. Indeed, if one counts the total number of office desktops as the potential for the desktop mapping or presentation graphics tools, there are approximately 68 million office desktops in the United States.

Coming Together of Industry Forces

The 1988 unit volume growth in mapping system sales principally arose from three complementary forces:

- Availability of good graphic performance and sufficient main memory on PCs to support the requirements of the classical and GIS mapping software products
- Availability of off-the-shelf map data bases that provide high-resolution, electronic road maps of the major metropolitan areas, from vendors like ETAK and Geographic Data Technology
- Growth of PC local area networks that enable PCs to connect to not only mainframe-based mapping software but also corporate data bases

Barriers that still confront industry growth include the following:

- Considerable time and expense is required to digitize customer data as well as interface to a mapping data base. (This barrier is the very opportunity for the highly active mapping service industry.)
- Facile, real-time data base manipulations for strategic decisions using map data bases require more memory than PCs currently support.
- Connectivity is still a problem because most PCs are not networked to mainframe data bases. Dataquest estimates that Apple is positioned well here because, whereas only 10 percent of IBM PCs have been shipped with a LAN, 38 percent of Apple Macs are connected.

1988 Key Mapping Events

The 1988 mapping market was highlighted by the following key events:

- Prime Computer Inc. and Wild Leitz Group's System 9 signed an intent to form a joint venture. This strong GIS partnership is expected to complement Prime's CADD 4X AM/FM product line.
- IBM reorganized its GFIS marketing efforts, increasing support to its third-party software partners. IBM's upgrade of the RT workstation will benefit Canada's ACDS, a company that has also strengthened its position through a recent U.S. distribution agreement with Integrated Information Systems (IIS).

- Digital Equipment, Synercom, and the U.K.'s Laser-Scan won the $60 million contract bid offered by British Gas. The British Gas Digital Records System will, over the next five years, create digital map data bases of the gas distribution networks throughout the United Kingdom.

- ESRI, which continues to be the premier GIS vendor, expanded its platform range on several fronts. It gathered in IBM to market and sell PC-based ARC/INFO on its PS/2 line and provided its larger-scale ARC/INFO product on Sun Microsystem's Sun 386i workstation.

- ETAK, with its management restructuring and product redirection, is headed for good fortune as a major high-resolution map data base supplier. Dataquest believes that the availability of map data bases is the key to the mapping industry growth.

What to Watch for in 1989

- The much-awaited emergence of Intergraph's TIGRIS product, a full-scale, object-oriented GIS

- Fleet management products like ETAK's Navigator that slowly begin to attract the attention of commercial distributors and the transportation industry

- Further strategic alliances between GIS vendors and relational data base companies—Industry leader Oracle stands to extend its product life through the graphic facilities of GIS vendors.

- Apple Computer's creation of a new low-tier market segment that is closely associated with presentation graphics—Apple, which coined the term "desktop" mapping, has, in fact, placed its mapping organization within its Desktop Publishing group. In addition, Apple's agreement with Digital puts the Macintosh in a strong position to leverage the many mapping applications on Digital platforms as well as the VAX-based commercial data base world.

- The impact of U.S. government GIS purchases to support the 1990 census

FACILITIES AND ARCHITECTURAL DESIGN

Building Momentum

From 1987's $1.19 billion facilities design (FD) market, sales of CAD systems for designing and managing plants, buildings, and infrastructure grew 17 percent in 1988. FD system sales continue to be dominated by PCs: 89 percent of all platforms shipped in 1988 were personal computers. There is little surprise in this trend, however. According to the American Institute of Architects, more than 80 percent of architectural design firms are 1- to 10-man operations.

1988 Key Events

The key 1988 events in facilities and architecture design included the following items:

- Autocad running on the Apple Macintosh
- Intergraph's novel "CAD–in–a–Van" sales program, targeted at small AEC firms
- Alliances among key suppliers for new product development
  - The IBM Architecture & Engineering Series, from IBM and Skidmore, Owings & Merrill
  - A future product expected from Autodesk alliance with the Computer–Aided Design Group

What to Watch for in 1989

Dataquest expects that in 1989, growth in the facilities design arena will advance over 1988, fueled by the following two principal sources:

- Accelerating penetration of low–cost PC AEC systems
- Synergy with the rapidly expanding GIS segment of the mapping market, particularly for AEC software associated with public works projects and the maintenance of municipal infrastructures

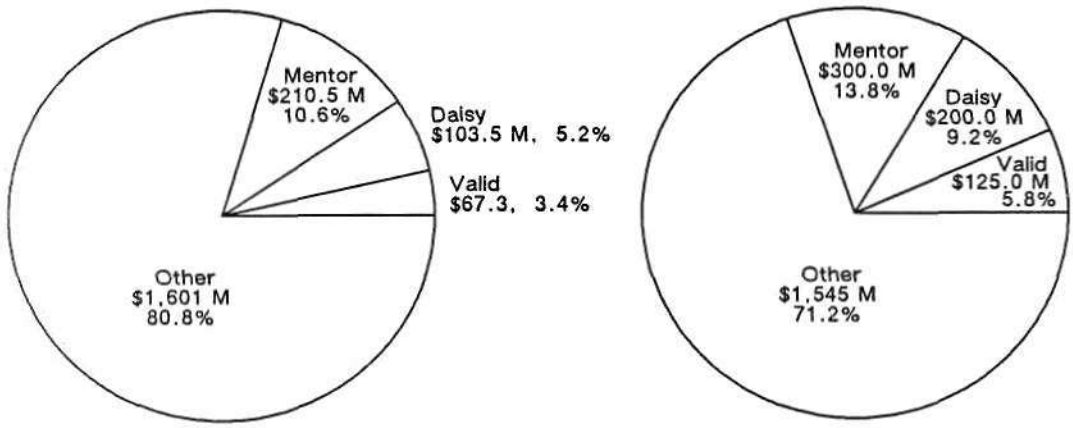
Lisa G. Thorell

1988: MERGERMANIA CONTINUES UNABATED

Depending on your point of view, merger and acquisition activity in the electronic design automation (EDA) market reached either epic or epidemic heights in 1988. By Dataquest's count, 35 EDA companies have been involved in merger and acquisition deals since the market's 1986 downturn. Who's winning? Apparently, the EDA "big three," Daisy, Mentor, and Valid are out in front. These companies (also known as the DMV) gained a collective 10 market share points and 64 percent revenue increase in 1988—a year in which we estimate the overall market only grew 10 percent (see Figure 1). As the gap between full-line and niche suppliers widens, these three players appear determined to dominate the chip-to-board design market, as well as control the engineer's desktop.

Figure 1

EDA Turnkey Market Leaders
(Percent of Revenue)



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Source: Dataquest
January 1989

Daisy Buys PCB Market Leadership

The EDA merger and acquisition phenomenon culminated in the near-operatic and loudly resisted pursuit of Cadnetix by Daisy in unquestionably the year's largest (approximately $100 million) and most significant acquisition. Although the products of both companies are now Sun-based, the initial prognosis for the success of a hostile takeover in such an R&D-intensive market was low. Daisy has taken a number of steps to turn a hostile takeover into a friendly and successful merger, like that achieved in Cadence, a merger of ECAD and SDA. Learning the secrets of successful PCB marketing and customer support from PCB leader Cadnetix may drive Daisy ahead of the competition.

As for the competition and their position in the PCB market, Valid opted for a similar merger with PCB design supplier Telesis in 1986, and Mentor is aggressively marketing a re-invigorated Board Station product that the company claims outsold the then U.S. PCB market leader, Cadnetix. All three ECAE vendors are now positioned to extend their ECAE market leadership into the PCB arena as well.

Mergers in IC CAD, Too

In IC design and verification, many companies are expanding their product offerings—from full-custom, polygon editors through silicon compilers. And, they seem to be using the acquisition method instead of R&D. Valid snapped up IC market leader Calma's IC division, Intergrated Measurement Systems (IMS), and Analog Design Tools. Mentor acquired Tektronix's CAE division and analog library supplier, Contour, thereby increasing its IC offerings as well as entering the CASE market. As mentioned earlier in this discussion, successful IC niche participants ECAD and SDA combined into Cadence, which in turn acquired Tangent and an OEM agreement from Intergraph. Silicon Compiler Systems, itself the product of an acquisition, acquired Calma look-alike Caeco. Daisy, which offers both ASIC and analog design products, did not make significant moves in the IC CAD market this past year.

The Year of the Sun

Both Daisy and Valid benefited significantly from porting their applications to the Sun family of technical workstations in 1988. Because Cadnetix was on the Sun it was particularly attractive to Daisy. While Mentor seems UNIX-resistant and committed to its partner, Apollo, Dataquest believes that were the EDA market leader to port to the Sun, the company would become invincible. However, we also believe that such a port, while in Mentor's own best interests, runs contrary to its corporate philosophy. Mentor prefers a unique relationship with a hardware vendor and does not seem to want to gamble on the results of point-for-point benchmarking on the same platform as its two main competitors.

The Lessons of Consolidation

Such large-scale consolidation implies the following for both niche and full-line end users alike:

- Today's end users are seeking an integrated design process and thus may be forced into a compromise. This may mean accepting less-than-state-of-the-art solutions that are integrated from a single, full-line vendor, rather than integrating niche supplier products into their own design environment or waiting for a CAD framework initiative to become a standard.

- Instead of allying with the multiplicity of niche participants this highly technology-driven market spawns, full-line suppliers will be forced to compete not only with each other, but with every market niche participant and start-up EDA company.

- Supplying competitive, full-design systems that span design specification, entry, and simulation through layout, verification, and test, represents an immense challenge. This, coupled with the critical mass required to compete in this market, argues against there being any new full-line suppliers entering the market for some time.

WHAT TO WATCH FOR IN 1989

- Full-line EDA suppliers like Daisy, Mentor, and Valid being challenged by more broad-based suppliers, such as Hewlett-Packard and Intergraph—These companies' products include workstations and test instrumentation, as well as other CAD/CAM applications besides EDA, such as mechanical CAD/CAM. Due to their hardware revenue bases, these suppliers are more able to leverage relationships with niche market participants, freeing themselves to concentrate on the broader issue of integrating the entire design process.

- Design "framework" integration support and some new products from both hardware and software suppliers—End users with extensive proprietary tools remain the primary market for the design framework products from companies like EDA Systems and TeamOne. However, it is highly likely in 1989 that full-line suppliers, and perhaps even a few workstation manufacturers, will move to introduce their own design management tools like the one from Cadence.

- Logic design automation taking off—This automated methodology, from vendors such as Silc, Synopsys, and Trimeter, directly challenges traditional ECAE suppliers Daisy, Mentor, and Valid, and offers the promise of linking logic design automatically to simulation. It is likely that in 1989, the "DMV" will move to check this challenge by developing or acquiring these products.

- Rapid and widespread adoption of I.E.E.E.'s 1076 standard VHDL, and design entry and simulation products designed to attract and capture the DOD market—This will also serve the "DMV" by strategically checking the momentum of companies like Synopsys and simulation-supplier Gateway Design Automation that support an HDL transition interim and represent a potent challenge to older-generation ECAE and simulation offerings.

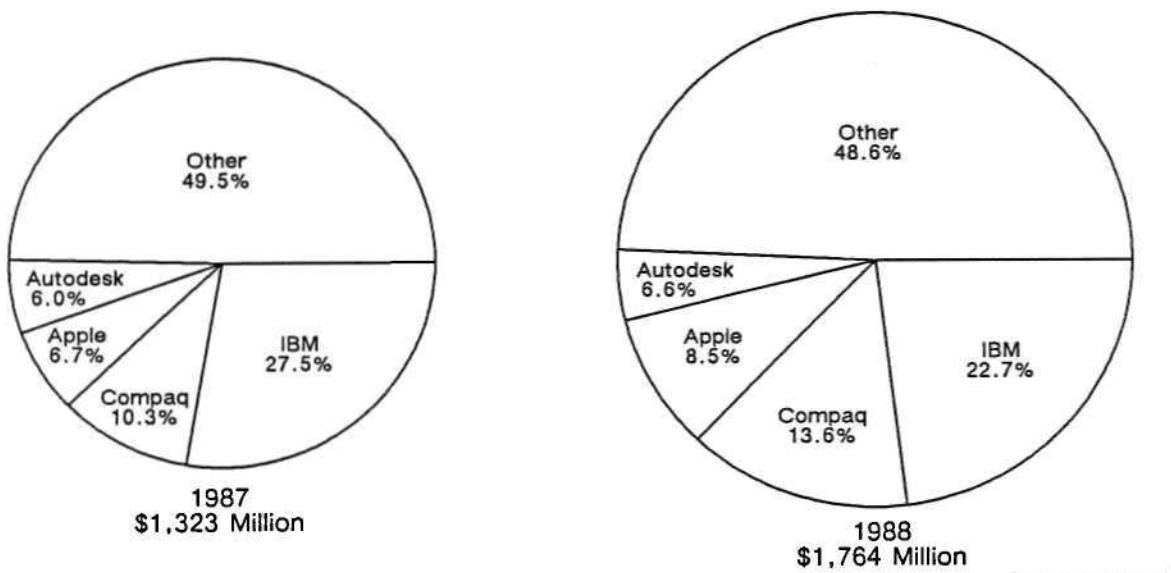
Tony Spadarella

1988: A YEAR OF UPWARD EXPANSION

For PC CAD, 1988 was a vintage year that exceeded our forecast of 26 percent growth. We estimate that this market grew 33 percent overall, to $1,764 million, as shown in Figure 1. The extra growth had a primary cause: average selling prices (ASPs) did not drop in PC CAD. PC and technical workstation vendors met head on, with PC hardware vendors relentlessly driving up performance and options while technical workstation vendors pushed their products toward the commodity arena.

Figure 1

PC CAD Market Share
(Percent of Revenue)



0002226-4

Source: Dataquest
January 1989

PC CAD all-stars in 1988 were familiar names: Compaq, Apple, and Autodesk, earning total 1988 PC CAD market shares of 13.6 percent, 8.5 percent, and 6.6 percent, respectively. Collectively, these three grew at a breathtaking 64 percent rate. IBM, operating at a substantial lead, easily maintained its top market position with a 22.7 percent market share. For CAD application requirements, IBM's PS/2 products were not developed enough at the high end (where the revenue growth was), so the company in fact lost market share.

Other market happenings in 1988 included the following:

- Tolerant market conditions supported a sea of smaller PC CAD software vendors quite comfortably. Many grew briskly, and some just held revenue steady, but very few lost revenue, left the market, or were acquired.

- In software, CAD application issues took a backseat to the furor over operating systems. Smaller vendors were forced to choose their investment(s): Mac OS, vanilla DOS, "doctored" DOS, OS/2, or UNIX.

- The only evidence of distress in this market was the fact that dealers and distributors entered an era of consolidation.

Hardware: PCs and Technical Workstations Collide

For several years, Dataquest has been predicting convergence of the PC and low-end technical workstation CAD markets, and 1988 was the year it became measurable. PC hardware manufacturers focused on CAD as a key driver of their high-end products, and worked steadily to drive up product performance. Technical workstation vendors began to push product lines down into PC CAD's established turf. Today, all players stand eye-to-eye on a fertile, unexplored playing field known as The Most Promising Market. The initial response has been to camouflage their products, so users cannot tell one from the other.

Spurred in part by independent software vendors' concerns about supporting multiple operating systems and platforms, technical workstation vendors like Sun and Silicon Graphics now claim to have "shrink-wrapped" UNIX for the masses, while offering built-in DOS for mass applications. Compaq, on the other hand, successfully drove its product line upward with its leading-edge 80386 systems. The company demonstrated outstanding performance on CAD applications and displayed leadership by supporting the EISA alternative computer bus and encouraging a variety of operating systems and windowing schemes.

In 1988, Apple shipped record numbers of Macintoshes into technical and engineering environments (19 percent of Mac IIs, at last count), and established a clear market awareness of Apple's potential as a serious CAD platform. However, few CAD software vendors actually shipped products for the Mac in 1988, with the result that we place much of Apple's revenue in the general-purpose technical application category, rather than in CAD.

Software: Moving Applications to the Proper Environment

Software vendors focused on riding into the converging PC/workstation market on the "right" platforms and operating systems. As the Macintosh emerged as the last virgin host in PC CAD hardware, the rush to port to the Mac was nearly audible. Versacad arrived first, and drew some early revenue. Schlumberger/Applicon arrived late in the year, and so, like Autodesk, is looking for 1989 revenue from the Mac.

A necessarily quieter port was to extended versions of DOS, primarily to products from Phar Lap Software of Cambridge, Massachusetts. Since the incorporation of these DOS extension products into PC CAD offerings is designed to be invisible, it has generally escaped user attention. Today, vendors such as Futurenet, Hewlett-Packard, MCS, and Viewlogic depend on these products to support high-end PC applications. Many more software suppliers are believed to be close to offering this enhanced performance, which is essentially a 32-bit virtual operating system that looks and feels to users like familiar old DOS.

Distribution: PC CAD's Battle Zone

The entire PC dealer/distributor industry appears to be rapidly entering a period of consolidation, and CAD applications will be taken along for the ride. Recent acquisitions include the tentative merger of Micro D with Ingram Industries and the tentative purchase of Entre Computers, a $560 million (including revenue from franchises) chain of VARs that often sport a CAD emphasis by Intelligent Electronics, the parent of TCBC, a retail-oriented chain. Mergers of smaller participants include the creation of Access Graphics Technology through the three-way combination of CAD Distributors, CADSources, and Advanced Product Group. We believe that intense profit margin pressures continue to plague the vast majority of independent PC CAD resellers.

Recognizing the limited supply of skilled technical application dealers, suppliers turned to winning the hearts and minds of these stressed resellers. Hardware suppliers lead in creative new reseller support concessions. Popular programs include Apple's offering credits for value-added behavior, in order to counter the higher prices paid by the low-volume, value-added resellers. Despite these efforts, we believe that reseller consolidations and mergers are the stronger trend because of the revenue and profit gained from volume buying and a national presence.

WHAT TO WATCH FOR IN 1989

- Emerging standard features—Now that PCs and technical workstations have begun converging into one market, they will start to offer more and more of each other's features, much like diners at a pot luck sampling each other's entrees.

- Continued high or higher, platform prices—The drive to maintain or grow ASPs at the PC end of CAD will continue. PC CAD vendors generally recognize that one of the easiest paths to higher revenue is to aim for a market that will support a slightly higher ASP.

- Increased market presence for Apple—A sizable collection of CAD products will be actually available to ship on the Macintosh, providing an opportunity for relatively higher growth for Apple in CAD. Mac-based CAD software announcements will continue.

- Maturing distribution strategies—For CAD software suppliers, developing effective distribution strategies in a consolidating dealer channel will be as important as the product itself.

- Challenges to resellers—Technical workstations will start to actually ship through dealers and VARs, and may sorely test reseller abilities to grow to meet new and more-sophisticated support requirements.

- Continued consolidation—Consolidation in the distribution channel will force a concrete definition of the term "value-added," a concept that today has more religious than market value.

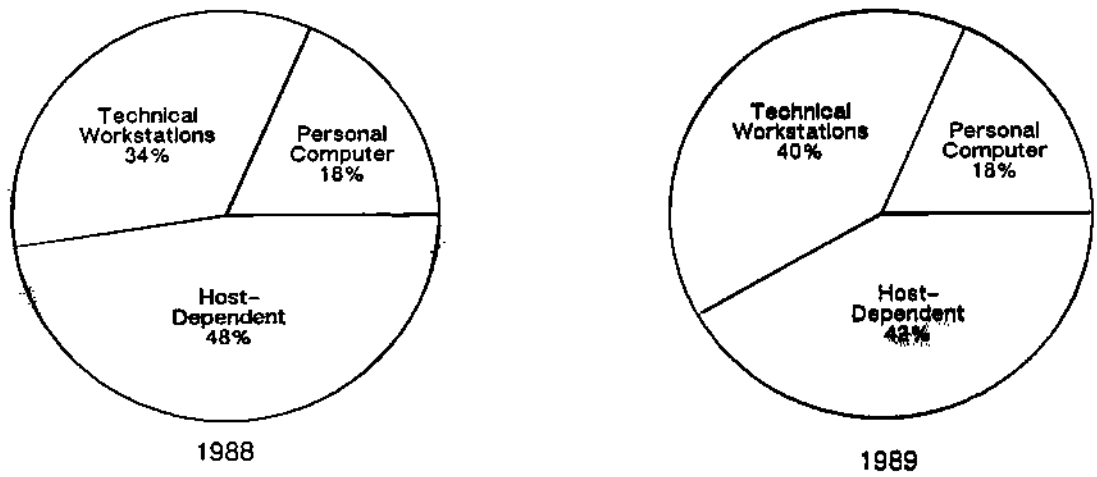
Kathryn Hale

1988: JAPAN BRACES FOR TECHNICAL WORKSTATION INVASION

As Figure 1 indicates, the major CAD/CAM companies in Japan are spearheading the shift from host-dependent platforms to technical workstations. Although the top 10 vendors' 1988 CAD/CAM revenue is still derived mainly from host-based sales, the presence of the technical workstations is clearly expanding. Fujitsu, Japan's number three market share leader, is intensifying its sales efforts into marketing its own G-250 workstation-based systems, as well as selling OEM Sun-based systems. Hitachi, number four in the market, is aggressively marketing its own 2050-G workstation. Fifth-ranked NEC has ported its CAD/CAM software packages onto its own EWS 4900 workstation. NEC is also hard at work porting third-party software packages onto EWS 4800 and so far has ported Autodesk, Racal-Redac, and Zuken's packages, among others. Most other major vendors have also correctly understood that support for technical workstation platforms is the right direction.

Figure 1

Estimated Asian CAD/CAM Market by Platform
(Percent of Revenue)



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Source: Dataquest January 1989

SUN'S STRATEGIC ALLIANCES

Sun seems to believe that strategic alliances are necessary to increase its revenue and shipments rapidly in Japan. In 1988, Sun concluded agreements with Fujitsu, Matsushita/Solborne, and Seiko. It is difficult to hire many capable staff members in Japan for sales, marketing, and engineering, proportionate to the revenue growth of the company. Strategic alliances are a good way to circumvent this problem. At the same time, it is important to balance how many and with whom the company should strategically combine.

OSF versus Unix International

During 1988, the fears of many Japanese computer firms about divergent or multiple operating system standards were eased by their belief that OSF and Unix International would be merged soon due to the progress made during talks held between the two groups. Their wishful thinking, however, may not be justified because OSF has announced that its next-generation OS/1 will be based on IBM's AIX Version 3. Because of the OSF's strong bias toward IBM, it appears that negotiations between the two groups will likely end. The Japanese firms that have already made their standard operating system positions clear are as follows:

- OSF—Hitachi
- Unix International—Fujitsu, NEC, Toshiba, Oki Electric

The major firms that have not committed to one system or another include Matsushita, Mitsubishi, and Sony.

The Aftermath of U.S–based Mergers and Acquisitions in Japan

In 1988, there were many mergers and acquisitions related to the CAD/CAM industry in the United States. Unfortunately, this created much confusion in the Japanese market with respect to sorting out distribution responsibilities. For example, Prime's acquisition of Computervision and Calma has created a bewildering array of support and distribution situations in Japan because individually, these companies already had a complex infrastructure in place, as shown in Table 1.

Table 1

Prime, Computervision, and Calma Japanese Distribution

Company	Japanese Distributor(s)
Prime	Prime Japan
Computervision	Computervision Japan Toshiba
Calma	C. Itoh Techno-Science

Source: Dataquest
January 1989

In addition to sorting out overlapping distribution responsibilities, the U.S. CAD/CAM mergers have led to other problems, including:

- Created a new level of uncertainty in the minds of Japanese buyers who are contemplating system purchases from U.S–based CAD/CAM companies
- Caused increasing difficulty in attracting capable sales, marketing, and engineering people who are wary of working for a U.S–based CAD/CAM vendor that might be merged or acquired
- Created a higher level of uncertainty for those U.S.–based firms operating in Japan that have not yet been merged or acquired

1989 KEY TRENDS AND ISSUES

- Further appreciation of the yen—Although the dollar is currently hovering at around ¥120 to ¥125, many financial analysts believe that the value of the dollar will continue to fall against the Japanese yen during 1989. Because of Japan's heavy reliance on exports, the Japanese economy could be adversely affected if the dollar falls to ¥100, as many are forecasting. Dataquest believes that a ¥100 dollar would very negatively affect the sale of CAD/CAM systems in Japan during 1989.
  - Japanese products would be more expensive than imported ones and not price–competitive with U.S. products.
- Continued strategic alliances: technical workstations—We expect to see a continuation of strategic alliance activity as the Japanese computer companies struggle to keep pace in the fast–growing technical workstation market. Look for new alliances from Hitachi, Mitsubishi, NEC, and Sony on the Japanese vendor side, and from Apollo, Silicon Graphics, and Stellar on the U.S. vendor front.

- Semiconductor slowdown could stall ECAD shipments--The book-to-bill ratio has been less than 1.0 since last August and the growth of the semiconductor market is expected to slow down in 1989. If the sluggishness is moderate, CAD/CAM investment will suffer little if any negative impact. If the downturn is serious, however, the investment climate could become critical, because 40 percent of CAD/CAM end users in Japan are electrical/electronic/semiconductor-related companies.

Yu Uemura

EUROPEAN CAD

1988: GOOD BUSINESS, GOVERNMENT GUARANTEED

The European CAD/CAM market had a good year in 1988, particularly when compared with its outstanding performance in 1987. During 1988, the major regions of mainland Europe began to realize the benefits of government incentives that stimulate the growth of CAD/CAM and manufacturing automation in industry.

In the early 1960s and 1980s, the United Kingdom initiated government support schemes that have resulted in current CAD penetration in the United Kingdom on the order of 7.5 percent, compared with 4.5 percent in France and 4 percent in West Germany.

Penetration in Germany is low, despite $228 million in government-sponsored incentive grants in 1985 and 1986. Only major German corporations have embraced CAD/CAM fully. Many of the midsized companies (100 to 1,000 employees) have no computer-based design aids. Consequently, a new scheme was introduced in 1987 and 1988 that is worth $280 million over five years and is aimed at these companies to help them integrate design and production.

France has a similar grant plan running as a pilot this year. Although it is more modest ($9 million), it is also aimed at small companies, with the object of helping them catch up with the United Kingdom, Germany, and Italy in industrial production. The Swiss, too, are introducing a crash program in 1989 whereby $113 million will be made available over six years to assist investment; half will be provided by central government and the other half by industrial organizations.

Impact of Consolidation in Europe

The intensive merger and acquisition activity that took place across the whole industry in 1988 had some specific effects in Europe. Although Digital's plan to offer turnkey CAD systems through its Cooperative Marketing Partners—the Digital Direct Sales (CMP-DDS) program—is worldwide, it is significant that the first announcement involved a European vendor, Matra Datavision. Many observers think that Digital may have "shot themselves in the foot." Digital, in turn, has gone to great pains to point out that almost all of its CMPs are happy. However, the announcement was delayed by three months because of negotiations with many of the old cooperative marketing partners. In theory, the DDS strategy appears sound and logical: combat large integrated system vendors such as IBM and Hewlett-Packard on their own terms. This is an area that Dataquest will be tracking closely in 1989.

One of the most logical takeovers so far, from a product standpoint, involves Daisy, Cadnetix, and HHB. It was expected that Racal-Redac would be fairly unhappy about this deal, as it strengthens the competition significantly and transfers Racal's OEM revenue for HHB products to the competition. However, Racal seems to have benefited in PCB sales. The confusion caused by the hostile takeover, the lawsuits and countersuits, and the eleventh-hour U-turns surrounding the deal all created a sales windfall to Racal's benefit. Racal has a new managing director, and we expect the company to form new alliances to counterbalance the Daisy-Cadnetix-HHB merger over time.

A similar situation exists with Digital, which was once very interested in Computervision. Since the announcement of the Prime/Calma acquisition, Digital now "gets its own back," as Prime will be paying Digital OEM revenue on all future VAX-based Calma sales.

THE CHANGING FACE OF CAMBRIDGE (UNITED KINGDOM)

Shape Data has fallen to McDonnell Douglas, giving the victor the opportunity to take a quantum leap in solids modeling technology with the new version of Romulus.

Cambridge Interactive Systems (CIS) has virtually disbanded. The future development and rationalization of CIS and Prime Medusa will largely be done in the United States. In its stead, European companies are moving to Cambridge to house their development teams, probably planning to take advantage of the indigenous expertise from the university and the availability of development staff at the dozen well-known CAD R&D operations.

1988 Sales

Prime/Computervision experienced a record third quarter for Medusa sales in Europe in what is normally a slack sales period. This was largely due to delayed purchases in the second quarter, a result of confusion about the merger that was announced in April. Other companies reported unusually strong activity, with 100 percent of quota being reached in the vacation month of August in some regions. Many companies exceeded their annual expectations by December. This is partly attributable to confidence in worldwide economies, and European perception that the Reagan-Thatcher friendship and economic boom will continue under the new U.S. administration. Second-half 1988 buying may also have been spurred by a "last chance" buying mentality before the predicted 1989 recession.

Opportunities for Europe

Of all the market segments, MCAE and GIS exhibit the strongest growth potential in Europe.

MCAE has been bolstered recently by the inclusion of computer-aided styling and software for conceptual MCAE. Products like Alias and Aries, software written to optimize the performance of the new workstations, are finding new markets. Until recently, the industrial design communities have had little choice of computer automation tools. This market is now ripe for development. The recent explosion in workstation shipments has fueled the success of this segment.

GIS and digital mapping are also poised for significant growth in Europe. The traditional vendors like IBM, Digital, and Prime, as well as the second-tier vendors like Honeywell Bull, Unisys, and Data General, are forming strategic alliances and implementing European strategies to exploit this market. New companies in Europe like ESRI and new previously nontechnical entrants like Wang will ensure development of this sector.

In terms of market share, there are no surprises at the top, with Intergraph, Digital, and IBM taking the lion's share. The excitement is at the low end with ESRI, Alber, Wild, and Laser-Scan reporting significant revenue. Interest here is also being sparked by Prime's General Markets Division, which recently purchased an 80 percent stake in the Swiss GIS vendor, Wild.

AM/FM on a Roll

Early in 1987, the council of Automated Mapping/Facilities Management (AM/FM) Europe decided to follow its U.S. parent and establish regional conferences. The objective of this was to widen the exposure of AM/FM by overcoming the difficulties of many users in traveling outside national boundaries to such events. The three countries chosen for the experiment were the United Kingdom, West Germany, and Spain.

The upsurge of U.K. interest in GIS has been fueled by the publication of a report by the Committee of Inquiry into Handling Geographic Information. This report focused on the problems of implementing the technology. It highlighted the measures required to ensure that data from government bodies, such as the Ordinance Survey and H.M. Land Registry, were made available to a wide audience in a timely fashion. Another impetus was the signing of the first-phase contract by British Telecom with Intergraph for the first major national system. Momentum has been established quickly and seems to be destroying filibustering efforts by the base data providers.

Thus, the mood going into the U.K. AM/FM conference in April 1988 was bullish. The West German conference followed suit later in the year, and the Spanish AM/FM conference is scheduled early in 1989.

Companies such as Data General, Honeywell Bull, and Unisys (which is based on Oracle's data base technology), have announced European strategies to exploit these markets.

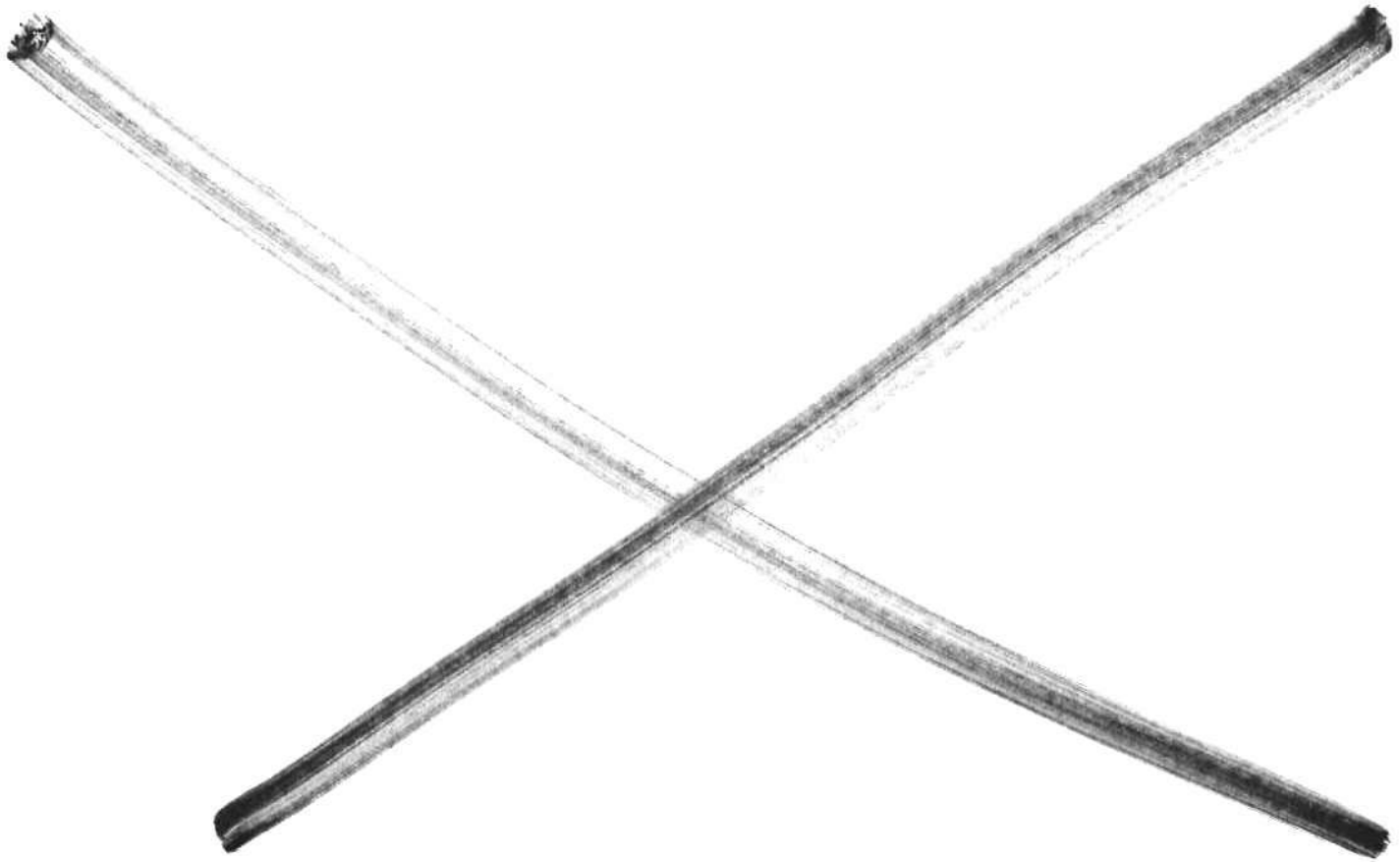
Living up to its new-found name, a company called Small World Systems Ltd. opened for business in Cambridge in late 1988. The prime movers in this organization include two of the founders of CIS, which was the original developer of Medusa. This company specializes in developing GIS software and providing consultancy services for information systems. Small World also will be concentrating on data base systems to allow GIS to move away from shared logic machines.

There is such a rush to achieve digital mapping that companies are spending two to three times the resources on data collection as on capital purchases. This has given rise to cooperative schemes between utility companies and government agencies and has established many bureau organizations to serve this market.

In the United Kingdom, the Ordinance Survey sponsored by the Government Survey Agency estimated that it would take until 2015 to digitize the entire United Kingdom. Now, because of cooperation and cost sharing between British Telecom and British Cog, this estimate has been cut to 1995.

Utility companies across Europe, particularly in the United Kingdom, Germany, and Spain, are positioning themselves to make significant investments in GIS and digital mapping. The relatively centralized structure of many European countries makes these governments good prospects. Thus, 1989 promises to be an important year for GIS in Europe.

Charles Clarke



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Industry *Events*

CCIS Code: Industry Events
1989-2

CAD/CAM INDUSTRY EVENTS

INTRODUCTION

The CAD/CAM Industry Events Newsletter is a collection of industry events that have taken place during February 1989. It is designed to inform the reader of key happenings in the marketplace by providing informative abstracts of less than seven lines for quick, easy scanning. The CAD/CAM Industry Events Newsletter covers acquisitions, product announcements, pricing, quarterly earnings, organizational changes, sales activities, and OEM agreements. Abstracts are organized by segments and listed alphabetically be company name in chronological order.

Clients who require additional information may take advantage of their inquiry privileges by calling Shaheen Nahouraii of the Client Inquiry Center, at (408) 437-8671.

Segments that may be listed in the newsletter include the following:

Computer Companies
Electronic Design Automation
Facilities Design Applications
General CAD/CAM
Graphics Companies
Input/Output Companies
Mapping Applications
Mechanical CAD/CAM Applications
Other
Personal Computer CAD/CAM
Technical Publications

COMPUTER COMPANIES

APOLLO COMPUTER

Apollo Computer introduced the Series 10000 Visualization System with RISC graphics. The Series 10000VS family of personal graphics supercomputers is based on Apollo's RISC-based, multiprocessing PRISM architecture and a new, 3D RISC graphics engine. Pricing for the Series 10000 begin at $94,900.
(Press Release, 02/01/89, 890310122854)

APOLLO COMPUTER

Apollo Computer and Siemens AG, Berlin and Munich, announced an agreement to co-develop a new customer service tool based on an expert, knowledge-based software program.
(Press Release, 02/13/89, 890310125021)

APOLLO COMPUTER

Apollo Computer announced that it has been awarded a sole source development contract by the United States government to deliver an implementation of the new American National Standards Institute (ANSI) standard Fiber Distributed Data Interface (FDDI). FDDI is a data network, based on dual counter-rotating fiber optic ring topology.
(Press Release, 02/14/89, 890310125236)

APOLLO COMPUTER

Apollo Computer announced it is working with CADAM Incorporated to recruit VAR's to sell a new software solution PROFESSIONAL CADAM on Apollo's UNIX workstation platform.
(Press Release, 02/21/89, 890301140457)

APOLLO COMPUTER

Apollo Computer announced that Robert L. Gable former president and chief executive officer of Computervision Corporation, and Raymond F. Pettit, senior vice president and chief financial officer of Rockefeller Group Incorporated have been elected to the board of directors of Apollo Computer.
(Press Release, 02/22/89, 890301085359)

APOLLO COMPUTER

Apollo Computer and Applix announced a joint marketing agreement, through which the latest version of Alis system will be sold on Apollo workstations by both companies.
(Press Release, 02/28/89, 890310123911)

APOLLO COMPUTER

Apollo Computer and Yourdon, a Kodak Company, announced a new CASE application package now available on Apollo workstations. Yourdon's CRADLE is a set of tools for software and systems engineers to handle complex development projects.
(Press Release, 02/28/89, 890310124126)

APOLLO COMPUTER

Apollo Computer and Applied Reasoning announced an agreement to jointly market Applied Reasoning's PC-coprocessor supporting DOS-based software for Apollo's UNIX-based workstations. PC-ELEVATOR 386 is now available from Applied Reasoning on Apollo's personal workstations.
(Press Release, 02/28/89, 890310123601)

HEWLETT-PACKARD

Hewlett-Packard Company announced a nine month lease for 216 HP 9000 graphics workstations totaling $1.85 million from the McDonnell Douglas Aircraft Company. The HP 9000 Model 360SRX graphics workstations will be used with the company's proprietary CAD software.
(Press Release, 02/21/89, 890306074652)

MIPS COMPUTER SYSTEMS

MIPS Computer Systems announced a new 12 mips entry-level server and a new line of graphics RISCstations. The new RISCstation Line provides graphics front ends that complement MIPS distributed solutions. The RISCstation Line includes a high resolution display station that sell for approximately $3,000 and a 12 mips desktop workstation. Both RISCstations run RISCwindows and MIPS user environment based on X Windows.
(Press Release, 02/21/89, 890306075010)

PRIME COMPUTER

Prime Computer announced that it has formed a strategic alliance with Novell Incorporated. developer of LAN software. The two companies plan to jointly develop LAN solutions that incorporate the PRIME EXL and Novell's NetWare software. Initially, the companies will produce a native, high-performance NetWare server and a non-dedicated UNIX NetWare server based on the Intel 80386 and Multibus II architecture.
(Press Release, 02/13/89, 890306125849)

PRIME COMPUTER

Prime Computer announced it is conducting shared research with Intel Corporation and others into a multiprocessing implementation of the UNIX operating system.
(Business Wire, 02/28/89, 890301155201)

SILICON GRAPHICS

Silicon Graphics and Kuck Associates Incorporated announced the availability of the POWER FORTRAN accelerator for the Silicon Graphics IRIS POWER Series of multiprocessors. The POWER FORTRAN Accelerator is priced at $5000.
(Press Release, 02/24/89, 890301133752)

SUN MICROSYSTEMS

Sun Microsystems and Fuji Xerox Company Ltd., have founded a joint venture named UNISOL Corporation. Sun and Fuji Xerox have contributed $4 million to establish UNISOL, which will develop and sell UNIX and OPEN LOOK-based productivity software for Japan's workstation market.
(Business Wire, 02/13/89, 890308124033)

SUN MICROSYSTEMS

Sun Microsystems announced that Intel Corporation has signed a multi-million dollar agreement to purchase its Sun386i workstations for use in the microcomputer component manufacturer's circuit design department. The agreement covers the purchase of several hundred workstations during the next two years.
(Press Release, 02/21/89, 890306072620)

SUN MICROSYSTEMS

Sun Microsystems announced that PROFESSIONAL CADAM is now available for the Sun-4 workstation family. Pricing for PROFESSIONAL CADAM on the Sun-4 family was not disclosed.
(Press Release, 02/21/89, 890306074416)

SUN MICROSYSTEMS

Sun Microsystems announced its intention to issue 3,211,573 shares of its common stock to AT&T. Sun's proceeds from the sale will be $79,110,000. Under terms of the agreement announced in January 1988, Sun can sell to AT&T, at Sun's option, newly issued shares in the amount equal to 15 percent of Sun's total outstanding common stock.
(Business Wire, 02/27/89, 890301082831)

SUN MICROSYSTEMS

Sun Microsystems introduced a migration path to the OPEN LOOK graphical user interface and X11 window standard. Sun's solution called OpenWindows, is an application environment that includes OPEN LOOK, X11/NeWS, and the new XView toolkit.
(Press Release, 02/28/89, 890310121523)

SUN MICROSYSTEMS

Sun Microsystems unveiled SunWrite, SunPaint, and SunDraw, based on the OPEN LOOK graphic user interface developed by Sun and AT&T. SunWrite is priced at $695, while SunPaint and SunDraw are each priced at $495. The three packages can be purchased together for $995.
(Press Release, 02/28/89, 890310120958)

ELECTRONIC DESIGN AUTOMATION

ASIX SYSTEMS

ASIX Systems announced the appointment of Brian E. Sear to the new position of executive vice president reporting to Wayne Pittenger, president.
(Press Release, 02/15/89, 890306104138)

ASIX SYSTEMS

ASIX Systems introduced ASIX-VIP (Verification/Integration Package) which integrates Daisy's CAE and CAD tools with the ASIX-1 development system. ASIX-VIP will be available mid-March and sells for $10,000.
(Press Release, 02/20/89, 890306104431)

CADNETIX

Cadnetix reported a loss of $19.98 million on revenues of $20.34 million for the quarter ending December 1988. In the same period for 1987, the company reported net income of $3.83 million on revenues of $21.07 million.
(Press Release, 02/14/89, 890306112420)

CADRE TECHNOLOGIES

Cadre Technologies' strategic partners endorsed the merger of Cadre and Oregon based MicroCASE Incorporated. Further details about the merger were not disclosed.
(Press Release, 02/01/89, 890309145827)

COMDISCO

Comdisco Systems has signed a joint development agreement with Plessey's Semiconductors Limited, Swindon, England, that will combine Comdisco Systems' Signal Processing Worksystem (SPW) with Plessey's design system for digital signal processing (DSP) ASICs.
(Press Release, 02/23/89, 890306100449)

DAISY SYSTEMS

Daisy Systems announced that it plans to expand Cadnetix Corporation's OEM relationship with Analogy Incorporated. Cadnetix has maintained a successful relationship with Analogy since January 1987, when the company became Analogy's first OEM. The current agreement between the two companies enables Cadnetix to sell Saber on the Sun-3 and Sun-4. Under the expanded agreement, Daisy will also offer Saber on the Sun-386i.
(Press Release, 02/07/89, 890306123946)

DAISY SYSTEMS

Daisy Systems reported a loss of $66.03 million on revenues of $32.00 million for the quarter ending December 1988. In the same period for 1987, the company reported net income of $1.01 million on revenues of $28.04 million.
(Press Release, 02/14/89, 890306124918)

DATA I/O

Data I/O reported net income of $1.67 million on revenues of $16.14 million for the quarter ending December 1988. In the same period for 1987, the company reported a loss of $5.63 million on revenues of $16.93 million.
(Business Wire, 02/21/89, 890308122759)

FUJITSU

Fujitsu's Integrated Circuits Division announced a business reorganization effective January 1989. Fujitsu has redefined its product areas and the division is now organized in two separate business units; Standard Products Operations and ASIC Operations.
(Business Wire, 02/13/89, 890308124354)

GATEWAY DESIGN AUTOMATION

Gateway Design Automation introduced Veritime timing analysis software for the verification of complex digital circuits, boards, and systems. Veritime is sold in conjunction with the Verilog-XL logic simulator. Workstation-based versions of Veritime start at $15,000 for existing Verilog-XL users. Veritime runs on Digital Equipment, Sun. and Apollo platforms.
(Press Release, 02/09/89, 890309155038)

GATEWAY DESIGN AUTOMATION

Gateway Design Automation and United Technologies Microelectronics Center (UTMC) announced an agreement under which UTMC will integrate Gateway's Verilog-XL and Verifault-XL in its HIGHLAND Design System. This agreement marks the third ASIC design house to standardize on Verilog-XL.
(Press Release, 02/14/89, 890306131119)

GATEWAY DESIGN AUTOMATION

Gateway Design Automation and Analogy announced a joint marketing agreement. Under terms of the agreement the two companies will design and market an interface between Gateway's Verilog-XL digital logic simulator and Analogy's Saber analog simulator. The interface will be a jointly developed and supported software product.
(Press Release, 02/27/89, 890306152352)

GENRAD

GenRad announced the availability of an EDIF option for its System HILO Logic Simulation Toolkit. The GenRad EDIF Interface is available on all computer systems supporting System HILO. Prices for single copies of the translator start from under $6,000.
(Press Release, 02/17/89, 890308120647)

INTEGRATED MEASUREMENT SYSTEMS

Cray Research has signed a contract with Integrated Measurement Systems (IMS) to purchase the company's Logic Master XL2 verification system in its Chippewa Falls, Wisconsin hardware development facility. The contract is valued at approximately $400,000.
(Press Release, 02/21/89, 890306103445)

INTEGRATED MEASUREMENT SYSTEMS

AOT Corporation has signed an OEM agreement with Integrated Measurement Systems (IMS) for the purchase of the company's digital test systems. The agreement, which totals $500,000, enables AOT to provide power mixed-signal test systems.
(Press Release, 02/21/89, 890306103827)

LOGIC MODELING SYSTEMS

Logic Modeling Systems announced an OEM relationship with Vantage Analysis Systems for sales and distribution of its simulator-independent hardware modeling system. The agreement establishes a comprehensive OEM relationship and integration of the Logic Modeling hardware modeler with the VantageSpreadsheet simulation environment.
(Press Release, 02/06/89, 890308151744)

MENTOR GRAPHICS

Mentor Graphics announced an order from Apple Computer. Apple plans to use Mentor Graphics' Apollo-based design workstations including the IDEA Series of Engineering Workstations, QuickFault, and Board Station for PCB layout. Mentor has agreed to provide design database transfer assistance, training programs, and on-site consultation.
(Business Wire, 02/01/89, 890310130335)

MENTOR GRAPHICS

Mentor Graphics introduced ProtoTherm, a PCB thermal analysis tool for electronic engineers evaluating the thermal performance of their designs early in the development process. ProtoTherm is priced at $19,500 and will be offered at a special introductory price of $15,000 until June 30, 1989, with the first shipment in March 1989.
(Press Release, 02/28/89, 890309143234)

PHASE THREE LOGIC

Phase Three Logic announced the development of an interface between CapFast Schematic Design packages and Silvar-Lisco's IC Routers. The Silvar-Lisco interface, developed under a contract with a United States government customer, converts CapFast to Silvar-Lisco's SDL format for gate array or standard cell physical layout.
(Press Release, 02/01/89, 890309150252)

SEATTLE SILICON

Seattle Silicon announced the shipment of seven ChipCrafter design automation systems to Oki Electric of Japan. The systems will be used for designing ASIC's by engineers in several Oki divisions. Shipments of these systems complete a $3 million initial phase of an ongoing research and development alliance between Oki and Seattle Silicon.
(Press Release, 02/28/89, 890301102627)

TERADYNE

Teradyne's Electronic Design Automation Group announced that Teradyne EDA products are now available on Sun Microsystems Sun-4 Series. This includes Teradyne's LASAR, AIDA, and VANGUARD product lines.
(Press Release, 02/24/89, 890302074846)

VALID LOGIC SYSTEMS

Valid Logic Systems reported net income of $2.43 million on revenues of $33.24 million for the quarter ending January 1989. In the same period for 1988, the company reported net income of $1.02 million on revenues of $21.06 million.
(Press Release, 02/09/89, 890308120132)

VALID LOGIC SYSTEMS

Valid Logic Systems introduced Transcribe, production documentation program that allows engineers to automatically generate flattened schematics from hi-level hierarchical or structured designs. Available now, Transcribe runs on Sun Microsystems' Sun 3 and 4 workstations and Digital Equipments VAXStation II GPX and 3000 Series workstations, and is priced at $19,900.
(Press Release, 02/14/89, 890310125710)

VALID LOGIC SYSTEMS

Valid Logic Systems announced the completion of the transactions to acquire Integrated Measurement Systems and Analog Design Tools.
(Press Release, 02/27/89, 890308120412)

VIEWLOGIC SYSTEMS

Viewlogic Systems and NEC Electronics announced that their ASIC product line will be supported by Viewlogic's CAE software. NEC's CMOS ASIC products will be supported under the agreement.
(Press Release, 02/21/89, 890301155742)

VLSI TECHNOLOGY

VLSI Technology and Valid Logic Systems announced that a Portable Library Design Kit is now available for designing VLSI's standard cell and gate array product families using Valid's EDA software. The Valid Portable Library is priced at $5,000 for the simulation models, design screener, and translation software. The library is currently being released for Sun-3 and Sun-4 platforms.
(Press Release, 02/15/89, 890308153136)

GENERAL CAD/CAM

HEWLETT-PACKARD

Hewlett-Packard and Cadre Technologies have reaffirmed their OEM relationships after the announcement of the Cadre Technologies and MicroCASE merger. The Hewlett-Packard/Cadre relationship has been centered around Cadre's Teamwork product for the past three and a half years. The HP Teamwork products run on the HP 9000 Series 300 workstations and are sold and supported by HP.
(Press Release, 02/01/89, 890309144702)

HEWLETT-PACKARD

Hewlett-Packard reported net income of $193 million on revenues of $2,083 million for the quarter ending January 1989. In the same period for 1988, the company reported net income of $179 million on revenues of $1,701 million.
(Press Release, 02/21/89, 890308121256)

HEWLETT-PACKARD

Hewlett-Packard announced a contract with Ford Aerospace Corporation for HP-UX workstations and peripherals valued at more than $42 million. Ford will use the equipment in the U.S. Army's Maneuver Control System and Non-Development Item programs for defense applications.
(Press Release, 02/28/89, 890310131945)

IBM

IBM introduced a new graphics processor in its 5080 graphics system family. The 5086 is used for interactive design and analysis. The $11,900 floor standing processor has increased memory (2MB expandable to 8MB) for the manipulation of larger and more complex models.
(Press Release, 02/07/89, 890310122101)

GRAPHICS COMPANIES

IBM

IBM introduced the 5086 Graphics Processor. Priced at $11,900 the 2MB base, expandable to 8MB will be available on February 24, 1989.
(Business Wire, 02/07/89, 890215071715)

MAPPING APPLICATIONS

GEOQUEST SYSTEMS

Geoquest Systems announced PetroView, an interactive applications module designed for petrophysicist and geologists.
(Press Release, 02/17/89, 890306084512)

PRIME COMPUTER

Prime Computer announced the acquisition of a majority interest in Wild Leitz Group's System 9 division. In addition, the two companies announced the formation of Prime Wild GIS Incorporated, a joint venture company in which Prime will be the principal shareholder. Prime Wild GIS Incorporated will market and develop System 9, a geographic information system.
(Press Release, 02/21/89, 890308124830)

SYNERCOM

Synercom reported net income of $.68 million on revenues of $4.24 million for the quarter ending January 1989. In the same period for 1988, the company reported net income of $.08 million on revenues of $4.12 million.
(Press Release, 02/21/89, 890302074447)

MECHANICAL CAD/CAM APPLICATIONS

CADAM

CADAM announced that customers who purchase CADAM Interactive Solids Design Software between January 1 and June 30, 1989, will receive free training as a bonus. The offer represents a discount of $3,990 from normal retail prices.
(Press Release, 02/06/89, 890309154634)

CADAM

CADAM announced that PROFESSIONAL CADAM software is now available on UNIX-based Apollo and Sun platforms.
(Business Wire, 02/21/89, 890308144523)

EVANS & SUTHERLAND

Evans & Sutherland reported net income of $2.21 million on revenues of $41.27 million for the quarter ending December 1988. In the same period for 1987, the company reported net income of $5.19 million on revenues of $43.01 million.
(Press Release, 02/21/89, 890310131007)

ICAD

Three firms recently awarded ICAD a total of $2 million in software and consulting contracts. The three firms are General Motors Corporation, Northrop Corporation, and the Southern Carlonia Research Authority.
(Press Release, 02/17/89, 890306103202)

MACNEAL-SCHWENDLER

MacNeal-Schwendler announced the MSC/XL, a new graphics-based pre- and post- processor for MSC/NASTRAN. Pricing for MSC/XL was not disclosed.
(Press Release, 02/10/89, 890310120535)

MANUFACTURING AND CONSULTING

Manufacturing and Consulting Services introduced an IGES Translator for its ANVIL-5000pc CAD/CAM software. The two-way translator provides a way for users to exchange data between the ANVIL-5000pc and any other CAD/CAM software that supports IGES. The IGES Translator is priced at $459. The ANVIL-5000pc is priced at $3,995.
(Press Release, 02/09/89, 890310115909)

MCDONNELL-DOUGLAS

McDonnell-Douglas and Sun Microsystems announced that its Unigraphics software will be available on Sun's engineering workstations. The two companies have also signed a letter of intent for a $25 million worldwide agreement allowing McDonnell Douglas to sell Sun engineering workstations for use with the Unigraphics software.
(Press Release, 02/27/89, 890310131411)

PRIME COMPUTER

Prime Computer announced that it has received orders from Carrier Corporation of Syracuse, New York, for more than $2.5 million in CAD/CAM systems. The Prime hardware and software will be used for product simulation and modeling, computer aided process planning, shop floor applications, tool inventory control, costing, and administration.
(Press Release, 02/16/89, 890306125545)

SDRC

SDRC and Nissan Motor Company Ltd. announced the formation of a joint venture company, ESTECH Corporation, to provide engineering and consulting services in the Far East. In addition, Nissan has selected SDRC as its preferred vendor for MCAE software on a worldwide basis.
(Press Release, 02/28/89, 890310124516)

VALISYS

Valisys announced that Coast Composites Incorporated, a subsidiary of Union Carbide Company, has signed a contract to purchase Valisys software combined with McDonnell Douglas' UNIGRAPHICS II CAD/CAM system and SNK machines with FANUC controls.
(Press Release, 02/06/89, 890309143924)

PERSONAL COMPUTER CAD/CAM

APPLE COMPUTER

Apple Computer announced that a lawsuit has been filed against the company for allegedly failing to disclose in a timely manner information related to the company's expected financial results for its second fiscal quarter.
(Business Wire, 02/02/89, 890308123616)

AUTODESK

Autodesk announced that it has obtained the non-exclusive rights to integrate Pixar's proprietary photorealistic imaging software into Autodesk's family of CAD/CAE products.
(Press Release, 02/20/89, 890310124804)

AUTODESK

Autodesk reported net income of $9.34 million on revenues of $34 million for the quarter ending January 1989. In the same period for 1988, the company reported net income of $6.40 million on revenues of $22.97 million.
(Business Wire, 02/21/89, 890308123222)

AUTODESK

Autodesk and Santa Cruz Operation announced that AutoCAD will be available for PC-based workstations running the SCO XENIX 386 Operating System. AutoCAD release 10 for SCO's XENIX Operating System is priced at $3,000.
(Business Wire, 02/22/89, 890228153259)

COMPAQ COMPUTER

Compaq Computer reported net income of $255 million on revenues of $2,100 million for the quarter ending December 1988. In the same period for 1987, the company reported net income of $136 million on revenues of $1,200 million.
(Business Wire, 02/01/89, 890308122426)

COMPAQ COMPUTER

Compaq Computer announced that is has reduced prices on the COMPAQ DESKPRO 386 product line by $200 per model.
(Business Wire, 02/06/89, 890310123412)

COMPAQ COMPUTER

Compaq Computer announced that it has notified Businessland Incorporated of its decision to terminate their relationship effective April 21, 1989.
(Business Wire, 02/21/89, 890308122220)

GENERIC SOFTWARE

Generic Software announced Generic CADD Level I for the Apple Macintosh. It will begin shipping the first week in March. Generic CADD Level I is priced at $149.95.
(Press Release, 02/21/89, 890308115528)

TECHNICAL PUBLICATIONS

INTERLEAF

Interleaf announced it has signed a volume purchase agreement with Sun Microsystems that enables Sun to install unlimited copies of Interleaf TPS Core software in its offices and subsidiaries worldwide.
(Press Release, 02/22/89, 890301160014)

Shaheen G. Nahouraii

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Industry *Events*

CCIS Code: Industry Events
1989-1

CAD/CAM Industry Events

This events newsletter lists worldwide, the major CAD/CAM conferences and tradeshows to be held during 1989. Tables 1, 2, and 3 list the major conferences and tradeshows held in the United States, Europe, and Japan respectively.

Clients of Dataquest's CAD/CAM Industry Service should note that this year's annual conference will be held September 11-13 at the Doubletree Hotel in Santa Clara, California. This conference will also include sessions sponsored by Dataquest's Graphics and Imaging, Manufacturing Automation, and Technical Computer Industry Services.

Shaheen G. Nahouraii

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TABLE 1

1989 MAJOR UNITED STATES CAD/CAM CONFERENCES AND TRADESHOWS

Name	Sponsor	Date	Location	Applications
AM/FM Conference 12	AM/FM International (303)779-8320	4/10-13	Marriott Hotel New Orleans, LA	Mapping, Facilities Management
NCGA Annual '89	NCGA 1-800-225-6242	4/16-20	Philadephia Civic Ctr Philadelphia, PA	Graphics, Workstations
National Design Engineering Spring '89	ASME (203)964-0000	4/24-27	McCormick Place Chicago, IL	MCAD
AEC Systems '89	AEC Systems, Inc. (203)666-6097	6/5-8	Anaheim Conv Ctr Anaheim, CA	AEC, PC-CAD
DAC '89	Design Automation & IEEE (303)530-4333	6/25-29	Las Vegas Conv Ctr Las Vegas, NV	ECAD
Siggraph '89	ACM (312)644-6610	7/31-8/4	Hynes Convention Ctr Boston, MA	Graphics HW, Workstations
URISA '89	URISA (202)543-7141	8/6-10	Marriott Copley Place Boston. MA	Mapping, GIS
Dataquest Annual Conf	Dataquest (408)437-8245	9/11-13	DoubleTree Hotel Santa Clara, CA	MCAD, AEC, Mapping, ECAD, Imaging, Graphics, CIM, Technical Computing
CAD/CAM '89	NCGA 1-800-225-6242	9/12-15	Santa Clara Conv Ctr Santa Clara, CA	MCAD, AEC, PC-CAD
National Design Engineering Fall '89	ASME (203)964-0000	10/10-12	Jacob Javitz Ctr New York, NY	MCAD
Autofact '89	CASA-SME (313)271-1500	10/30-11/2	Cobo Hall Detroit, MI	MCAD, CIM
Mapping/GIS '89	NCGA 1-800-225-6242	11/13-16	Westin Bonneventure Los Angeles, CA	Mapping, GIS

TABLE 2

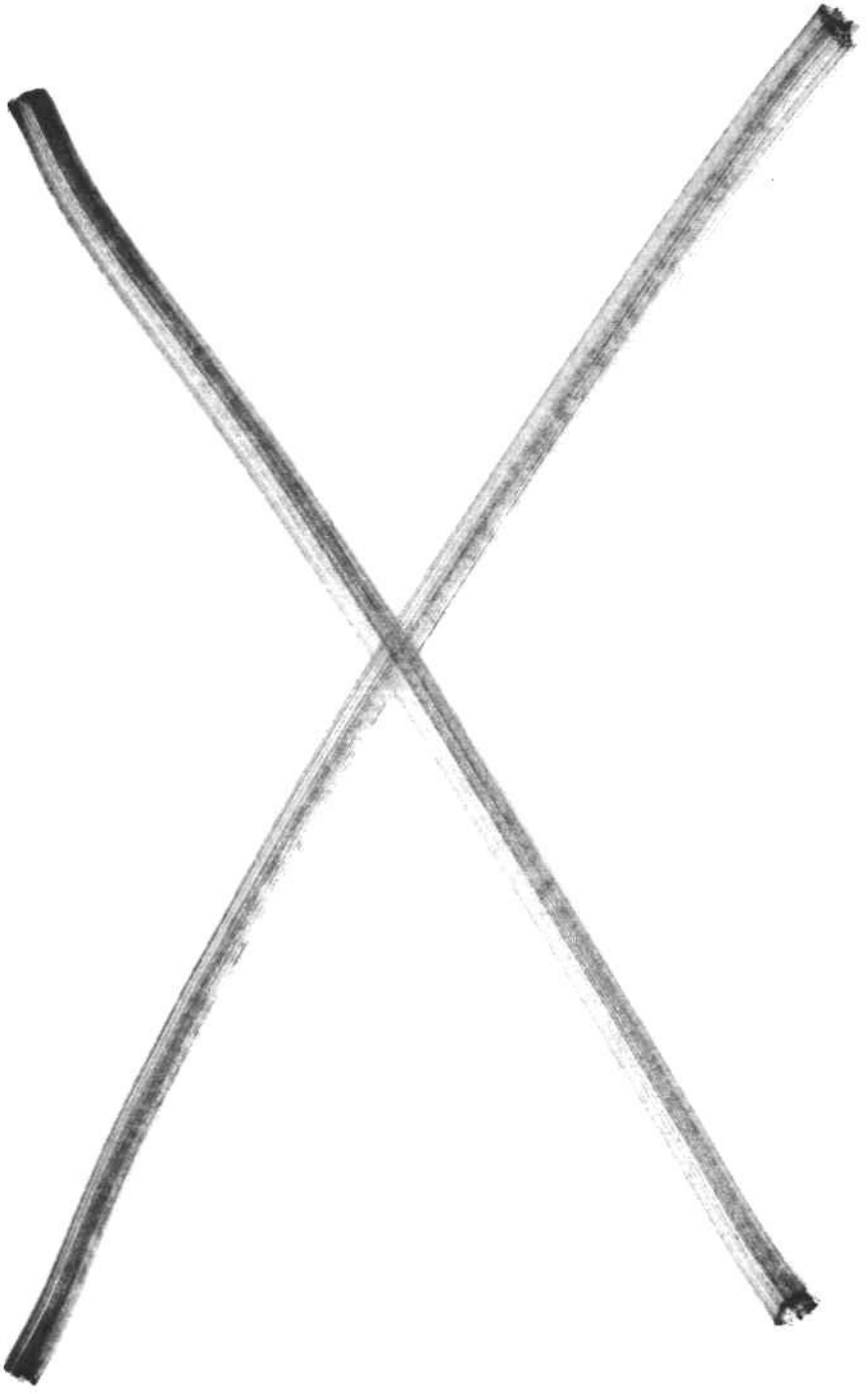
1989 MAJOR EUROPEAN CAD/CAM CONFERENCES AND TRADESHOWS

Name	Phone	Date	Location	Applications
MICAD	Not Available	2/13-17	Paris France	MCAD, AEC, Mapping, ECAD, Graphics, CIM
Cebit	(49)-511-891	3/8-15	Hannover Messeglande West Germany	Computers, Graphics, Software, Peripherals
CAD-CAM '89	(44)-1-404-4844	3/14-16	NEC Birmingham United Kingdom	MCAD, AEC, Mapping, CIM
SICOB	(33)-1-4261-5242	4/17-22	Paris Parc de Expositions France	Computers, Software
CAT '89	(49)-711-25890	6/6-9	Stuttgart Killesberg Messeglande West Germany	MCAD, CIM
Informat	(34)-3-423-3101	6/5-10	Feria de Barcelona Spain	Computers, Graphics, Software
SMAU	(39)-2-701-765	10/5-9	Quartiere Fiera Milano Italy	Computers, Graphics, Software
Systems	(49)-89-51070	10/16-20	Munich Messeqelande West Germany	Computers, Graphics, CAD Software
SIMO	(34)-1-448-4794	11/17-24	Madrid Recinto Ferial Casa de Campo Spain	ECAD

TABLE 3

1989 MAJOR JAPAN CAD/CAM CONFERENCES AND TRADESHOWS

Name	Sponsor	Date	Location	Applications
ADES Japan '89	Cahners Exposition (03)-349-8501	1/18-21	Harumi, Tokyo	EDA
Mechatronics Japan '89	Nihon Economic Newspaper (03)-270-0251	2/27-3/2	Harumi, Tokyo	MCAD, CIM, Machine Tools
Osaka CAD/CAM/CAE Systems '89	Nikkan Kogyo Newspaper (06)-941-6872	5/18-21	Intechs Osaka, Osaka	MCAD, AEC, CIM, Workstations
Tokyo CAD/CAM/CAE Systems '89	Nikkan Kogyo Newspaper (03)-222-7232	5/26-29	Harumi, Tokyo	MCAD, AEC, CIM, Workstations
Nagoya CAD/CAM/CAE Systems '89	Nikkan Kogyo Newspaper (052)-398-1771	6/10-13	Trade Center, Nagoya	MCAD, AEC, CIM, Workstations
Computer Graphics Osaka '89	Nihon Noritsu Kyokai (06)-261-7151	6/14-17	Osaka Castle Hall, Osaka	Graphics, Workstations
Nicograph '89	Nihon Economic Newspaper (03)-252-8157	11/7-10	Sunshine City, Tokyo	Graphics, MCAD, AEC



Dataquest
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Research Newsletter

RDBMS MARKET IN JAPAN

EXECUTIVE SUMMARY

Twenty years have passed since Dr. E.F. Codd proposed the relational model. During that time, several relational database management system (RDBMS) products have been introduced. Many of these products now have high functionality, capability, and performance. RDBMS products have been used since about 1985 in Japan. RDBMS initially ran on minicomputers, mainly on the VAX. There were few commercial users at that time, and few people paid attention to RDBMS in Japan. Now, RDBMS occupies the attention of Japanese vendors and users because of the following factors:

- Rapid growth of the Japanese UNIX workstation market and the propagation of UNIX workstations into the business computer market
- Improvement of the functionality and performance of RDBMS
- RDBMS now able to cope with distributed and heterogeneous vendor environments
- Japanese language support
- Consolidation of sales activity by Japanese distributors

RDBMS is one of the most important applications as UNIX breaks into the business computer market. This newsletter reviews the 1989 Japanese RDBMS market and takes a look at what is ahead, focusing on RDBMS products that run on multiple UNIX platforms. Table 1 shows the RDBMS products and their Japanese distributors.

RDBMS MARKET PERFORMANCE

Dataquest estimates that the RDBMS market size in Japan in 1989 (see Figure 1) was $18.8 million. This size shows a growth rate of 140 percent from $7.9 million in 1988. Market size includes revenue from licensing fees of the RDBMS and accompanying products such as query and fourth-generation languages and development tools and excludes revenue from manuals, maintenance fees, user education, and applications.

Unify leads the RDBMS market (see Figure 2), with a 33.0 percent share, followed by Informix with 32.8 percent and Oracle with 13.7 percent. Dataquest forecasts a compound annual growth rate (CAGR) of UNIX workstation commercial market factory revenue of 74 percent from 1989 through 1994, and a large percentage of these workstations need RDBMS. Dataquest forecasts a strong growth rate for RDBMS with a CAGR of 95 percent to $271 million from 1989 through 1994.

There is the view that the propagation of object-oriented database management systems (OODBMSs) can be a factor in limiting RDBMS market growth. The Dataquest view is that the OODBMS market will start to grow in Japan around 1992. The growth will be centered on technical uses mostly in CAD/CAM applications. On the other hand, the RDBMS market will grow

TABLE 1
UNIX RDBMS Products and Distributors in Japan

Product	Distributor	Delivery Date
Empress	MKC	April 1989
Informix	ASCII	March 1987
Ingres	Ingres Japan	August 1987
Oracle	Oracle	September 1987
Sybase	Nippon Timeshare	July 1987
Unify	Air	1985

Source: Dataquest (October 1990)

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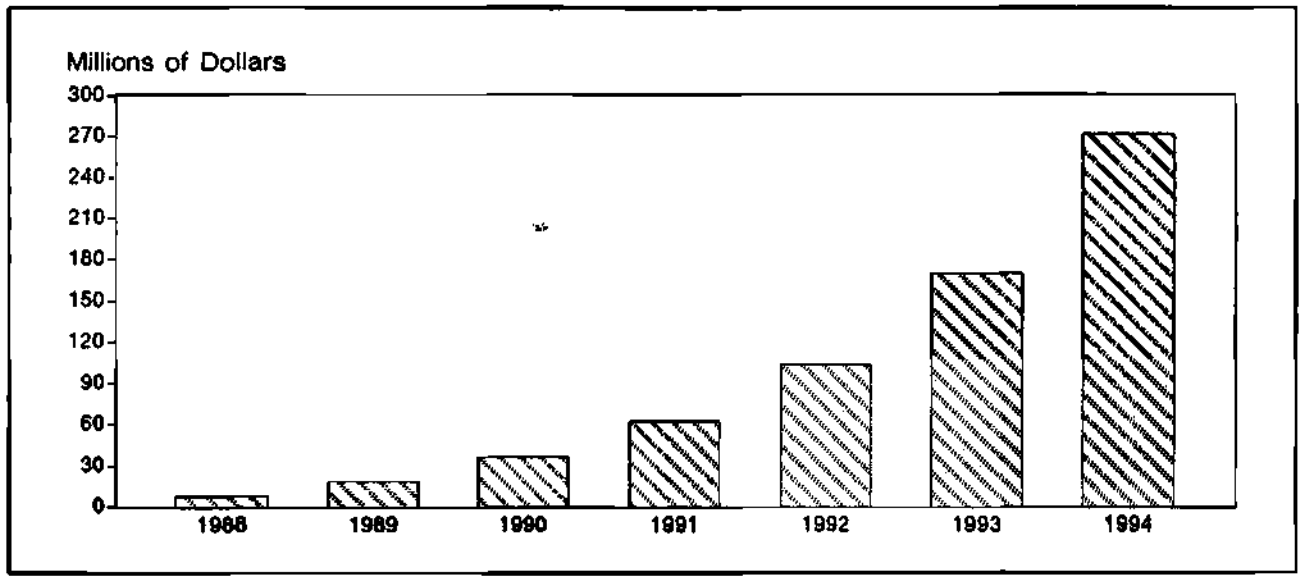
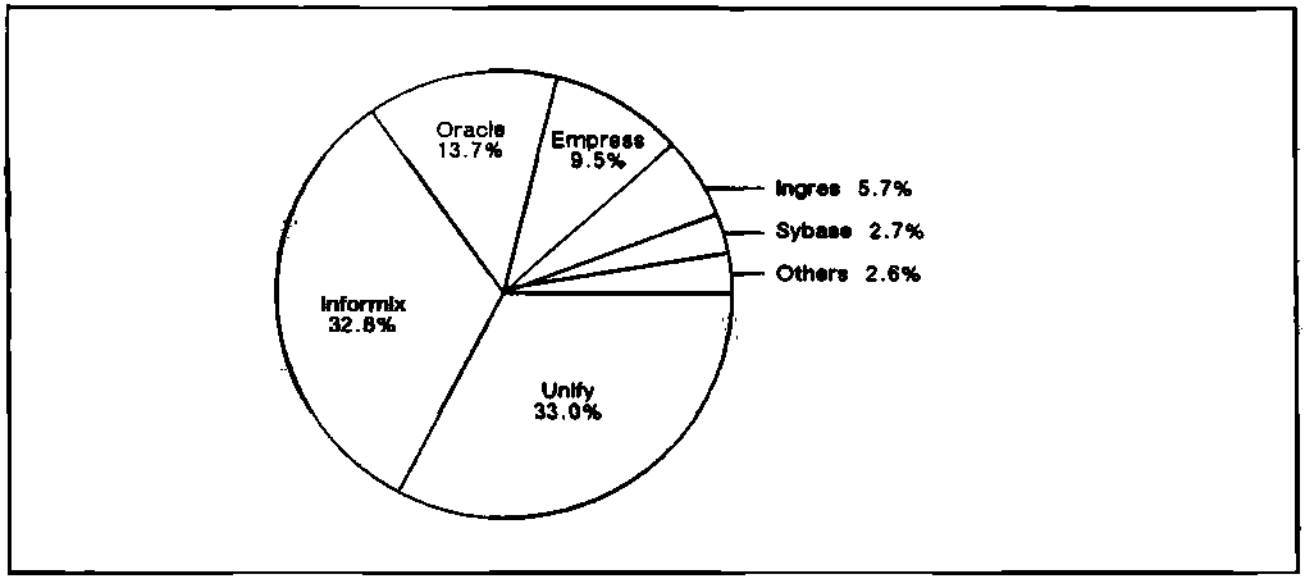
FIGURE 1
Japanese RDBMS Market History and Forecast Licensing Revenue (Millions of Dollars)



Source: Dataquest (October 1990)

FIGURE 2
Japanese RDBMS Vendors' 1989 Market Share by Licensing Revenue



Source: Dataquest (October 1990)

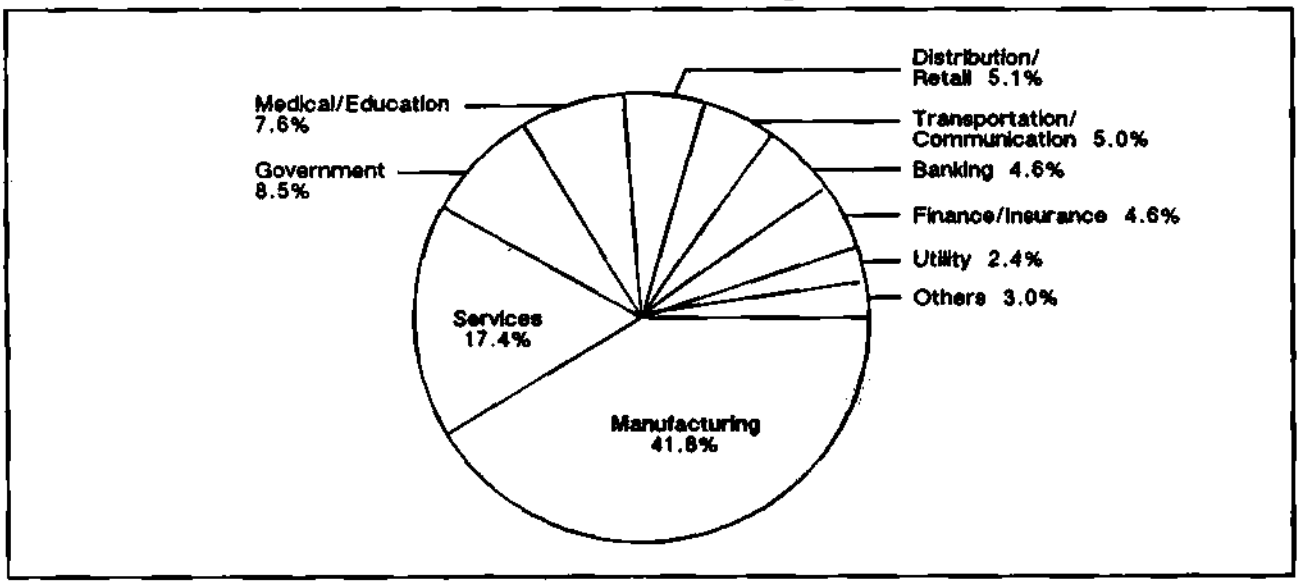
mainly in the business computer market. Thus, in only a few cases will OODBMS and RDBMS compete directly in the market over the next five years. Moreover, RDBMS technology is being enhanced to include OODBMS features such as object management, variable-length data, video and voice, and visual programming. As a result, Dataquest believes that both RDBMS and OODBMS will be used in application and user environments and grow cooperatively in the early 1990s.

VERTICAL MARKETS AND APPLICATIONS

The number one RDBMS user environment (see Figure 3) is manufacturing with 41.8 percent, followed by services with 17.4 percent, and government with 8.5 percent. From the application point of view for each industry, RDBMS is used for the following relatively large systems:

- Manufacturing—MRP, factory control, and inspection data management

FIGURE 3
RDBMS by User Environment, 1989 Japanese Market Licensing Revenue



Source: Dataquest (October 1990)

- Services—Point of sale, ticket reservations, and member administration
- Government—Account billing for water services, register management, vital statistics, and surveys (mainly in local self-government)
- Banking and finance—Trading system, investment, and transaction history management

Almost all applications are purchased from VARs or developed in-house. There are few, if any, shrink-wrapped applications.

DATAQUEST ANALYSIS

One of the major attractions of an RDBMS is the set of high-productivity software tools such as 4GL, report writers, and CASE-style environments. All RDBMSs support distributed computing, with relatively inexpensive systems solutions and flexible configurations. These advantages suggest that the combination of RDBMS and UNIX can be a menace to mainframe and office computer systems with proprietary operating systems and proprietary database systems (turnkey integrated systems are known as office systems in Japan).

Workstations or personal computers connected to UNIX-based parallel or fault-tolerant servers are potential competition for mainframes. Such a configuration requires systems integrators who are vendor independent and who have the technical experience and knowledge to integrate UNIX, RDBMSs, and LANs. There are few such systems integrators currently in Japan.

Personal computers connected with workstations are potential competition for office systems. It is very expensive to migrate from office systems to personal computers because of the lack of computing power or data-handling ability of personal computers. A distributed UNIX system integrates inexpensively with existing personal computer and shrink-wrapped software that is available. Shrink-wrapped applications developed with 4GL or embedded SQL on an RDBMS have begun to appear. More shrink-wrapped UNIX applications are needed in the commercial market. Especially needed are applications such as accounting, personnel, marketing, and sales that have been popular on office computers.

Japan is less dependent on shrink-wrapped applications than the United States is. Shrink-wrapped software will be accepted more and more in Japan because of the lack of software engineers and the increasing demand for applications.

Dataquest expects software VAR business based on RDBMS to grow rapidly in Japan. RDBMS has an important role for the growth of UNIX in the commercial market. Dataquest sees that the advantage of open systems is that it can provide an ideal computing environment for the user when RDBMS vendors, systems integrators, and applications vendors share their experience and know-how.

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Yu Uemura
Satoshi Uchiyama

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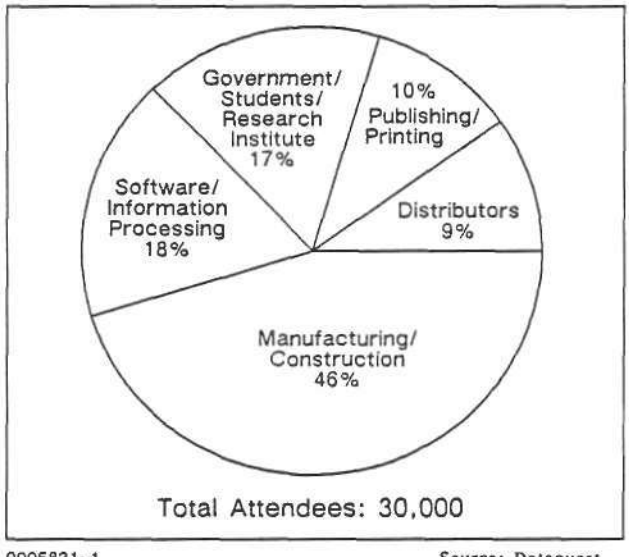
Research Newsletter

NICOGRAPH '89: HOT MARKET IN JAPAN

INTRODUCTION

In November, Nicograph '89 was held in Tokyo. Nicograph is one of the major trade shows focusing on the MCAD, AEC, mapping, and graphics industries. Of 130 participants, 80 companies displayed CAD/CAM equipment. Approximately 30,000 people attended the exhibition and/or the accompanied technical sessions. The attendees' business demographics are shown in Figure 1. The demographics are similar to those in 1988; the total number of attendees increased 2.4 percent.

FIGURE 1
Nicograph '89: Attendees by Business Segment



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Source: Dataquest January 1990

Source: Dataquest
January 1990

Two important speakers flew across the Pacific to speak at the sessions. Edward McCracken, president and CEO of Silicon Graphics, discussed 3-D computer visualization. Dr. Marvin Minsky, professor at MIT, titled his lecture "Art and the Society of Mind."

The inexpensive entrance fee to the exhibition (¥1,000 per person) permitted a high attendance, and a sizable number of potential investors also listened to the detailed presentations. The investors' positive evaluation is important to the exhibitors, and they budgeted a large amount of money for the booths (¥250,000 per 35-square-foot space).

This newsletter will target several key trade show participants and their products in the following market segments:

- MCAD/MCAE
- Stereo lithography
- AEC
- Mapping/GIS

Expanding MCAE Markets

Multiple mergers and acquisitions in the MCAD market not only reduced purchases of MCAD systems in Japan but also appear to have helped push remaining growth toward MCAE software buys. Most MCAD systems sold to date were mainframe-based 2-1/2-D drafting/documentation tools with limited engineering and analysis capability. Drafting is a rapidly maturing market in Japan, and market growth has moved to advanced users installing MCAE software packages running on UNIX-based technical workstations. Usually, these packages are unbundled and the total seat cost is less than that offered by full-line suppliers running on host-dependent systems. We will look at several

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MCAE tools providing engineering and analysis functions with solid modelers and the companies producing those MCAE tools.

Parametric Technology Corporation (PTC)

PTC's Pro/ENGINEER software package attracted quite a few people to its distributors' booths: C. Itoh, Technodia, Techno-Science, and Tokyo Electron. Pro/ENGINEER's inherent feature-based solid-modeling technique has at last captured aggressive engineers' attention in Japan, where the end-users' adoption of breakthrough technology on CAD/CAM usually lags 18 months behind the United States. The package is unbundled at ¥3,600,000 for the standard configuration, and there are currently 130 licensed installations. At the show, PTC announced its Pro/MANUFACTURING package, which also commanded attention.

Although Pro/ENGINEER currently runs on major United States-based workstations and NEC's EWS-4800, we believe that the package will be ported onto most of the popular workstations sold in Japan because of the importance of offering software to run on hardware in the Japanese installed base.

Ricoh

The competing product to Pro/ENGINEER in the expanding solid-modeling market comes from Ricoh Corporation, which has been leading the electronics and office automation industries. Its DESIGNBASE is the first solid-modeling software package developed and marketed by a Japanese company and was shown at Ricoh's multiple OEM/VARs booths as well as at its own booth. The OEM/VARs include Argo Graphics, Asahi-Techno Computer, Kubota Computer, and Marubeni Hytech, as well as others.

DESIGNBASE was developed originally as a solid-modeling library that allows users to enhance its kernel functions, so that users can customize the solid-modeler for specific applications. With undo/redo operations of DESIGNBASE, solid models can be regenerated or modified quickly. Modifications such as union, subtraction, and intersection of two solids (including polyhedrons, quadric surfaces, and free-form surfaces) are supported. Intersection curves are calculated precisely without using any approximation, even in the cases where curved surfaces intersect. DESIGNBASE supports straight lines, arcs, Bezier curves, and rational Bezier curves. Also, rounding can be done on edges or vertices of any shape. Complex filet surfaces that could not be generated by traditional solid modelers can be realized easily.

The package is unbundled at ¥3,500,000 for the standard configuration and runs on multiple workstations from Hewlett-Packard, Silicon Graphics, Sony, Stardent, and Sun Microsystems. Although most of the 100 licenses are installed in Japan, we believe that Ricoh will strengthen its marketing activities for DESIGNBASE in the global market.

Aries Technology

Aries' product named ConceptStation attracted the engineers who focus on design, engineering, and analysis. The product is marketed as the personal MCAE tool by ISI-Dentsu. ISI-Dentsu has distributed SDRC's I-DEAS product for many years, and the company decided to represent Aries. ISI-Dentsu was convinced that the products would complement each other, with Aries' strategy—"ConceptStation targets typical design engineers rather than skilled analysts."

The product is penetrating the market with its integrated design and analysis capability, parametric design module, easy-to-use graphical user interface, and reasonable price of ¥5,000,000 at full software configuration. ConceptStation runs on Compaq 386 and Sun workstations, is available either bundled or unbundled, and has 100 licenses currently installed in Japan.

Nihon Unisys

Nihon Unisys demonstrated UNICAD/SOLID, the solid-modeling system based on its own technical workstation. The company offers a full-line CAE/CAD/CAM system with UNICAD/SOLID, machining software SCULPTOR, pre- and postprocessor APPEX and NASTRAN, and has installed a sizable number of licenses on its mainframe over many years. We believe that the company was convinced that the preferred platforms for users were shifting from mainframes toward workstations and the company executed the software-porting job promptly. The UNICAD/SOLID turnkey system and full-line CAE/CAD/

CAM system are priced at ¥18 million and ¥30 million, respectively, for the minimum configuration.

Nihon Unisys has become an OEM of Sun workstations recently, and we believe that the UNICAD/SOLID package on Sun workstations will help expand Nihon Unisys' business.

EMERGING STEREO LITHOGRAPHY MARKET

Two years ago 3D Systems announced its Stereo Lithography Apparatus (SLA) and more than 100 systems have been installed so far, mostly in the United States and Europe. This unique technique is critical for those who need to make actual tangible models automatically, in addition to models rendered on a 3-D screen.

In Japan, as well as in the United States and Europe, the market has proven viable. Two products similar to SLA have come from Japanese companies. One product is Solid Object Ultra-Violet Laser Plotter (SOUP) from Mitsubishi Corporation. The prototype produced by SOUP is free from distortion and shrinkage, because after-cure is not necessary. Also shell model (thin wall) is producible. Mitsubishi has installed nine SOUP systems in Japan, including its internal customers.

Another product is the Solid Creation System from Sony and Japan Synthetic Rubber (JSR). High-power argon laser is available as well as helium-cadmium laser, so bigger prototypes are producible. Also, JSR, a major chemical manufacturer, can offer the specific resin to meet the desires of users. Both products have adopted the patented technology invented in the Osaka Prefectural Industrial Research Institute.

The basic technology used in the three products is the same; i.e., accumulating a large number of thin horizontal layers of resin cured (solidified) by ultraviolet (UV) laser. The scan path of UV laser is programmed on CAD data transferred from the CAD system interface. Major differences among these products are shown in Table 1.

A UNIQUE VENDOR IN THE AEC MARKET

The AEC market requires vendors to be aware of detailed design and construction requirements that vary by country and even by regions within countries. In Japan, many vendors have overlooked the need to employ experts within the AEC community to help develop products and, instead, have relied primarily on repackaged mechanical design products. This reliance on repackaged products has created a barrier to growth in AEC CAD.

ARC/Yamagiwa, a 65-employee company, seems to be breaking the barrier with its unique strategy.

This company was founded in 1981 as a joint venture between Applied Research of Cambridge, a subsidiary of McDonnell Douglas, and Yamagiwa Electric, a long-established lighting/consumer electronics retailer. Various AEC software modules have been developed successfully at ARC's research and development facility in the United Kingdom with the feedback from worldwide users, including Japanese users.

As ARC/Yamagiwa employs a sizable number of authorized architects, the complex requirements on AEC applications are solved more quickly than at the hardware-driven vendors. The company believes that the excellence and abundance of application software modules are the keys to success in the AEC market, because a large proportion of the users, mostly architects, are interested in what they can do with the specific software packages, rather than the leading-edge hardware technology. Fifteen AEC/mapping modules run on Digital Equipment's minicomputers and VAXstation under VMS, and 70 users have installed 300 workstations.

ARC/Yamagiwa's primary competitors are Fujitsu, with ICAD/Build package on its mainframe, and Mutoh Industries, with Intergraph's AEC package.

GROWING GEOGRAPHIC INFORMATION SYSTEMS

In the mapping market, major participants come not only from computer vendors, but also from measurement and survey companies that have an advantage in expertise and experience. Many measurement and survey companies were exhibiting conventional systems at Nicograph '89. The best-attended booths were those showing geographic information systems (GIS); they attracted users from utilities, research laboratories, and various nongovernmental firms.

ESRI's ARC/INFO product demonstrated its high-level analysis ability at the booth of PASCO, a major aerial survey company. ARC/INFO software

TABLE 1
Stereo Lithography Products

Manufacturer	SOUP Mitsubishi Corporation	Solid Creation System Sony/JSR	SLA 3D Systems
Resin	Epoxy	Urethane-acrylate	Epoxy-acrylate
After-Cure	Unnecessary	Necessary a few minutes with UV light	Dependent upon applications
Scanning System	XY-table	Galvano-mirror	Galvano-mirror
Laser	He-Cd (325nm,30/40mW) Ar (planned)	He-Cd (325nm, 20mW) Ar (351&364nm,0.4-5W)	He-Cd (325nm, 15mW) Ar (planned)
Controller	Sun/Alliant	Sony (News)	286-based PC
Maximum Prototype Producible	470x350x350mm^3 (He-Cd)	200mm^3 (He-Cd) 1,000mm (Ar)	254mm^3 (He-Cd) in SLA-250
Price	¥44,000,000 with CAD I/F without control workstation	¥50,000,000 without CAD I/F	¥37,000,000 without CAD I/F with postcure apparatus
CAD Systems Interfaced (excluding internal tools)	CATIA CADDS(CV) Pro/ENGINEER DESIGNBASE Autocad Grade(Hitachi Zosen) Prime Design	CATIA CADDS(CV) GEOMOD(SDRC) DESIGNBASE Fresdam (Sony/Tek) Caelum (Toyota)	CATIA CADDS(CV) Pro/ENGINEER GEOMOD(SDRC) ConceptStation CADKEY EUCLID(Matra) I/EMS(Intergraph) Prime Design Catis(TIS) UNICAD/SOLID

Source: Dataquest
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package runs on the IBM PC, IBM mainframe, and Sun workstation (most users select Sun workstations as the preferred platform). Right now, ESRI's major competitor is Mutoh Industries, selling Intergraph's geographic information systems.

Although only 20 ARC/INFO systems are installed, PASCO is encouraged by the positive strong reactions of potential customers that the GIS market will expand rapidly in the next few years. Other companies offering mapping systems include C. Itoh, INS Engineering Corporation, Kansai Kousoku, Marketing Intelligence Corporation, and Techno-Science.

DATAQUEST CONCLUSIONS

The major change in the Japanese CAD/CAM market from 1988 to 1989 is that end users have begun to insist on buying standard hardware platforms with unbundled software. As in other regions, separate software and hardware enables buyers to scrutinize price more closely, resulting in lower prices on both software and hardware. Software vendors have begun to appreciate the advantage of software-only sales, which is that the vendors become exempt from the maintenance and inventory of multiple hardware platforms and the subsequent risk of a fall in hardware prices. This

advantage gives software vendors some room to lower the software price itself. Nicograph '89 demonstrated this trend specifically, and we believe that software unbundling will play a more important role, particularly on technical workstations.

Although the exhibits were diversified—from MCAD, AEC, mapping, and graphics to workstations—and several key participants such as IBM and NEC declined to participate this year, Dataquest believes that Nicograph is a worthwhile CAD/CAM trade show. Nicograph provides publicity for products for a mass user audience, rather than concentrating on a smaller number of actual buyers.

If a vendor wishes to concentrate on actual buyers, we recommend creation of a private exhibition, featuring attractive sessions and speakers. Digital, Hewlett-Packard, ISI-Dentsu, Silicon Graphics, Sony, Sun, Tokyo Electron, and some other companies hold annual exhibitions in Japan, coinciding with major product announcements.

In general, MCAD users have become wiser and more prudent as a result of being caught in a proprietary environment and undergoing a baptism of fire with the relentless mergers and acquisitions among their suppliers. This experience also has brought skepticism to the market for conventional drafting/documentation systems. Although the drafting CAD market is big, we believe that the rapid growth exists in the MCAE market, where unbundled software packages are offered on multiple UNIX workstations.

Apparently, the behaviors and the preferences of AEC/mapping users are different from those of MCAD users. We believe that complete kanji/Japanese support and laborious modifications/customizations based on users' input are critical to penetrate the AEC/mapping market. Although the initial investment is large, Dataquest expects a fruitful business to result because of the relatively low penetration in this market. Except for the PC-based AEC market, only a few participants dominate the market, enjoying repeat orders from price-insensitive buyers.

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HIGH-TECH BUSINESS OPPORTUNITIES IN INDIA

INTRODUCTION

Key opportunities exist for high-technology business in India. This newsletter discusses important recommendations by the Joint Scientific Committee, which was appointed by India's Prime Minister Rajiv Gandhi to outline a microelectronics blueprint for the next 10 years. The committee recommends free-market-driven, private-sector development of the electronics components and systems business in India, collaborating with leading foreign companies as needed. The Indian government would play a guiding role in defining technology road maps and coordinating industrial strategies.

The committee has identified several areas for short-term business development. These include design centers for ASICs, microprocessors, and gallium arsenide microwave ICs; semiconductor foundry facilities; and advanced printed circuit board and packaging technology. The markets for these technologies will include low-cost personal computers, office automation products, consumer appliances, telecommunications, and industrial automation. We at Dataquest believe that this information is of particular interest to our clients in the semiconductor design, manufacturing, equipment, and materials industries.

BACKGROUND

The world has seen the meteoric rise of countries such as Japan, Korea, and Taiwan, based on carefully orchestrated industrial strategies for penetrating all segments of the electronics food chain, from discrete devices to complete systems. Top government policy makers in India are increasingly aware of the importance of microelectronics and its value-added leverage in electronic systems. As shown in Table 1, the Department of Electronics has outlined ambitious production levels for India to become a world player in the electronics business.

Table 1

Semiconductor Components and Electronics Production
(Millions of Dollars)

Year	Annual Components Production	Annual Electronics Production
1988	$ 10	$ 4,500
1995	$ 800	$15,000
2001	$1,600	$30,000

Source: Department of Electronics
Government of India

India is the 10th-ranked industrial country in the world, with a population of 800 million and a gross national product of $225 billion. It has the third-largest engineering and scientific human resource base in the world. The English language is used widely for business communication. Recently, India has emerged as a powerhouse in software products and services. To round out its high-technology portfolio, India is currently embarking into VLSI design and manufacturing to meet the needs of advanced electronic systems.

BUSINESS OPPORTUNITIES IN INDIA

The following areas have been identified by the committee as short-term priorities for high-technology business development in India:

- VLSI design centers—The committee proposed that design centers be set in major industrial cities in India to encourage VLSI use in reducing system costs and improving system performance. Dataquest believes that significant opportunities exist for ASIC design, software, and CAD companies in India.

- VLSI fabs for ASICs—World-class semiconductor manufacturing capability is essential to India's electronic systems business success. Collaboration opportunities exist in setting up fabs for IC manufacturing. A high level of compatibility with ASIC design and software tools will be required. Foreign ASIC companies with a full range of CAD, software, and manufacturing capabilities will have an advantage in penetrating the Indian market.

- Microprocessor and digital signal processor design—The Indian government considers the development of microprocessors and digital signal processors essential for advanced system architectures. Companies with expertise in these areas have an opportunity for licensing their technology and developing a low-cost manufacturing source for their products.

- Microwave IC design—Domestic design capability development for GaAs microwave ICs for satellite communications is a priority. Opportunities exist for design and CAD collaboration. The devices will be manufactured by relevant partners at foundries in either Japan or the United States.

- Advanced printed circuit boards and VLSI packaging—The Indian government has emphasized the need for multilayer board technology and high-pin-count VLSI packaging using surface-mount and TAB techniques. Opportunities exist for semiconductor and board-assembly companies to expand in India.

DATAQUEST CONCLUSIONS

Dataquest believes that India offers exciting opportunities for high-technology companies to expand their markets. With its newly liberalized industrial policies, its tremendous technical resources, and its huge domestic markets, India could well be the next Asian economic miracle.

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1988 ASIAN CAD/CAM MARKET: VENDORS BENEFIT FROM WEAK DOLLAR; JAPANESE RUSH TO TECHNICAL WORKSTATIONS

SUMMARY

Japan's $2.5 billion CAD/CAM market, the Asian region's preeminent market, spearheaded a recovery in 1988 from the two-year slump that resulted from rapid yen appreciation. Also in 1988, the UNIX and Sun fever hit Japan with unprecedented market impact. Japanese CAD/CAM sales swelled 23 percent, fueled by an aggressive entrance into the technical workstation market by Japan's major computer suppliers—Fujitsu, Hitachi, and NEC.

Overall Asian CAD/CAM sales soared 21 percent, which also benefited from a weakened dollar. Given low penetration rates and high-growth potential in the rest of the region (China, Hong Kong, Korea, Singapore, and Taiwan), Asia appears destined to retain a significant slice of the global CAD/CAM market, especially in view of the following facts:

- Today's Asian CAD/CAM market accounts for $2.8 billion, or 27 percent, of worldwide CAD/CAM revenue. Dataquest forecasts that the market will top $3.2 billion in 1989.
- Although only the third-largest regional CAD market after North America (37 percent) and Europe (34 percent), Japan, with a whopping 91 percent of the Asian market, is the second-largest CAD/CAM-using nation in the world.
- For the first time, Asian CAD/CAM suppliers control more than 50 percent of this regional market—unlike Europe, where U.S. vendors continue to enjoy market dominance.

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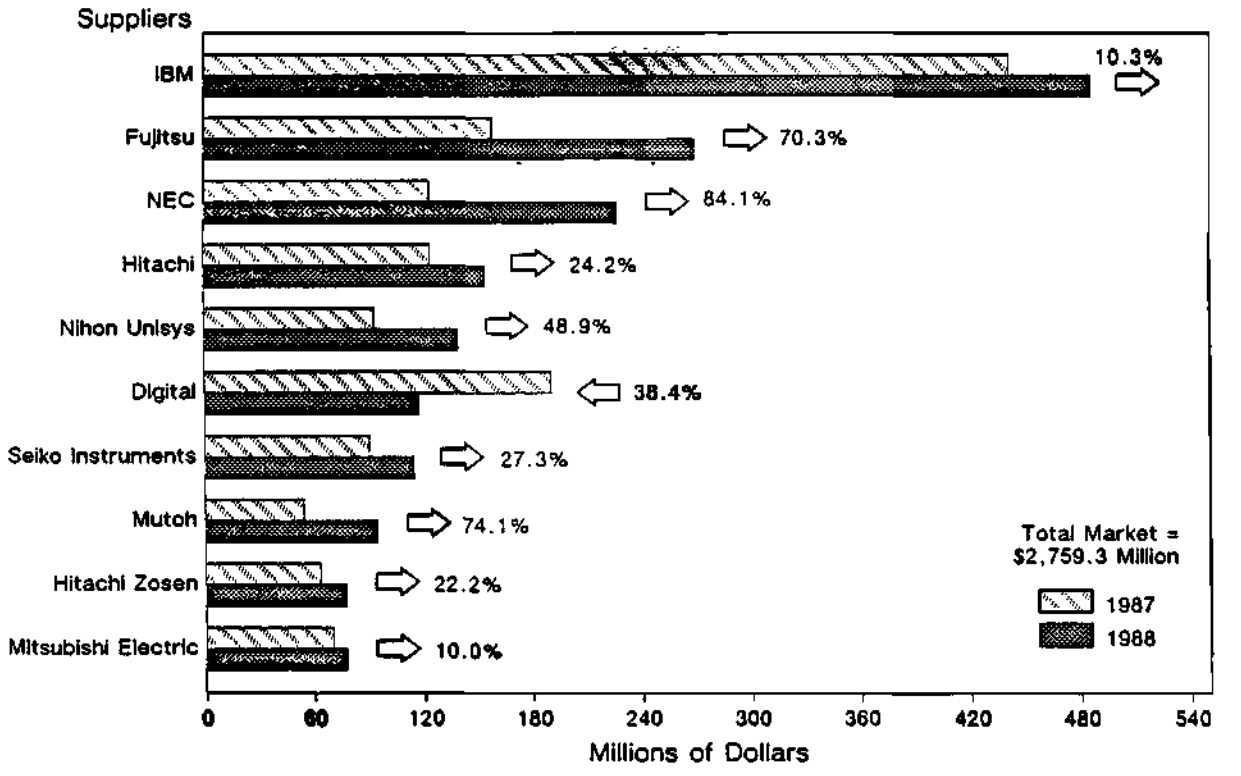
ASIAN MARKET LEADERS

Figure 1 and Tables 1 through 8 indicate vendor market share by total market and by application for all of Asia. (Tables are included at the end of this document.) Although both manufacturers' and resellers' revenue are listed in these tables to show relative market share, double counting has been eliminated in all bottom-line totals.

As the numbers indicate, U.S. vendors control just 47.1 percent of Asia's CAD/CAM, while Asian vendors account for 52.1 percent of sales. (European suppliers control the remainder.) Asia is the only regional CAD market that did not continue to be dominated by American suppliers in 1988.

Figure 1

1988 Asian CAD/CAM Market Leaders
1987-1988 Total Revenue and Growth
(Millions of Dollars and Percent Change)



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Source: Dataquest June 1989

Number One: IBM

IBM continued to lead 1988 CAD/CAM sales in Asia, racking up 17.6 percent market share points and sales in excess of $486 million. The company's Asian market share grew 10.3 percent in revenue between 1987 and 1988. IBM's strength lies mainly in mechanical CAD, where it ranks first, and in the AEC and mapping areas, where it ranks third. IBM primarily sells the mainframe-based design products CADAM, CATIA, and CAEDS, as well as unbundled PCs and the PC-based MicroCADAM product. To retain market leadership in Japan, where technical workstation fever is rampant, IBM will have to reinforce its technical workstation product offerings.

Number Two: Fujitsu

Growing 70 percent over 1987, Fujitsu pulled ahead of the pack to become the region's largest local supplier, thus positioning itself to ride the technical workstation wave that began sweeping Japan in 1988. Fujitsu ranked second only to IBM in the Asian CAD/CAM market, with sales swelling to $269 million for a 9.7 percent share of market.

Such dramatic growth can be directly attributed to Fujitsu's new identity as a full-line hardware supplier. Fujitsu's platforms now range from PCs to mainframes, a result of its OEM agreement with Sun for technical workstations.

Also distinguishing Fujitsu is the revenue contribution made by its application products for AEC, mapping, and PCB layout. Fujitsu ranked first in both AEC and mapping in 1988 and placed second in the PCB design market. Fujitsu also is aggressively positioning itself to become the leading supplier of the Sparc RISC processor—the same chip used in the Sun-4 workstation.

Number 3: NEC

NEC captured third place in the Asian CAD/CAM market, growing 84 percent over 1987 to $226.4 million, for an 8.2 percent share of market. Like Fujitsu, NEC has successfully shifted from mainframe-based systems to the technical workstation—in NEC's case, its own EWS4800 technical workstation. NEC shipments were almost as high as IBM's total workstation shipments in Asia—largely attributed to NEC's unbundling of its own PC.

NEC has a strong application focus, and offers all major CAD/CAM applications except for IC layout. It ranks second in both MCAD and AEC market shares, and third in ECAE and PCB layout markets.

With high vertical integration similar to that of Fujitsu, NEC's wider strategic plans include microprocessor production—in particular, the MIPS RISC chip—with manufacturing plans for 20,000 to 30,000 chips per month.

Number 4: Hitachi

Hitachi retains its market position as the fourth-largest supplier. In 1988, it had revenue of $154 million, a 5.6 percent market share, and grew 24 percent over 1987. As do Fujitsu and NEC, Hitachi now offers a full-line of hardware platforms.

Hitachi's application strengths and market share position in those markets are as follows: MCAD (number 4), AEC (number 4), and mapping (number 5). Hitachi's current workstation offerings, the TWS2050G and R-7300, use a 68020MPU. The company has not announced which RISC chip it will eventually employ.

Number 5: Nihon Unisys

Moving up from sixth- to fifth-place supplier in 1988 was Nihon Unisys, with $138.5 million in revenue and a 5.0 percent share of market. Revenue in 1988 represented growth of 49 percent over 1987. Nihon Unisys offers technical workstations and host-based systems, primarily for the MCAD market, where it ranks fourth.

Number 6: Digital

Digital Equipment Corporation slipped to sixth place in the overall Asian CAD/CAM market in 1988, with $117 million in sales, which represents a decline of 38 percent from 1987.

Number 7: Seiko Instruments

In 1988 Seiko's total revenue grew 27 percent, including OEM sales of Daisy and McDonnell Douglas. Seiko sales of its own SX-8000 IC layout product led the IC design market in Asia, capturing a commanding 34.6 percent market share of that application market.

Number 8: Mutoh Industries

Mutoh's revenue grew 74 percent in 1988, based on its sales of both Intergraph and its own products.

Number 9: Hitachi Zosen

Hitachi Zosen grew its revenue by 22 percent in 1988, to $77 million. Hitachi Zosen mainly sells technical workstations into the MCAD marketplace.

Number 10: Mitsubishi Electric

Mitsubishi grew 10 percent in revenue, offering products in MCAD, AEC, mapping, and PCB. Its strength is primarily in the mapping market, where it garnered a second-place standing in overall market share.

Number 11: Prime

Prime Computer, which merged with Computervision (only in the United States and not in Japan), had 1988 sales of $75 million and grew 67 percent in Asia. Prime Computer Japan and Computervision Japan have announced plans to merge Asian operations in the near future.

Number 12: Mentor

Mentor Graphics grew 67 percent over 1987, with $74 million in sales. The leading player in the global EDA (electronic design automation) market, Mentor ranks first in ECAE, fourth in IC layout, and sixth in PCB layout in the Asian markets. Mentor traditionally offers turnkey products running on technical workstations from Apollo Computer. Apollo's recent acquisition by Hewlett-Packard makes it imperative that Mentor clarify its future hardware plans in order to protect market position in Asia, as well as in Europe and North America.

ASIAN FORECAST BY APPLICATION

The following discussion is based on the data contained in Table 9.

Mechanical CAD/CAM (MCAD)

Although the MCAD grew 23 percent in 1988, such high levels of growth are not forecast to continue. Dataquest believes that MCAD's rapid growth actually represents a rebound effect from earlier investment cutbacks. These were cutbacks undertaken by electronic and automotive companies that, in grappling with the yen's super-appreciation in 1986 and 1987, watched significant portions of their profit margins erode. During the next five years, even given conservative predictions of shifts from expensive host-based systems to systems based on PCs and technical workstations, average selling prices, hence overall market growth rates, will be lower.

AEC

The AEC market rose 41 percent between 1987 and 1988. Such a high growth rate in this market is understandable, given the lower workstation penetration rates. While lower AEC penetration rates also are the case in Japan, the market there specifically has benefited during the past three years from the government's economic policy aimed at expanding domestic demand through subsidization of, and aggressive investment by, the Japanese construction industry. The rapid growth of this market is forecast to moderate during the next five years.

Mapping

Mapping market revenue soared 75 percent in 1988. In Japan, high growth again was the by-product of low penetration and the government's economic policy regarding the encouragement of domestic demand. Considering the continuous requirement for mapping systems, not just in Japan but throughout Asia, the market is forecast to experience sustained high growth over the next five years.

EDA

The ECAE, IC, and PCB market segments in 1988 grew at 32 percent, 55 percent, and 38 percent, respectively. Major local vertically integrated electronic companies manufacture semiconductors in addition to computers, consumer electronics, and telecommunication equipment. These companies saw substantial profits in 1988, particularly in the memory market, where 1Mb DRAM chips commanded a price of more than $15 each. Aided by exchange rate stabilization, these windfall profits resulted in significant levels of reinvestment in R&D, particularly for EDA.

While continued high growth is forecast for each of EDA's three application areas, ECAE and IC layout markets will grow more rapidly than the PCB market. These applications are closely allied with the ASIC market in which growth is forecast at a 16.4 percent compound annual growth rate (CAGR) through 1994 and in which Fujitsu, NEC, Toshiba, and Hitachi, all major Asian EDA vendors, ranked first, second, fourth, and eighth, respectively, in 1988.

ASIAN FORECAST BY REGION

The following discussion is based on the data contained in Table 10.

Excluding Japan, market forecasting in the newly industrialized countries of Asia is largely based on macroeconomic forecasts for individual regions, because penetration rates at this stage are so low. The following factors summarize what we see as possibly affecting regional Asian CAD/CAM market growth in 1989.

Key factors in Japan include the following:

- Strong GDP growth in 1989
- Three percent consumption tax effective April 1, 1989
- Strong Tokyo stock market unaffected by the Recruit stock scandal
- Exchange rate stabilization driving aggressive investments
- High profit margins of semiconductor suppliers

- Steel and automotive companies enjoying a healthy business climate
- Prime rate of 2.5 percent to be raised to 3.0 percent in near future

Key factors in Korea include the following:

- Strong GDP rate coming off the Olympics
- Strong Seoul stock market after the Olympics
- Continued aggressive trade policy with U.S.S.R. and China
- Some degree of labor unrest and sabotage
- Aggressive investment plans in 1989 estimated at 9.16 trillion won in 1989, up 40.3 percent from 1988
- Key industries investing in CAD/CAM include automotive, electronics, steel, machinery, petrochemical, and aerospace companies

Key factors in China include the following items:

- Strong 10 percent growth well into the 1990s
- Stronger commercial ties with the Soviet Union will contribute to stronger commercial relations with South Korea
- Possible economic slowdown as management reform and new labor laws are installed
- Political instability leading to possible disruption of trade

ASIAN FORECAST BY PLATFORM

The following discussion is based on the data contained in Table 11.

All the top 20 Asian market leaders now offer technical workstation-based systems. Most vendors have begun to de-emphasize host-based systems in favor of technical workstations in order to conform to the rapidly evolving market structure.

Although all major computer vendors initially tried to develop their own technical workstation, the environment now has changed completely. For example, Sun now sells through local OEMs C. Itoh Scientific, Fujitsu, Nippon Steel, Seiko, and Toshiba. MIPS has similar agreements with Kubota, NEC, Sony, and Sumitomo Electric.

The possibility of M&A (merger and acquisition) activity continues to loom over the technical workstation market, as mainframe and minicomputer giants seek to absorb the leading-edge technology, which is at present the exclusive property of technical workstation vendors. In April 1989, Hewlett-Packard acquired Apollo Computer. The next M&A deal could well involve a major Japanese computer company seeking to recover market momentum. In any event, the UNIX world has forever upset the power balance that existed in the Asian CAD/CAM and computer markets.

ASIAN AVERAGE PRICE PER SEAT

The following discussion is based on the data contained in Table 12.

As in the previous five years, average selling prices are forecast to decline rapidly during the next five years. Specifically, expensive host-based systems will fall sharply due to marketwide pressure for lower prices. Asian end users, until now "captives" in a proprietary OS world, have been freed into the world of UNIX and MS-DOS, where they can be expected to choose the most cost-effective hardware solution from among many competing options.

ASIAN REVENUE SOURCE

The following discussion is based on the data contained in Table 13.

As end users switch to lower-priced technical workstations and PC-based systems, hardware, software, and service revenue for the less cost-effective host-dependent systems will decline during the forecast period. Conversely, technical workstation-related revenue is forecast to grow rapidly, given the greater number of available software packages and the implicit leap in hardware performance needed when upgrading to RISC architecture. Hardware and software revenue derived from PC-based systems is forecast to grow only until 1991, when networked technical workstations using UNIX will begin to encroach on the high-end PC market as well.

Many Asian market leaders still rely heavily on host-dependent system revenue, including IBM (84 percent of total revenue), Nihon Unisys (71 percent), Digital (66 percent), Toshiba (56 percent), Fujitsu (55 percent), and Hitachi (55 percent). We believe that these suppliers are attempting to balance their product offerings by offering a full line for hardware platforms.

We also believe that software revenue will grow at the fastest overall rate. The average selling price of software packages is virtually immune to erosion due to the unique nature of each package and to software vendors' ability to provide competitive differentiation. Hardware vendors, by contrast, are constrained from such differentiation by virtue of industry standard operating systems and architectures; hence, price decreases are inevitable. The CAGR of hardware remains half of that for software throughout the forecast.

ASIAN FORECAST BY DISTRIBUTION CLASS

The following discussion is based on the data contained in Table 14.

Given the current emphasis on standards and open architecture by vendors—and their increasing popularity among end users—unbundling, which refers to the ability of end users to purchase hardware and software from separate suppliers, is also destined to become popular. And, vendors themselves are beginning to recognize the inherent difficulties of developing and marketing both leading-edge software and leading-edge hardware products. Currently, technical workstations and PCs, as well as software packages for technical workstations and PCs, are mainly sold unbundled.

Yu Uemura
Tony Spadarella

Table 1

1988 Asian Market Share
(Millions of Dollars/Actual Units)

Company	Total Revenue	Hardware Revenue	Software Revenue	Wkstns Shipped	Market Share: Total Revenue	Market Share: Hardware Revenue	Market Share: Software Revenue	Market Share: Wkstns Shipped
IBM	486.3	296.5	123.3	12,038	17.6%	17.9%	15.5%	19.4%
Fujitsu	269.0	166.0	66.7	2,975	9.7%	10.0%	8.4%	4.8%
NEC	226.4	176.0	37.1	11,400	8.2%	10.6%	4.7%	18.4%
Hitachi	154.0	100.9	37.7	1,500	5.6%	6.1%	4.8%	2.4%
Nihon Unisys	138.5	96.9	31.9	700	5.0%	5.8%	4.0%	1.1%
Digital	117.0	95.8	.0	1,475	4.2%	5.8%	.0%	2.4%
Seiko Instruments	113.9	56.6	45.9	1,030	4.1%	3.4%	5.8%	1.7%
Mutoh Industries	94.0	50.1	28.6	1,489	3.4%	3.0%	3.6%	2.4%
Hitachi Zosen	77.0	38.7	30.7	932	2.8%	2.3%	3.9%	1.5%
Mitsubishi Electric	77.0	37.8	24.5	400	2.8%	2.3%	3.1%	.6%
Prime Computer	75.0	33.7	20.2	649	2.7%	2.0%	2.5%	1.0%
Mentor Graphics	74.0	26.6	32.6	1,044	2.7%	1.6%	4.1%	1.7%
Toshiba	69.8	42.0	14.3	1,250	2.5%	2.5%	1.8%	2.0%
Hewlett-Packard	64.2	41.0	13.2	2,324	2.3%	2.5%	1.7%	3.8%
Zuken	58.5	30.0	22.7	350	2.1%	1.8%	2.9%	.6%
C. Itoh Techno-Science	57.1	32.3	4.8	247	2.1%	1.9%	.6%	.4%
Sun	57.0	51.3	.0	2,709	2.1%	3.1%	.0%	4.4%
Daisy Systems	37.6	20.1	12.5	267	1.4%	1.2%	1.6%	.4%
Sharp System Products	36.2	15.9	16.7	100	1.3%	1.0%	2.1%	.2%
Intergraph	35.3	20.5	7.3	386	1.3%	1.2%	.9%	.6%
Tokyo Electron	32.2	9.1	9.2	80	1.2%	.5%	1.2%	.1%
Marubeni Hytech	29.2	9.8	16.5	45	1.1%	.6%	2.1%	.1%
Hakuto	27.0	13.5	10.7	300	1.0%	.8%	1.3%	.5%
Apollo	25.0	17.6	.0	2,000	.9%	1.1%	.0%	3.2%
McDonnell Douglas	23.5	8.9	8.2	249	.9%	.5%	1.0%	.4%
Valid	23.5	10.3	8.9	216	.9%	.6%	1.1%	.3%
Info. Services Int'l. Dentsu	20.0	2.3	13.9	30	.7%	.1%	1.8%	.0%
Sumisho Electronics	20.0	11.0	7.0	250	.7%	.7%	.9%	.4%
Innotech	19.2	.0	17.3	0	.7%	.0%	2.2%	.0%
Cadence	18.3	.0	15.8	0	.7%	.0%	2.0%	.0%
Mitsui Engineering	17.0	12.2	3.1	114	.6%	.7%	.4%	.2%
Toyo Information Systems	16.5	8.1	6.7	150	.6%	.5%	.8%	.2%
Asahi Optical	15.4	7.7	6.2	199	.6%	.5%	.8%	.3%

(Continued)

Table 1 (Continued)

1988 Asian Market Share
(Millions of Dollars/Actual Units)

Company	Total Revenue	Hardware Revenue	Software Revenue	Wkstns Shipped	Market Share: Total Revenue	Hardware Revenue	Software Revenue	Wkstns Shipped
Kyocera	3.8	.2	3.3	0	.1%	.0%	.4%	.0%
Zycad	3.5	3.1	.1	2	.1%	.2%	.0%	.0%
Nippon Kokan	3.5	.4	.3	0	.1%	.0%	.0%	.0%
LSI Logic	3.3	.6	2.4	11	.1%	.0%	.3%	.0%
Rikei	3.2	.7	2.3	0	.1%	.0%	.3%	.0%
Technovision	3.2	.0	3.2	0	.1%	.0%	.4%	.0%
ISICAD	2.1	1.2	.6	21	.1%	.1%	.1%	.0%
VLSI Technology	2.0	.3	1.5	26	.1%	.0%	.2%	.0%
Swanson Analysis	2.0	.0	2.0	0	.1%	.0%	.2%	.0%
Kubota Computer	1.5	.9	.5	20	.1%	.1%	.1%	.0%
ESRI	1.3	.1	1.0	2	.0%	.0%	.1%	.0%
Manufacturing Consultants	1.2	.0	1.0	0	.0%	.0%	.1%	.0%
Auto-Trol	1.0	.4	.3	12	.0%	.0%	.0%	.0%
Synercom	.7	.0	.4	0	.0%	.0%	.0%	.0%
Landmark Graphics	.6	.5	.0	5	.0%	.0%	.0%	.0%
PDA Engineering	.5	.0	.5	0	.0%	.0%	.1%	.0%
Calay	.4	.1	.3	5	.0%	.0%	.0%	.0%
Other Companies	264.3	186.9	107.8	11,069	9.6%	11.3%	13.6%	17.9%
All Companies	2,759.3	1,657.1	793.9	61,964	100.0%	100.0%	100.0%	100.0%
All U.S.-Based Companies	1,299.7	805.5	348.7	37,729	47.1%	48.6%	43.9%	60.9%
All Asian-Based Companies	1,437.8	840.2	437.5	24,122	52.1%	50.7%	55.1%	38.9%
All European-Based Companies	21.9	11.5	7.8	114	.8%	.7%	1.0%	.2%
All Hardware Companies	454.5	464.4	.5	37,693	16.5%	28.0%	.1%	60.8%
All Turnkey & SW Companies	2,304.8	1,192.8	793.5	24,271	83.5%	72.0%	99.9%	39.2%

Source: Dataquest June 1989

Table 2

1988 Asian Mechanical Market Share
(Millions of Dollars/Actual Units)

Company	Total Revenue	Hardware Revenue	Software Revenue	Wkstns Shipped	Market Share Total Revenue	Market Share Hardware Revenue	Market Share Software Revenue	Market Share Wkstns Shipped
IBM	427.2	256.4	111.1	9,084	25.5%	24.6%	24.7%	24.4%
NEC	140.7	111.0	21.5	7,095	8.4%	10.7%	4.8%	19.1%
Nihon Unisys	128.8	90.2	29.6	653	7.7%	8.7%	6.6%	1.8%
Hitachi	115.5	75.7	28.3	1,125	6.9%	7.3%	6.3%	3.0%
Fujitsu	107.6	66.4	26.7	1,297	6.4%	6.4%	5.9%	3.5%
Mutoh Industries	75.2	43.4	24.6	1,188	4.5%	4.2%	5.5%	3.2%
Hitachi Zosen	69.3	34.8	27.6	846	4.1%	3.3%	6.1%	2.3%
Digital	64.4	52.8	.0	811	3.8%	5.1%	.0%	2.2%
Prime Computer	55.7	25.5	14.6	491	3.3%	2.5%	3.3%	1.3%
Toshiba	52.6	30.0	10.9	1,010	3.1%	2.9%	2.4%	2.7%
Mitsubishi Electric	46.2	21.0	15.1	237	2.8%	2.0%	3.4%	.6%
Seiko Instruments	36.1	17.8	14.7	476	2.2%	1.7%	3.3%	1.3%
Hewlett-Packard	35.5	22.5	7.4	1,133	2.1%	2.2%	1.6%	3.0%
Tokyo Electron	27.6	8.3	8.3	53	1.6%	.8%	1.8%	.1%
Hakuto	24.3	12.1	9.6	270	1.5%	1.2%	2.1%	.7%
McDonnell Douglas	23.5	8.9	8.2	249	1.4%	.9%	1.8%	.7%
Sun	23.4	21.0	.0	1,111	1.4%	2.0%	.0%	3.0%
Info. Services Int'l. Dentsu	20.0	2.3	13.9	30	1.2%	.2%	3.1%	.1%
Sharp System Products	19.5	8.6	9.0	54	1.2%	.8%	2.0%	.1%
Sumisho Electronics	15.4	8.3	5.5	196	.9%	.8%	1.2%	.5%
C. Itoh Techno-Science	14.6	10.7	2.3	75	.9%	1.0%	.5%	.2%
Toyo Information Systems	13.2	6.4	5.4	120	.8%	.6%	1.2%	.3%
Mitsui Engineering	10.9	7.9	1.9	78	.6%	.8%	.4%	.2%
Intergraph	10.8	6.3	2.3	118	.6%	.6%	.5%	.3%
Hitachi Seiko	10.5	4.9	5.6	177	.6%	.5%	1.2%	.5%
Matra Datavision	10.1	7.5	1.0	86	.6%	.7%	.2%	.2%
Apollo	9.9	7.0	.0	795	.6%	.7%	.0%	2.1%
Graphtec Engineering	9.8	4.9	3.9	0	.6%	.5%	.9%	.0%
SDRC	8.4	.0	8.4	0	.5%	.0%	1.9%	.0%
Compaq	7.8	7.8	.0	1,488	.5%	.7%	.0%	4.0%
Schlumberger (Applicon)	7.7	1.3	4.2	38	.5%	.1%	.9%	.1%
Control Data	7.4	5.1	1.0	87	.4%	.5%	.2%	.2%
MacNeal-Schwendler	6.8	.0	6.8	0	.4%	.0%	1.5%	.0%

(Continued)

Table 2 (Continued)

1988 Asian Mechanical Market Share
(Millions of Dollars/Actual Units)

Company	Total Revenue	Hardware Revenue	Software Revenue	Wkstns Shipped	Market Share Total Revenue	Market Share Hardware Revenue	Market Share Software Revenue	Market Share Wkstns Shipped
Other Companies	131.4	112.8	42.6	6,132	7.8%	10.8%	9.5%	16.5%
All Companies	1,675.5	1,041.0	448.7	37,199	100.0%	100.0%	100.0%	100.0%
All U.S.-Based Companies	804.0	523.1	197.2	22,544	48.0%	50.2%	43.9%	60.6%
All Asian-Based Companies	861.5	510.4	250.5	14,570	51.4%	49.0%	55.8%	39.2%
All European-Based Companies	10.1	7.5	1.0	86	.6%	.7%	.2%	.2%
All Hardware Companies	263.8	274.9	.3	21,777	15.7%	26.4%	.1%	58.5%
All Turnkey & SW Companies	1,411.7	766.1	448.4	15,422	84.3%	73.6%	99.9%	41.5%

Source: Dataquest
June 1989

Table 3

1988 Asian AEC Market Share
(Millions of Dollars/Actual Units)

Company	Total Revenue	Hardware Revenue	Software Revenue	Wkstns Shipped	Market Share Total Revenue	Market Share Hardware Revenue	Market Share Software Revenue	Market Share Wkstns Shipped
Fujitsu	80.7	49.8	20.0	972	27.1%	24.3%	29.2%	9.4%
NEC	29.6	23.3	4.6	1,470	9.9%	11.4%	6.7%	14.2%
IBM	29.2	21.6	4.9	2,106	9.8%	10.5%	7.2%	20.4%
Hitachi	23.1	15.1	5.7	225	7.8%	7.4%	8.3%	2.2%
Digital	17.6	14.3	.0	221	5.9%	7.0%	.0%	2.1%
Intergraph	15.0	8.8	3.2	165	5.1%	4.3%	4.6%	1.6%
Mutoh Industries	11.3	4.0	2.4	181	3.8%	2.0%	3.5%	1.8%
Nihon Unisys	9.7	6.8	2.2	47	3.3%	3.3%	3.3%	.5%
Toshiba	9.0	6.3	1.8	125	3.0%	3.1%	2.6%	1.2%
Hewlett-Packard	7.9	5.3	1.5	413	2.6%	2.6%	2.1%	4.0%
Hitachi Zosen	7.7	3.9	3.1	46	2.6%	1.9%	4.5%	.4%
Mitsubishi Electric	7.7	4.3	1.9	54	2.6%	2.1%	2.7%	.5%
C. Itoh Techno-Science	6.7	4.9	1.1	32	2.3%	2.4%	1.7%	.3%
Prime Computer	6.3	2.7	1.9	65	2.1%	1.3%	2.8%	.6%
CPU	5.4	1.4	3.8	300	1.8%	.7%	5.5%	2.9%
Century Research Center	4.6	2.3	1.8	52	1.5%	1.1%	2.7%	.5%
Apple Computer	4.6	4.0	.0	1,064	1.5%	2.0%	.0%	10.3%
Apollo	3.8	2.6	.0	301	1.3%	1.3%	.0%	2.9%
Toyo Information Systems	3.3	1.6	1.4	30	1.1%	.8%	2.0%	.3%
Uchida Yoko	3.1	2.0	.8	0	1.0%	1.0%	1.2%	.0%
Compaq	2.7	2.7	.0	518	.9%	1.3%	.0%	5.0%
Hakuto	2.7	1.4	1.1	30	.9%	.7%	1.6%	.3%
Autodesk	2.5	.0	2.5	0	.8%	.0%	3.6%	.0%
Sun	2.1	1.9	.0	98	.7%	.9%	.0%	1.0%
ISICAD	1.8	1.0	.5	17	.6%	.5%	.7%	.2%
Sumisho Electronics	1.6	.9	.6	20	.5%	.4%	.8%	.2%
Andor	1.4	.3	1.1	15	.5%	.1%	1.6%	.1%
Seiko Instruments	1.0	.4	.4	54	.3%	.2%	.6%	.5%
Mitsui Engineering	.9	.6	.2	5	.3%	.3%	.2%	.0%
Sony	.6	.6	.0	36	.2%	.3%	.0%	.3%
CADAM	.6	.0	.6	6	.2%	.0%	.8%	.1%
Auto-Trol	.6	.3	.2	7	.2%	.1%	.2%	.1%

(Continued)

Table 3 (Continued)

1988 Asian AEC Market Share
(Millions of Dollars/Actual Units)

	Total	Hardware	Software	Wkstns	Market Share			
	Total	Hardware	Software	Wkstns	Total	Hardware	Software	Wkstns
Company	Revenue	Revenue	Revenue	Shipped	Revenue	Revenue	Revenue	Shipped
Design Automation	.5	.0	.5	0	.2%	.0%	.7%	.0%
Ustation	.5	.4	.1	99	.2%	.2%	.1%	1.0%
Kubota Computer	.4	.2	.1	5	.1%	.1%	.2%	.0%
Graphtec Engineering	.3	.1	.1	0	.1%	.1%	.2%	.0%
Control Data	.2	.1	.0	2	.1%	.1%	.0%	.0%
Other Companies	28.6	27.6	9.9	2,248	9.6%	13.5%	14.5%	21.8%
All Companies	297.8	204.8	68.3	10,328	100.0%	100.0%	100.0%	100.0%
All U.S.-Based Companies	106.5	85.6	16.8	6,699	35.8%	41.8%	24.5%	64.9%
All Asian-Based Companies	191.3	119.2	51.6	3,629	64.2%	58.2%	75.5%	35.1%
All European-Based Companies	.0	.0	.0	0	.0%	.0%	.0%	.0%
All Hardware Companies	66.4	71.6	.1	7,482	22.3%	35.0%	.1%	72.4%
All Turnkey & SW Companies	231.4	133.2	68.3	2,846	77.7%	65.0%	99.9%	27.6%

Source: Dataquest
June 1989

Table 4

1988 Asian Mapping Market Share
(Millions of Dollars/Actual Units)

Company	Total Revenue	Hardware Revenue	Software Revenue	Wkstns Shipped	Market Share Total Revenue	Market Share Hardware Revenue	Market Share Software Revenue	Market Share Wkstns Shipped
Fujitsu	26.9	16.6	6.7	324	22.5%	22.4%	22.2%	18.6%
Mitsubishi Electric	15.4	8.2	5.7	56	12.9%	11.0%	19.0%	3.2%
IBM	14.6	8.9	3.7	361	12.2%	12.0%	12.2%	20.7%
Digital	11.7	9.6	.0	147	9.8%	13.0%	.0%	8.5%
Hitachi	7.7	5.1	1.9	75	6.4%	6.8%	6.3%	4.3%
Mutoh Industries	7.5	2.7	1.6	120	6.3%	3.6%	5.3%	6.9%
Intergraph	7.3	4.2	1.5	80	6.1%	5.7%	5.1%	4.6%
Prime Computer	6.8	2.9	1.9	51	5.7%	3.9%	6.2%	2.9%
Mitsui Engineering	5.3	3.7	1.1	31	4.4%	5.0%	3.5%	1.8%
Uchida Yoko	3.8	2.4	1.0	0	3.2%	3.3%	3.3%	.0%
NEC	2.8	2.0	.6	19	2.3%	2.6%	1.9%	1.1%
Sun	1.6	1.4	.0	74	1.3%	1.9%	.0%	4.2%
Century Research Center	1.5	.8	.6	17	1.3%	1.0%	2.0%	1.0%
ESRI	1.3	.1	1.0	2	1.1%	.1%	3.3%	.1%
Toshiba	.8	.5	.2	10	.6%	.7%	.5%	.6%
Synercom	.7	.0	.4	0	.6%	.0%	1.2%	.0%
Landmark Graphics	.6	.5	.0	5	.5%	.6%	.0%	.3%
Autodesk	.4	.0	.4	0	.4%	.0%	1.4%	.0%
Apple Computer	.4	.3	.0	84	.3%	.4%	.0%	4.8%
Andor	.3	.1	.3	4	.3%	.1%	.8%	.2%
Hewlett-Packard	.2	.2	.0	29	.1%	.2%	.0%	1.6%
Other Companies	11.6	7.9	3.7	313	9.7%	10.6%	12.4%	17.9%
All Companies	119.7	74.1	30.0	1,745	100.0%	100.0%	100.0%	100.0%
All U.S.-Based Companies	51.6	32.7	10.7	1,133	43.1%	44.1%	35.7%	64.9%
All Asian-Based Companies	68.1	41.4	19.3	612	56.9%	55.9%	64.3%	35.1%
All European-Based Companies	.0	.0	.0	0	.0%	.0%	.0%	.0%
All Hardware Companies	17.7	16.3	.0	800	14.8%	22.0%	.0%	45.9%
All Turnkey & SW Companies	102.0	57.8	30.0	944	85.2%	78.0%	100.0%	54.1%

Source: Dataquest
June 1989

Table 5

1988 Asian EDA Market Share
(Millions of Dollars/Actual Units)

Company	Total Revenue	Hardware Revenue	Software Revenue	Wkstns Shipped	Market Share Total Revenue	Market Share Hardware Revenue	Market Share Software Revenue	Market Share Wkstns Shipped
Seiko Instruments	76.8	38.4	30.7	500	11.5%	11.4%	12.4%	3.9%
Mentor Graphics	74.0	26.6	32.6	1,044	11.1%	7.9%	13.2%	8.2%
Zuken	57.9	29.7	22.5	347	8.7%	8.8%	9.1%	2.7%
Fujitsu	53.8	33.2	13.4	382	8.1%	9.9%	5.4%	3.0%
NEC	53.4	39.8	10.5	2,815	8.0%	11.8%	4.2%	22.2%
Daisy Systems	37.6	20.1	12.5	267	5.6%	5.9%	5.0%	2.1%
C. Itoh Techno-Science	35.9	16.7	1.4	141	5.4%	5.0%	.5%	1.1%
Sun	30.0	27.0	.0	1,426	4.5%	8.0%	.0%	11.2%
Valid	23.5	10.3	8.9	216	3.5%	3.1%	3.6%	1.7%
Digital	23.4	19.1	.0	295	3.5%	5.7%	.0%	2.3%
Marubeni Hytech	23.1	7.6	13.2	35	3.5%	2.2%	5.3%	.3%
Hewlett-Packard	20.7	13.0	4.4	750	3.1%	3.9%	1.8%	5.9%
Innotech	19.2	.0	17.3	0	2.9%	.0%	7.0%	.0%
Cadence	18.5	.0	15.8	0	2.8%	.0%	6.4%	.0%
Sharp System Products	16.7	7.3	7.7	46	2.5%	2.2%	3.1%	.4%
Asahi Optical	15.4	7.7	6.2	199	2.3%	2.3%	2.5%	1.6%
IBM	15.3	9.6	3.7	486	2.3%	2.9%	1.5%	3.8%
Apollo	11.3	8.0	.0	904	1.7%	2.4%	.0%	7.1%
Racal-Redac	11.1	3.8	6.3	22	1.7%	1.1%	2.5%	.2%
Wacom	10.9	4.1	6.1	633	1.6%	1.2%	2.5%	5.0%
Kanematsu Semiconductor	8.5	3.5	4.2	65	1.3%	1.0%	1.7%	.5%
Futurenet	8.3	.0	7.0	0	1.2%	.0%	2.8%	.0%
Hitachi	7.7	5.1	1.9	75	1.2%	1.5%	.8%	.6%
Mitsubishi Electric	7.7	4.3	1.9	54	1.2%	1.3%	.7%	.4%
Toshiba	7.5	5.2	1.5	104	1.1%	1.5%	.6%	.8%
Scientific Calc.	7.2	1.3	3.8	28	1.1%	.4%	1.5%	.2%
Silicon Compiler Systems	7.0	.0	6.3	0	1.0%	.0%	2.5%	.0%
Yokogawa Electric	6.5	3.8	2.3	44	1.0%	1.1%	.9%	.3%
Prime Computer	6.1	2.7	1.8	42	.9%	.8%	.7%	.3%
Tokyo Keiki	5.4	2.2	2.7	25	.8%	.6%	1.1%	.2%
Uchida Yoko	5.3	3.4	1.4	85	.8%	1.0%	.6%	.7%
Silvar-Lisco	4.7	.0	3.2	0	.7%	.0%	1.3%	.0%

(Continued)

Table 5 (Continued)

1988 Asian EDA Market Share
(Millions of Dollars/Actual Units)

Company	Total Revenue	Hardware Revenue	Software Revenue	Wkstns Shipped	Market Share: Total Revenue	Market Share: Hardware Revenue	Market Share: Software Revenue	Market Share: Wkstns Shipped
Tokyo Electron	4.6	.8	.9	27	.7%	.2%	.4%	.2%
Kyocera	3.8	.2	3.3	0	.6%	.0%	1.3%	.0%
Zycad	3.5	3.1	.1	2	.5%	.9%	.0%	.0%
LSI Logic	3.3	.6	2.4	11	.5%	.2%	1.0%	.1%
Sumisho Electronics	3.0	1.8	.9	33	.5%	.5%	.4%	.3%
Sony	2.4	2.1	.0	146	.4%	.6%	.0%	1.2%
Compaq	2.3	2.3	.0	432	.3%	.7%	.0%	3.4%
Intergraph	2.2	1.2	.4	24	.3%	.4%	.2%	.2%
VLSI Technology	2.0	.3	1.5	26	.3%	.1%	.6%	.2%
CADAM	1.9	.0	1.7	4	.3%	.0%	.7%	.0%
Century Research Center	1.6	.8	.6	18	.2%	.2%	.3%	.1%
Autodesk	1.4	.0	1.4	0	.2%	.0%	.6%	.0%
Control Data	.9	.6	.1	10	.1%	.2%	.0%	.1%
Apple Computer	.8	.7	.0	175	.1%	.2%	.0%	1.4%
Ustation	.7	.6	.1	134	.1%	.2%	.0%	1.1%
Rikei	.6	.2	.3	0	.1%	.1%	.1%	.0%
Calay	.4	.1	.3	5	.1%	.0%	.1%	.0%
Andor	.3	.1	.3	4	.0%	.0%	.1%	.0%
Other Companies	92.6	38.6	51.6	2,375	13.9%	11.4%	20.9%	18.7%
All Companies	666.3	337.2	246.9	12,692	100.0%	100.0%	100.0%	100.0%
All U.S.-Based Companies	337.6	164.1	124.0	7,353	50.7%	48.7%	50.2%	57.9%
All Asian-Based Companies	316.9	169.2	116.0	5,311	47.6%	50.2%	47.0%	41.8%
All European-Based Companies	11.9	3.9	6.8	28	1.8%	1.2%	2.8%	.2%
All Hardware Companies	106.6	101.6	.1	7,633	16.0%	30.1%	.0%	60.1%
All Turnkey & SW Companies	559.8	235.7	246.8	5,058	84.0%	69.9%	100.0%	39.9%

Source: Dataquest
June 1989

Table 6

1988 Asian Electronic CAE Market Share
(Millions of Dollars/Actual Units)

Company	Total Revenue	Hardware Revenue	Software Revenue	Wkstns Shipped	Market Share: Total Revenue	Market Share: Hardware Revenue	Market Share: Software Revenue	Market Share: Wkstns Shipped
Mentor Graphics	53.4	19.0	23.7	862	21.9%	15.5%	26.7%	14.6%
Seiko Instruments	28.5	14.2	11.4	231	11.7%	11.6%	12.8%	3.9%
Daisy Systems	24.7	12.6	8.6	197	10.1%	10.2%	9.6%	3.3%
Marubeni Hytech	23.1	7.6	13.2	35	9.5%	6.2%	14.9%	.6%
NEC	21.8	15.6	5.0	1,206	8.9%	12.7%	5.6%	20.5%
Valid	18.7	8.3	7.1	199	7.7%	6.7%	8.0%	3.4%
Sun	16.6	14.9	.0	787	6.8%	12.2%	.0%	13.4%
Digital	11.7	9.6	.0	148	4.8%	7.8%	.0%	2.5%
Fujitsu	10.8	6.6	2.7	130	4.4%	5.4%	3.0%	2.2%
Hewlett-Packard	8.9	5.7	1.9	402	3.7%	4.6%	2.1%	6.8%
Zuken	8.8	4.5	3.4	45	3.6%	3.6%	3.9%	.8%
Futurenet	8.3	.0	7.0	0	3.4%	.0%	7.9%	.0%
Apollo	7.1	5.0	.0	565	2.9%	4.1%	.0%	9.6%
Wacom	5.1	1.9	2.9	239	2.1%	1.6%	3.2%	4.1%
Innotech	3.8	.0	3.5	0	1.6%	.0%	3.9%	.0%
Toshiba	3.7	2.6	.8	52	1.5%	2.1%	.8%	.9%
Zycad	3.5	3.1	.1	2	1.5%	2.5%	.1%	.0%
LSI Logic	3.0	.5	2.1	10	1.2%	.4%	2.4%	.2%
Cadence	2.7	.0	2.3	0	1.1%	.0%	2.6%	.0%
Silicon Compiler Systems	2.1	.0	1.9	0	.9%	.0%	2.1%	.0%
Tokyo Electron	1.8	.6	.6	8	.7%	.5%	.7%	.1%
VLSI Technology	1.7	.2	1.2	22	.7%	.2%	1.4%	.4%
Racal-Redac	1.5	.5	.8	3	.6%	.4%	.9%	.1%
IBM	1.1	1.1	.0	187	.5%	.9%	.0%	3.2%
Compaq	1.0	1.0	.0	192	.4%	.8%	.0%	3.3%
Silvar-Lisco	.9	.0	.6	0	.4%	.0%	.7%	.0%
Kanematsu Semiconductor	.9	.0	.8	0	.3%	.0%	.9%	.0%
Century Research Center	.8	.4	.3	9	.3%	.3%	.4%	.2%
Sony	.8	.7	.0	47	.3%	.5%	.0%	.8%
Control Data	.5	.4	.1	5	.2%	.3%	.1%	.1%
Intergraph	.4	.2	.1	4	.2%	.2%	.1%	.1%
Apple Computer	.2	.2	.0	53	.1%	.2%	.0%	.9%

(Continued)

Table 6 (Continued)

1988 Asian Electronic CAE Market Share
(Millions of Dollars/Actual Units)

Company	Total Revenue	Hardware Revenue	Software Revenue	Wkstns Shipped	Market Share Total Revenue	Market Share Hardware Revenue	Market Share Software Revenue	Market Share Wkstns Shipped
Ustation	.2	.2	.0	51	.1%	.2%	.0%	.9%
Other Companies	28.2	11.2	17.4	848	11.5%	9.2%	19.5%	14.4%
All Companies	244.1	122.5	88.8	5,893	100.0%	100.0%	100.0%	100.0%
All U.S.-Based Companies	183.9	89.6	67.3	4,140	75.4%	73.2%	75.7%	70.3%
All Asian-Based Companies	58.6	32.4	20.7	1,749	24.0%	26.4%	23.3%	29.7%
All European-Based Companies	1.5	.5	.8	4	.6%	.4%	.9%	.1%
All Hardware Companies	53.0	49.5	.0	3,641	21.7%	40.4%	.0%	61.8%
All Turnkey & SW Companies	191.1	73.0	88.8	2,252	78.3%	59.6%	100.0%	38.2%

Source: Dataquest June 1989

Table 7

1988 Asian IC Layout Market Share
(Millions of Dollars/Actual Units)

Company	Total Revenue	Hardware Revenue	Software Revenue	Wkstns Shipped	Market Share: Total Revenue	Market Share: Hardware Revenue	Market Share: Software Revenue	Market Share: Wkstns Shipped
Seiko Instruments	44.6	22.3	17.8	236	34.6%	48.6%	27.2%	18.5%
C. Itoh Techno-Science	32.1	14.2	.5	114	24.9%	31.0%	.8%	8.9%
Cadence	15.4	.0	13.1	0	12.0%	.0%	20.1%	.0%
Innotech	15.4	.0	13.8	0	11.9%	.0%	21.1%	.0%
Mentor Graphics	9.8	3.4	4.4	82	7.6%	7.5%	6.6%	6.4%
Sun	7.8	7.0	.0	369	6.0%	15.2%	.0%	28.9%
Fujitsu	5.4	3.4	1.3	100	4.2%	7.5%	2.0%	7.8%
Silicon Compiler Systems	4.9	.0	4.4	0	3.8%	.0%	6.7%	.0%
Daisy Systems	4.4	2.6	1.4	16	3.4%	5.6%	2.1%	1.3%
Kyocera	3.8	.2	3.3	0	2.9%	.3%	5.0%	.0%
Silvar-Lisco	3.8	.0	2.6	0	2.9%	.0%	3.9%	.0%
Digital	3.5	2.8	.0	44	2.7%	6.2%	.0%	3.5%
Valid	2.8	1.2	1.1	9	2.2%	2.7%	1.6%	.7%
Apollo	2.1	1.5	.0	169	1.6%	3.3%	.0%	13.3%
Wacom	1.5	.6	.8	70	1.2%	1.2%	1.3%	5.5%
Hewlett-Packard	1.2	.8	.3	28	.9%	1.7%	.4%	2.2%
Sony	1.0	.8	.0	63	.8%	1.8%	.0%	4.9%
Autodesk	.6	.0	.6	0	.5%	.0%	1.0%	.0%
Rikei	.6	.2	.3	0	.4%	.4%	.5%	.0%
Intergraph	.4	.2	.1	4	.3%	.4%	.1%	.3%
LSI Logic	.3	.1	.2	1	.3%	.1%	.4%	.1%
VLSI Technology	.3	.0	.2	4	.2%	.1%	.3%	.3%
Ustation	.2	.2	.0	49	.2%	.4%	.0%	3.9%
Control Data	.2	.1	.0	2	.1%	.2%	.0%	.2%
Prime Computer	.1	.0	.1	0	.0%	.0%	.1%	.0%

(Continued)

Table 7 (Continued)

1988 Asian IC Layout Market Share
(Millions of Dollars/Actual Units)

Company	Total Revenue	Hardware Revenue	Software Revenue	Wkstns Shipped	Market Share: Total Revenue	Hardware Revenue	Software Revenue	Wkstns Shipped
Other Companies	27.7	3.5	20.5	266	21.5%	7.6%	31.3%	20.8%
All Companies	128.9	45.8	65.5	1,275	100.0%	100.0%	100.0%	100.0%
All U.S.-Based Companies	66.6	21.4	33.9	811	51.7%	46.8%	51.7%	63.6%
All Asian-Based Companies	62.3	24.4	31.7	464	48.3%	53.2%	48.3%	36.4%
All European-Based Companies	.0	.0	.0	0	.0%	.0%	.0%	.0%
All Hardware Companies	16.0	13.9	.0	779	12.4%	30.4%	.0%	61.1%
All Turnkey & SW Companies	112.9	31.9	65.5	496	87.6%	69.6%	100.0%	38.9%

Source: Dataquest
June 1989

Table 8

1988 Asian PCB Layout Market Share
(Millions of Dollars/Actual Units)

Company	Total Revenue	Hardware Revenue	Software Revenue	Wkstns Shipped	Market Share Total Revenue	Market Share Hardware Revenue	Market Share Software Revenue	Market Share Wkstns Shipped
Zuken	49.1	25.2	19.0	302	16.7%	14.9%	20.6%	5.5%
Fujitsu	37.7	23.2	9.4	152	12.8%	13.7%	10.2%	2.8%
NEC	31.5	24.2	5.5	1,609	10.7%	14.3%	5.9%	29.1%
Sharp System Products	16.7	7.3	7.7	46	5.7%	4.3%	8.3%	.8%
Asahi Optical	15.4	7.7	6.2	199	5.2%	4.6%	6.7%	3.6%
IBM	14.2	8.5	3.7	299	4.8%	5.0%	4.0%	5.4%
Mentor Graphics	10.8	4.1	4.5	101	3.7%	2.5%	4.9%	1.8%
Hewlett-Packard	10.6	6.6	2.3	320	3.6%	3.9%	2.4%	5.8%
Racal-Redac	9.6	3.3	5.4	19	3.3%	1.9%	5.9%	.3%
Daisy Systems	8.6	4.9	2.5	54	2.9%	2.9%	2.7%	1.0%
Digital	8.2	6.7	.0	103	2.8%	4.0%	.0%	1.9%
Hitachi	7.7	5.1	1.9	75	2.6%	3.0%	2.0%	1.4%
Mitsubishi Electric	7.7	4.3	1.9	54	2.6%	2.6%	2.0%	1.0%
Kanematsu Semiconductor	7.7	3.5	3.5	65	2.6%	2.0%	3.7%	1.2%
Scientific Calc.	7.2	1.3	3.8	28	2.5%	.8%	4.1%	.5%
Yokogawa Electric	6.5	3.8	2.3	44	2.2%	2.3%	2.5%	.8%
Prime Computer	6.1	2.7	1.7	42	2.1%	1.6%	1.9%	.8%
Sun	5.7	5.1	.0	270	1.9%	3.0%	.0%	4.9%
Tokyo Keiki	5.4	2.2	2.7	25	1.8%	1.3%	2.9%	.5%
Uchida Yoko	5.3	3.4	1.4	85	1.8%	2.0%	1.5%	1.5%
Wacom	4.3	1.6	2.4	324	1.5%	1.0%	2.6%	5.9%
Seiko Instruments	3.8	1.9	1.5	33	1.3%	1.1%	1.6%	.6%
Toshiba	3.7	2.6	.8	52	1.3%	1.5%	.8%	.9%
C. Itoh Techno-Science	3.7	2.5	.8	27	1.3%	1.5%	.9%	.5%
Sumisho Electronics	3.0	1.8	.9	33	1.0%	1.1%	1.0%	.6%
Tokyo Electron	2.8	.2	.3	19	1.0%	.1%	.3%	.3%
Apollo	2.1	1.5	.0	169	.7%	.9%	.0%	3.1%
Valid	1.9	.8	.7	8	.7%	.5%	.8%	.2%
CADAM	1.9	.0	1.7	4	.6%	.0%	1.8%	.1%
Intergraph	1.5	.8	.3	16	.5%	.5%	.3%	.3%
Compaq	1.3	1.3	.0	240	.4%	.7%	.0%	4.3%
Century Research Center	.8	.4	.3	9	.3%	.2%	.3%	.2%

(Continued)

Table 8 (Continued)

1988 Asian PCB Layout Market Share
(Millions of Dollars/Actual Units)

					Market Share			
Company	Total Revenue	Hardware Revenue	Software Revenue	Wkstns Shipped	Total Revenue	Hardware Revenue	Software Revenue	Wkstns Shipped
Autodesk	.7	.0	.7	0	.3%	.0%	.8%	.0%
Sony	.7	.6	.0	36	.2%	.4%	.0%	.7%
Apple Computer	.5	.5	.0	123	.2%	.3%	.0%	2.2%
Calay	.4	.1	.3	5	.1%	.1%	.3%	.1%
Cadence	.4	.0	.3	0	.1%	.0%	.3%	.0%
Andor	.3	.1	.3	4	.1%	.0%	.3%	.1%
Control Data	.3	.2	.0	3	.1%	.1%	.0%	.1%
Ustation	.2	.2	.0	33	.1%	.1%	.0%	.6%
Other Companies	36.7	23.8	13.7	1,261	12.5%	14.1%	14.8%	22.8%
All Companies	293.3	168.9	92.5	5,524	100.0%	100.0%	100.0%	100.0%
All U.S.-Based Companies	87.0	53.1	22.9	2,401	29.7%	31.4%	24.7%	43.5%
All Asian-Based Companies	196.0	112.4	63.7	3,098	66.8%	66.6%	68.8%	56.1%
All European-Based Companies	10.3	3.4	6.0	25	3.5%	2.0%	6.4%	.4%
All Hardware Companies	37.6	38.2	.0	3,213	12.8%	22.6%	.0%	58.2%
All Turnkey & SW Companies	255.7	130.8	92.5	2,311	87.2%	77.4%	100.0%	41.8%

Source: Dataquest
June 1989

Table 9

Asian CAD/CAM Market by Application
(Millions of Dollars/Actual Units)

	1988	1989	1990	1991	1992	1993	CAGR
All Applications							
Revenue	2,759	3,191	3,601	3,821	4,107	4,422	9.9%
Systems	54,131	71,470	90,200	106,040	119,500	133,220	19.7%
Workstations	61,964	78,720	96,810	111,400	124,420	137,720	17.3%
Mechanical							
Revenue	1,676	1,861	2,029	2,053	2,159	2,264	6.2%
Systems	30,931	39,800	49,280	57,110	62,920	68,680	17.3%
Workstations	37,199	45,640	54,680	61,530	67,130	72,640	14.3%
AEC							
Revenue	298	360	401	419	422	440	8.1%
Systems	9,753	13,740	17,920	21,300	24,320	27,740	23.3%
Workstations	10,328	14,320	18,430	21,700	24,600	27,930	22.0%
Mapping							
Revenue	120	152	183	212	236	261	16.9%
Systems	1,431	1,950	2,480	2,980	3,460	4,010	22.9%
Workstations	1,745	2,280	2,800	3,280	3,720	4,240	19.4%
Electronic CAE							
Revenue	244	316	390	445	509	570	18.5%
Systems	5,795	7,750	10,190	12,670	15,230	17,650	24.9%
Workstations	5,893	7,810	10,230	12,690	15,260	17,670	24.6%
IC Layout							
Revenue	129	171	218	259	289	325	20.3%
Systems	1,248	1,890	2,520	2,910	3,290	3,650	23.9%
Workstations	1,275	1,900	2,520	2,910	3,290	3,650	23.4%
PCB Layout							
Revenue	293	330	380	433	492	563	13.9%
Systems	4,973	6,340	7,820	9,070	10,280	11,500	18.3%
Workstations	5,524	6,770	8,150	9,280	10,420	11,590	16.0%

Source: Dataquest
June 1989

Table 10

Asian Market by Region
(Millions of Dollars/Actual Units)

	1988	1989	1990	1991	1992	1993	CAGR
Asia							
Revenue	2,759	3,191	3,601	3,821	4,107	4,422	9.9%
Systems	54,131	71,470	90,200	106,040	119,500	133,220	19.7%
Workstations	61,964	78,720	96,810	111,400	124,420	137,720	17.3%
China							
Revenue	42	53	63	67	80	88	15.7%
Systems	787	1,340	1,840	2,240	2,650	3,120	31.7%
Workstations	1,088	1,640	2,170	2,560	3,030	3,510	26.4%
Hong Kong							
Revenue	41	48	55	59	65	70	11.1%
Systems	927	1,520	1,950	2,290	2,580	2,880	25.4%
Workstations	1,194	1,700	2,120	2,440	2,750	3,040	20.6%
Japan							
Revenue	2,531	2,917	3,287	3,459	3,720	4,005	9.6%
Systems	49,607	63,990	80,400	94,100	105,720	117,400	18.8%
Workstations	55,887	69,810	85,560	97,870	109,080	120,410	16.6%
Korea							
Revenue	68	81	91	122	113	124	12.9%
Systems	1,320	2,130	2,760	3,390	3,920	4,520	27.9%
Workstations	1,766	2,570	3,200	4,050	4,390	5,000	23.1%
Singapore							
Revenue	26	32	37	41	45	46	12.6%
Systems	517	855	1,143	1,399	1,604	1,814	28.5%
Workstations	676	1,028	1,320	1,575	1,791	1,978	24.0%
Taiwan							
Revenue	50	60	68	73	85	89	12.3%
Systems	972	1,637	2,120	2,613	3,036	3,496	29.2%
Workstations	1,353	1,960	2,439	2,906	3,372	3,785	22.8%

Source: Dataquest
June 1989

Table 11

Asian Market by Platform
(Millions of Dollars/Actual Units)

	1988	1989	1990	1991	1992	1993	CAGR
All Platforms							
Revenue	2,759	3,191	3,601	3,821	4,107	4,422	9.9%
Systems	54,131	71,470	90,200	106,040	119,500	133,220	19.7%
Workstations	61,964	78,720	96,810	111,400	124,420	137,720	17.3%
Technical Workstation							
Revenue	1,101	1,527	2,002	2,412	2,794	3,186	23.7%
Systems	15,523	23,800	34,300	44,880	56,120	67,080	34.0%
Workstations	15,524	23,800	34,300	44,880	56,120	67,080	34.0%
Host-Dependent/Server							
Revenue	1,184	1,147	1,054	856	790	732	-9.2%
Systems	2,312	2,610	2,660	2,400	2,470	2,510	1.7%
Workstations	10,145	9,860	9,270	7,760	7,380	7,000	-7.2%
Personal Computer							
Revenue	475	517	545	552	524	505	1.2%
Systems	36,295	45,060	53,240	58,760	60,910	63,640	11.9%
Workstations	36,295	45,060	53,240	58,760	60,910	63,640	11.9%

Source: Dataquest
June 1989

Table 12

Asian Average Selling Price
(Thousands of Dollars)

	1988	1989	1990	1991	1992	1993	CAGR
Turnkey & Hardware-Only							
Technical Workstation	53.1	46.7	41.4	36.9	33.0	30.5	-10.5%
Host-Dependent/Server	425.1	355.1	316.2	280.7	247.4	222.3	-12.2%
Personal Computer	10.8	9.3	8.2	7.5	6.8	6.1	-10.8%
All Platforms	40.7	34.4	29.9	26.1	24.1	22.5	-11.2%
Turnkey							
Technical Workstation	82.1	76.5	71.4	66.9	63.4	62.3	-5.4%
Host-Dependent/Server	623.9	585.4	545.2	524.5	492.9	464.0	-5.8%
Personal Computer	27.7	25.5	23.1	21.5	20.1	18.3	-8.0%
All Platforms	99.1	90.8	83.2	73.5	68.3	65.8	-7.9%
Hardware-Only							
Technical Workstation	16.7	15.2	13.8	12.5	11.4	10.9	-8.2%
Host-Dependent/Server	150.8	123.2	111.6	103.3	99.3	95.6	-8.7%
Personal Computer	6.2	6.2	6.1	5.8	5.3	5.0	-4.2%
All Platforms	12.1	11.3	10.5	9.6	9.2	8.9	-6.0%

Source: Dataquest
June 1989

Table 13

Asian Revenue Source
(Millions of Dollars)

	1988	1989	1990	1991	1992	1993	CAGR
All Platforms							
Hardware	1,657	1,795	1,960	2,003	2,070	2,149	5.3%
Software	794	1,006	1,197	1,343	1,520	1,711	16.6%
Service	337	390	443	474	517	562	10.8%
Total	2,759	3,191	3,601	3,821	4,107	4,422	9.9%
Technical Workstation							
Hardware	574	771	983	1,143	1,276	1,408	19.7%
Software	363	537	733	926	1,120	1,326	29.6%
Service	157	218	286	343	397	452	23.5%
Total	1,101	1,527	2,002	2,412	2,794	3,186	23.7%
Host-Dependent/Server							
Hardware	732	700	635	514	469	431	-10.1%
Software	298	293	277	226	215	203	-7.4%
Service	161	154	142	116	106	98	-9.5%
Total	1,184	1,147	1,054	856	790	732	-9.2%
Personal Computer							
Hardware	351	324	342	346	325	311	-2.4%
Software	133	176	187	192	185	182	6.3%
Service	19	17	16	15	13	12	-8.0%
Total	475	517	545	552	524	505	1.2%

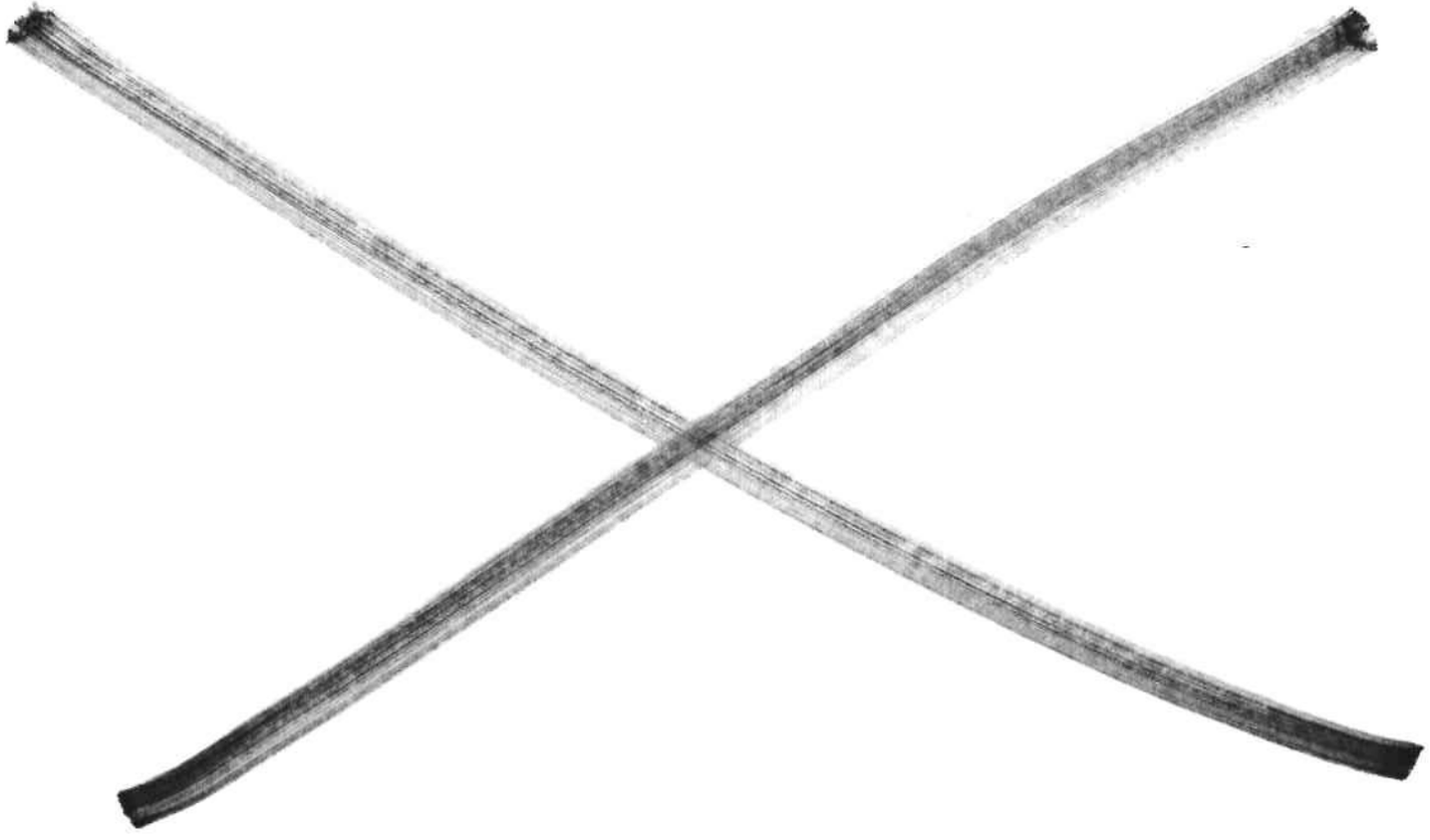
Source: Dataquest
June 1989

Table 14

Asian Turnkey Versus Unbundled
(Millions of Dollars/Actual Units)

	1988	1989	1990	1991	1992	1993	CAGR
Total Hardware and Software Revenue							
Turnkey	1,746	1,943	2,074	2,088	2,139	2,184	4.6%
Unbundled	705	858	1,083	1,258	1,451	1,676	18.9%
Total	2,451	2,801	3,158	3,347	3,590	3,861	9.5%
Hardware Revenue							
Turnkey	1,193	1,278	1,339	1,324	1,333	1,340	2.4%
Unbundled	464	517	621	679	737	809	11.8%
Total	1,657	1,795	1,960	2,003	2,070	2,149	5.3%
Software Revenue							
Turnkey	553	665	735	764	806	844	8.8%
Unbundled	241	341	462	579	714	867	29.2%
Total	794	1,006	1,197	1,343	1,520	1,711	16.6%
Workstation Shipments							
Turnkey	24,271	26,870	29,580	31,700	33,960	35,190	7.7%
Unbundled	37,693	51,850	67,230	79,700	90,460	102,520	22.2%
Total	61,964	78,720	96,810	111,400	124,420	137,720	17.3%

Source: Dataquest
June 1989



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Research Newsletter

PC DEALERS: CAN ANYONE SPARE A DIME?

EXECUTIVE SUMMARY

This newsletter presents an analysis of the state of the entire US PC dealer channel, with emphasis on retail operations selling to commercial applications. Many of the observations presented here also apply to CAD/CAM/CAE resellers. We will complete this analysis next month, when we will publish a detailed study of leading CAD/CAM/CAE resellers, based on our November 1990 survey.

In early September, hundreds of PC dealers, vendors, and industry luminaries swooped down on New Orleans, Louisiana, to try to sort out some of the reseller channel's nagging problems—namely, untapped business, eroding profit, poor technology training, market segmentation, and market development funds.

The occasion that marked the gathering was the three-day annual convention of ABCD: The Microcomputer Industry Association, a member organization for nearly every type of major PC reseller, including franchisees, value-added resellers (VARs), distributors, and independent dealers.

Without a doubt, the most pressing problem facing PC dealers and computer makers right now is the severe profit crunch swarming all over the channel. Frankly, many dealers are not making any money and do not believe that they will be able to survive financially into the middle part of this decade.

This is an opinion with which Dataquest agrees. We project that half of the current roster of 4,500 storefront dealers will be out of business by 1994. Simply put, selling PC products for a living, when viewed as a return on investment, is a losing proposition for many dealers, and it might not get better soon.

NO ANSWERS—AT LEAST NOT YET

One unsightly aspect of a declining gross profit margin for resellers is the growing rift between manufacturers and dealers. Most vendors put the lion's share of blame on resellers' backs for not turning five bucks into ten, while dealers accuse vendors of refusing to downscale their own profit to help the channel. What dealers want is more support money. What vendors want is a clean, profitable channel—but only if they can get it without sacrificing too much.

For example, when Businessland Inc. began to lose money last year, the chain complained that Compaq Computer Corp.'s refusal to give Businessland more support dollars than its rivals had a hand in the reseller's undoing. Businessland's point—that its margins were inadequate to support the services its vendors/suppliers would like—was probably a valid one.

Generally speaking, when pressed, manufacturers acknowledge that their gross margin is usually double that of the most flush dealer, but they claim that the funds are needed for cutting-edge research and development. Apple Computer Inc. has long been fond of defending its high gross margin with that argument, but to dealers struggling to pay their bills, it is a hollow claim.

One of the worst parts of the whole profitability morass is that with dealer profits at an all-time low, resellers and distributors are faced with abandoning the idea of boosting margins by selling margin-rich high-end computers. Often, high-end gear requires special training to use. Resellers can take advantage of that requirement with some clients and charge extra for the training, which helps margins. The whole scenario is a potentially profitable business model that many manufacturers are advocating as one answer for dealers.

But unless things improve, dealers may be forced as a group to sell only the products they can

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afford to sell, which bodes ill for new players trying to gain entry into the channel.

SOME POSSIBILITIES

Obviously, by now it should be clear that no quick fix miraculously curing all dealers' problems is going to appear on the horizon. Still, there are some working solutions that could provide direction.

For the most part, dealers and vendors are working with a ten-year-old model for their relationship that has become outmoded and ineffective. For the last ten years, multitiered pricing has driven the reseller side of the industry, meaning that the more a dealer buys from a manufacturer, the deeper the dealer's discount becomes. But that scheme has inhibited the channel's ability to build capital resources and forced it to discount products heavily to move inventory.

Hence, the channel and manufacturers must redefine how they work with customers. Right now, customers tend to view the channel as a source of hardware and not as an avenue for gaining technical expertise, service, or support. Customers buy service and support but not usually from PC resellers. That equation translates into low margin and meager profit.

DATAQUEST PERSPECTIVE

What follows are a few suggestions for arresting the downward spiral in which dealers and manufacturers are trapped:

- Ten years ago, the channel was built with the idea of achieving market share, both for vendors and dealers. The notion of shared profitability was as foreign then as high margin is now. But now dealers need to be encouraged in a different way by asking them to rely less on moving hordes of boxes and more on adding value—and margin—to a sale. Manufacturers and dealers need to compile a long-term road map for working together, rather than rely on a quarter-by-quarter evaluation or some other outdated method of evaluation.
- Success in the channel will come to those vendors and resellers that understand the impact of certain products in the marketplace and are able to gauge user demand correctly. In short, dealers need to sell only those products they can afford to sell and not the ones they cannot abide.
- Dealers and manufacturers must work in concert and not in opposition for the multimillion-dollar service business, much of which is being left on the table. Dealers' strategic focus should be on the service and support business, and, if need be, manufacturers have to push this opportunity on dealers. Bluntly put, customers have unbundled service from product purchases—they usually do not buy service from a dealer—and resellers will need to work hard to gain some of that business.
- The authorization process, by which a vendor grants a dealer the right to sell its products, needs to be revamped. At the very least, manufacturers must segment dealers by market and perhaps also by products offered. Not everyone can chase the same fly ball. Adding value through some kind of market or product expertise should be the overriding factor as to why an outlet gets authorized.
- Overdistribution is no longer an issue in diluting dealer profits. Rarely does a dealer face competition down the street and around the corner that drives prices ever lower. The leading three vendors—Apple, Compaq, and IBM—all have pared their dealer rosters considerably in the last few years. More cuts will come, but the idea that reducing the number of dealers will solve profitability issues is not sound thinking.
- Dealer survival has become a skills game, and manufacturers must absorb some of the burden for teaching resellers some business tactics.
- Confining dealers' use of market development funds to certain activities such as building a service and support unit or other similar actions is ridiculous. If dealers need the money to prop up a sagging bottom line, they should be allowed to do so. Fixing some greater ills will arrest the alleged misuse of support dollars by dealers.

Taken together, these seven suggestions do not constitute a quick answer. But if these suggestions can get dealers and vendors working together, admittedly a highly dubious proposition, the road to dealer profitability can be made less bumpy.

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Kathryn Hale
Douglas H. Kass

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Research *Bulletin*

SILICON GRAPHICS FUELS PCS WITH WORKSTATION-CLASS 3-D GRAPHICS

INTRODUCTION

The next two weeks appear to be the time for every major workstation vendor to strut its stuff. Silicon Graphics (SGI) is not to be left out. On October 30, SGI announced its new IRISVISION 3-D graphics board. The day before, the company announced the 4D/310, a new low end to its Power Series. And, last week, SGI announced the 4D/35 upgrade to the Personal Iris.

This bulletin summarizes the recent announcements by SGI and provides Dataquest's analysis of the IRISVISION product.

SUMMARY OF ANNOUNCEMENTS

The IRISVISION is a high-resolution graphics adapter card designed for either the MicroChannel or the AT bus. The board utilizes SGI's proprietary geometry engine and six companion VLSI chips. It can support 8- or 24-bit color, requires either a 386 or 486 processor, and occupies two expansion slots. The suggested retail price for the AT version of IRISVISION/8 is $3,495, and IRISVISION/24 is $4,995. The suggested retail price for the MicroChannel version is $3,995. The board will be available in January 1991 in the United States and in the second quarter of 1991 internationally. Also announced with IRISVISION was an AutoCAD Rel. 11 ADI driver that allows AutoCAD users to render and manipulate DXF files.

The 4D/310 is the new low end to the Power Series. It is based on the 33-MHz R3000. The price ranges from $24,900 for the server configuration to $74,900 for the 4D/310 VGX. Along with this announcement, SGI lowered the price of the 4D/85 to $29,900 and the rest of the 4D/300 series by as much as 28 percent. For example, the top-of-the-line 4D/380S now sells for $144,900.

The 4D/35, announced on October 22, is an upgrade to the Personal Iris. The upgrade includes not only a faster CPU (35-MHz R3000A) but also a faster system bus (30 MHz and a 120-MB/sec. peak) and increased memory size (up to 128MB). The 4D/35 will be available in the first quarter of 1991. The 4D/35 upgrade is available for $5,000 with the purchase of a new 4D/25 and $9,000 for existing 4D/20 and 4D/25 customers. No system price has been announced.

DATAQUEST ANALYSIS

SGI always has been known as a premier 3-D graphics vendor. Yet this reputation also was a weakness; the company was thought of as a niche player. In order to expand its market presence, SGI either had to stimulate demand for high-end graphics or offer a 2-D workstation that represented a much larger percentage of the workstation market. With the IRISVISION, the company has chosen not to dismiss its competitive advantage but to extend its 3-D capabilities into a new market segment—the personal computer market.

By offering a 3-D graphics-board product for the personal computer market, the company has greatly expanded its potential market opportunities. Dataquest estimates that, in 1989, 366,000 high-end graphics boards were sold for personal computers—more than the total 295,000 2-D and 3-D workstations sold in that same year.

In addition to the VGA pass-through capabilities, SGI has made available to the personal computer user graphics capabilities previously found only on the workstation. The immediate beneficiaries will be the technical PC users of applications such as computer-aided design. But by making the graphics power available to a large

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creative software development community, the potential for future high-end graphics applications for even nontechnical users is much greater.

Although there are short-term advantages to IRISVISION, Dataquest sees it primarily as a very good strategic product for SGI. As the computer market moves toward standards, each company must look hard not only at how it can differentiate itself but also at how it can leverage its proprietary products into becoming a standard instead of into becoming obsolete. With this product, SGI is continuing its attempt to establish its proprietary Graphics Library (GL) as a standard.

The company is maneuvering along the double-edged sword of standards very well. SGI does not have the volume to make GL a de facto standard. Therefore, the company must choose its partners carefully—and it did. SGI chose two areas that have the size or potential size to make GL a standard—IBM and the personal computer market. If SGI is successful with this strategy, then it will have gained more than it lost. The company still will retain its competitive edge with its hardware, which is optimized for the Graphics Library, and it will gain an increased application software base, an increased customer base, and a new source of revenue—board-level products.

In addition, by offering a graphics board instead of a complete low-end system, SGI has minimized the market risks and R&D investment associated with entering the Intel 80x86 world. But the company still will gain the benefits of further developing its distribution channels and developing the knowledge base necessary for when it does offer a low-priced workstation. As prices decline for workstations, distribution channels will become more important. An October 1990 CAD distributor and value-added reseller (VAR) study conducted by our CAD/CAM Industry Service (CCIS) shows that only 6 percent of the companies surveyed are CAD dealers of SGI products, compared with 26 percent that sell Sun Microsystems' products. Clearly, this is an area that SGI needs to strengthen.

In conclusion, the distinction between a personal computer and a workstation gets more hazy with the announcement of the IRISVISION. For some PC users, the need to upgrade to a workstation has been eliminated. For other users, this product provides an entry point to high-end graphics. Either way, SGI is positioning itself to be there. The primary challenges the company faces are further developing its distribution channels, recruiting software developers, and working closely with the independent software vendors during development or porting of applications to its Graphics Library.

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Laura C. Segervall

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Research Newsletter

THE i486—WHY ALL THE COMMOTION?

The Intel 80486 has arrived. Will it challenge the workstations? What will it do to the 80386 machines? This newsletter explores the i486 and its impact on the PC market both today and in the future.

THE 80486

Intel, in developing the 80486 series, has maintained binary compatibility. This is both an advantage and a handicap. Maintaining compatibility takes advantage of the vast array of software available for the 80XXX series. However, this restricts the design of the chip to the problems associated with descriptor tables, real mode, and protected mode. In essence, the i486 is a repackaging of the i386 and 387 in one case with some substantial refinements to increase speed. By adding cache memory in the chip and streamlining the instruction execute cycle time for most common instructions, the i486's performance is two to four times greater than the i386's.

Since the 80286-based PC is still the largest seller both in the United States and worldwide, where does the new i486 system fit? If yearly unit sales of PCs using the Intel series of processors are plotted and normalized as in Figure 1, we see a distribution curve slowly moving toward the high end over time. The high-end fringe always has room for the fastest, most advanced systems. The introduction of the i486 is aimed at applications at this end for a variety of reasons.

First and foremost, the cost of the chip is roughly 4 times that of the high-end i386, which is 10 times the cost of the mainstream 80286. Translating this cost to the end user places the system in a specialized mode. The most value for the end user may be obtained by pairing the most costly chip with additional hardware so that users receive what they pay for. A simple analogy for this is that the most expensive features are added to the most expensive car. Adding leather upholstery to a Cadillac is proportionally less expensive than adding it to a Pinto. Therefore, users first will see the i486 in tower systems with large disk drives. As the price of the chip drops, desktop systems will be more common.

Second, applications exist that demand the fastest possible speed. These primarily are multiuser systems, running either terminals or server systems for a network. As the PC evolves naturally, multiuser/multitasking functions will increase in importance. For the short term, however, these applications are limited.

Third, workstation-type applications have been developed for the PC that satisfy many of the requirements of workstation users. Any increase in speed is welcomed if more applications can be ported to the PC and therefore defray the cost of true workstations. This raises the question of whether the 80486 now rivals the low-end workstations and minicomputers.

THE IMPACT OF COST

Although some manufacturers like IBM have i486 desktop systems now, the most prevalent packaging style is the tower. As the cost of the i486 declines, it will emerge as single-user systems in desktop and portable packaging styles. Motherboard manufacturers already have i486 boards available, so it is a matter of time before the smaller manufacturers are competing in price in this market. This will place even more of a downward price pressure on the i386DX products. Figure 2 indicates Dataquest's expected average selling prices (ASPs) of i386 and i486 systems. (Inflation has not been allowed for.)

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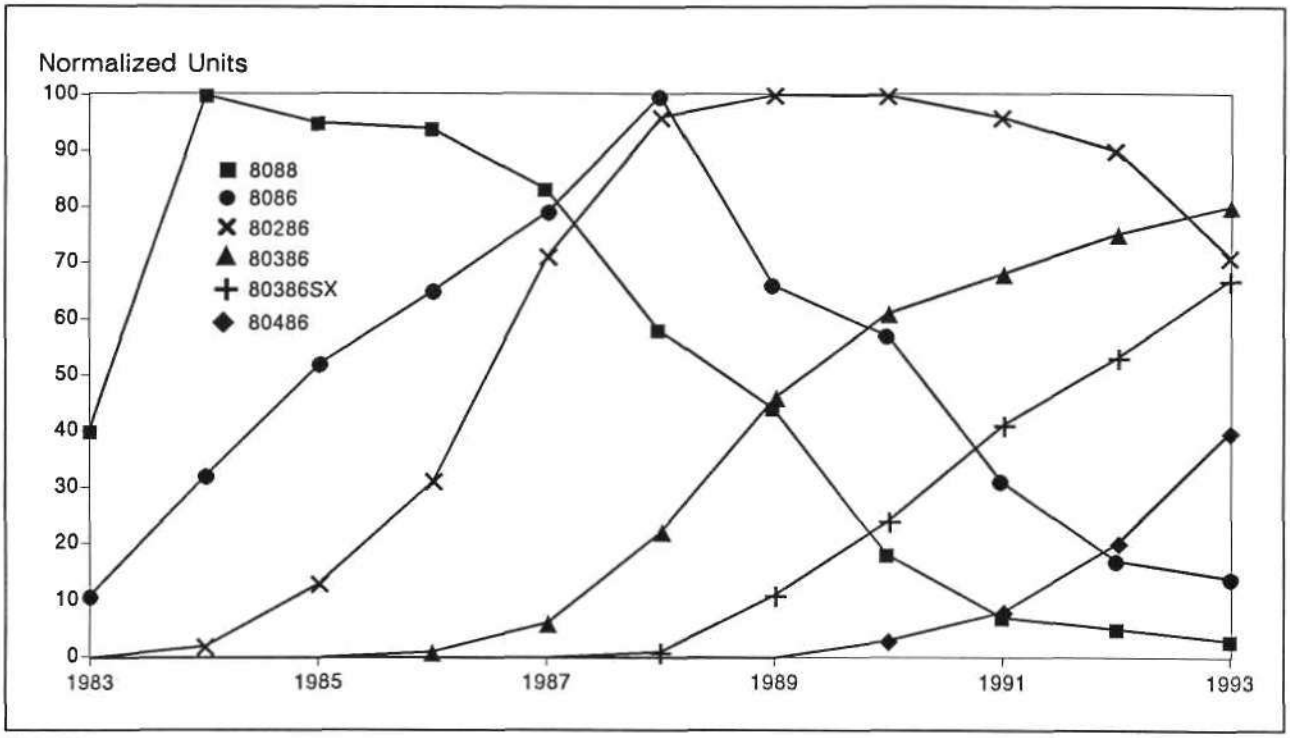
FIGURE 1
80XXX Distribution Curves



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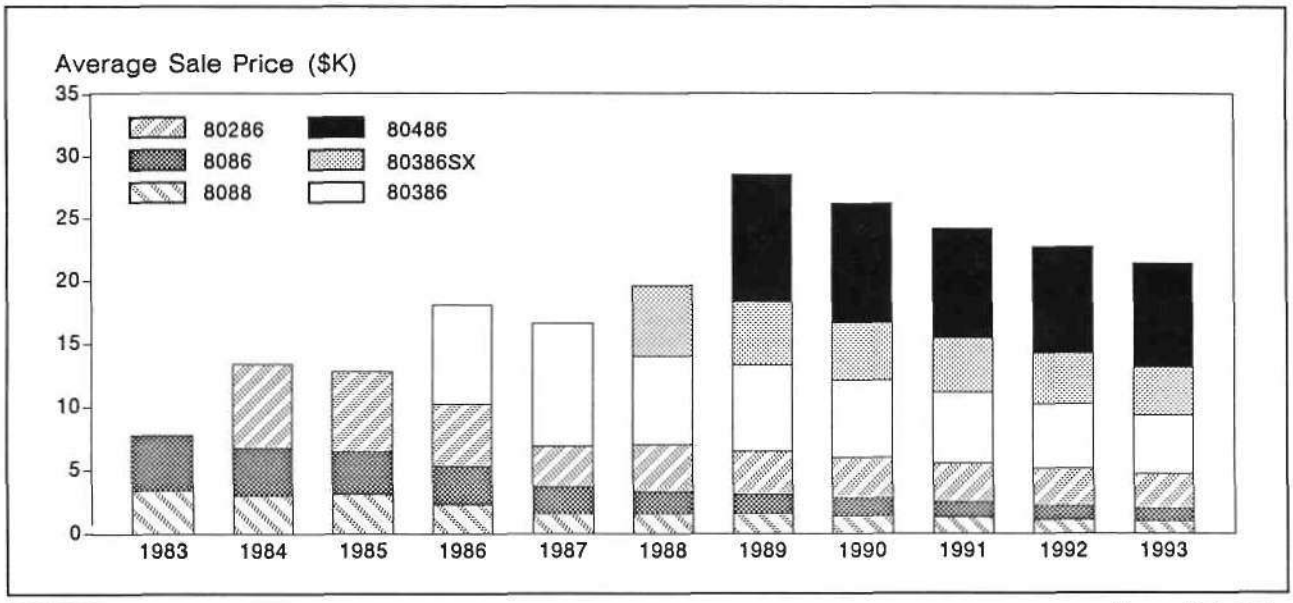
Source: Dataquest
March 1990

FIGURE 2
U.S. ASP of 80XXX PCs (No Compensation for Inflation)



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Source: Dataquest
March 1990

THE IMPACT OF SPEED

The evolution of the microprocessors and speeds has generated an extremely complicated array of segments within the PC industry. Is a fast i286 faster than a slow i386? Will the 20-MHz i386SX surpass the 16-MHz i386DX? How will the i486 affect the market? The EISA and MCA buses compound the confusion, so determining how the market will evolve becomes a difficult task.

Clearly, not all of the speed segments can survive. We see this with the decline of 16- and 20-MHz 80386 sales. The process is not one of clean crossovers, however. Users may be classified as those who need pure speed, regardless of the cost, and those who want the speed but are cost-conscious. This simplistic look states that a number of 33-MHz i386 sales will become 80486 sales instead as systems become available. This loss of sales in the 33-MHz segment will be soon filled in as price pressures place this segment within reach of new users. This migration will continue as users move up the speed path. Dataquest has noted that users tend to maintain the level of prices they are willing to pay, opting for more features instead of lower prices (see Figure 2).

THE IMPACT ON WORKSTATIONS AND MINIS

On Minis

Dataquest does not see the 80486 (single or multiuser systems) playing in the minicomputer market in the near future. There are several major reasons for this statement. First is the lack of minicomputer-level software available to exploit the power of the 80486. For example, on-line transaction processing (OLTP) is an important application in the mini world. At the moment, no software exists to allow OLTP applications to run on either the new- or the older-technology microcomputers. The only application area PCs can use to compete in the mini market is the departmental file server or network manager.

Secondly, Dataquest does not believe that a typical mini user would refrain from purchasing a mini to purchase a PC system that functions only as a file server. The investment would not satisfy the user's need for multiple applications (including file server, manufacturing control, and OLTP) and the ability to use the installed base of minicomputer software. In the future, as the PC architecture evolves with the introduction of minicomputer features and the availability of high-performance, multiuser software, the PC will become a force to be reckoned with.

On Workstations

The 80486-based PC is ideally suited to pick off another segment previously reserved for workstations. As stated, low-end applications already have migrated into the PC platform. Dataquest expects this to continue when the PC can satisfy the low-end requirements of a workstation application. Single-processor PCs are already making inroads. For example, the IBM Model 80 and the Compaq Deskpro 386 are being used by some businesses in high-performance, single-user applications (DTP, CAD, and multimedia). In addition, some of these machines have been put to use as file servers and network managers. Dataquest believes that using PCs in workstation applications has many advantages, including price/performance, Intel 80XXX compatibility, and software installed-base compatibility.

DATAQUEST CONCLUSIONS

Most importantly, the 80486 will provide more of the same. In other words, Dataquest expects the i486 to provide the next progressive step in the continual migration up the speed-performance ladder.

Second, applications that can satisfy 90 percent of a user's needs will migrate from the workstation environment and find a place with the i486—much like the low-end CAD/CAM programs available today on MS/PC-DOS products.

Third, the mini market is safe from intrusion due to the investment in software and peripheral products. Although raw speed may be compared, other factors make any attempt at a true comparison ludicrous.

THE FUTURE

What can we expect from the future? The PC architecture itself will change by decoupling the I/O bus from the processor, memory, cache, graphics, and so on. Copying computer architectures from minicomputers will occur in much the same way that the mini copied the mainframe. As this occurs, we truly will obtain the multitasking and/or multiuser PCs that are hinted at today. Today, however, we must be content with more of the same.

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Robert Charlton

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Research Newsletter

SUCCESS IN THE CAD/CAM/CAE DEALER CHANNEL

EXECUTIVE SUMMARY

Distribution channels are now a strategic weapon in marketing CAD/CAM/CAE products. A continuing drop in system selling prices combined with Autodesk's phenomenal success building a worldwide CAD dealer network have caused the entire CAD/CAM/CAE industry to begin focusing on more efficient ways to sell products. Still unknown is whether the existing dealer channel has the capacity to meet the potential demand. This newsletter analyzes today's CAD VARs and dealers, based on a recent Dataquest survey.

DEFINITIONS

A few quick definitions are necessary: a VAR (value-added reseller) is a vendor that primarily resells another company's product. In the CAD market, the terms VAR and dealer are interchangeable, because only a small portion of (typically low-priced) CAD is sold through classic storefront dealers counting on walk-in trade.

These resellers, the VARs and dealers, are fundamentally different from the ISV (independent software vendor), which owns the software copyright, or the OEM, which takes ownership by relabeling another vendor's product before sale.

THE GROWING VAR/DEALER CHANNEL

In 1989, VARs and dealers sold approximately 13 percent of all CAD/CAM/CAE products. Although vendors vary in their dependence on VARs and dealers (from 100 percent of both Autodesk's and Compaq's sales to less than 5 percent each of sales from Intergraph and Sun Microsystems, Inc.), all CAD vendors are looking to the VAR/dealer channel for increased future support.

CAD/CAM/CAE is now an established component within the entire VAR/dealer channel, with an estimated 10 percent of all VARs claiming to sell design automation products. While CAD is a finite market, the application offers dealers higher profit margins and less competition than would be found reselling mainstream business applications. Most existing CAD dealers began as PC-based Autocad dealers, but many have expanded their range of products within the design automation market.

TODAY'S CAD DEALERS

Dataquest recently completed another comprehensive survey of the U.S. CAD VAR/dealer channel (a similar survey of European dealers is under way). The most obvious change from last year is that many dealers had a tough year: 20 percent dropped out of the CAD business, as shown in Figure 1.

Most of the vendor failures were those dealers that began early as CAD resellers, typically as Autocad dealers. This group of dealers represented a cross section of human ability, some with more technical knowledge than business sense. As market conditions tighten, dealers with the weakest business sense have begun to drop off.

This newsletter analyzes those dealers still selling CAD/CAM/CAE, based on an in-depth survey of 150 sites. These dealers were selected to emphasize successful operations, but even successful dealers are not large: the average dealer reports $1.5 million in annual CAD revenue, and only the exceptional dealer reaches as much as $4 million.

Similar to the CAD industry as a whole, hardware is the biggest contributor to the typical dealer's revenue, although the dealers derive higher percentages of revenue from software and service than the CAD industry average (see Table 1).

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CCIS Personal CAD Newsletters 1990-1

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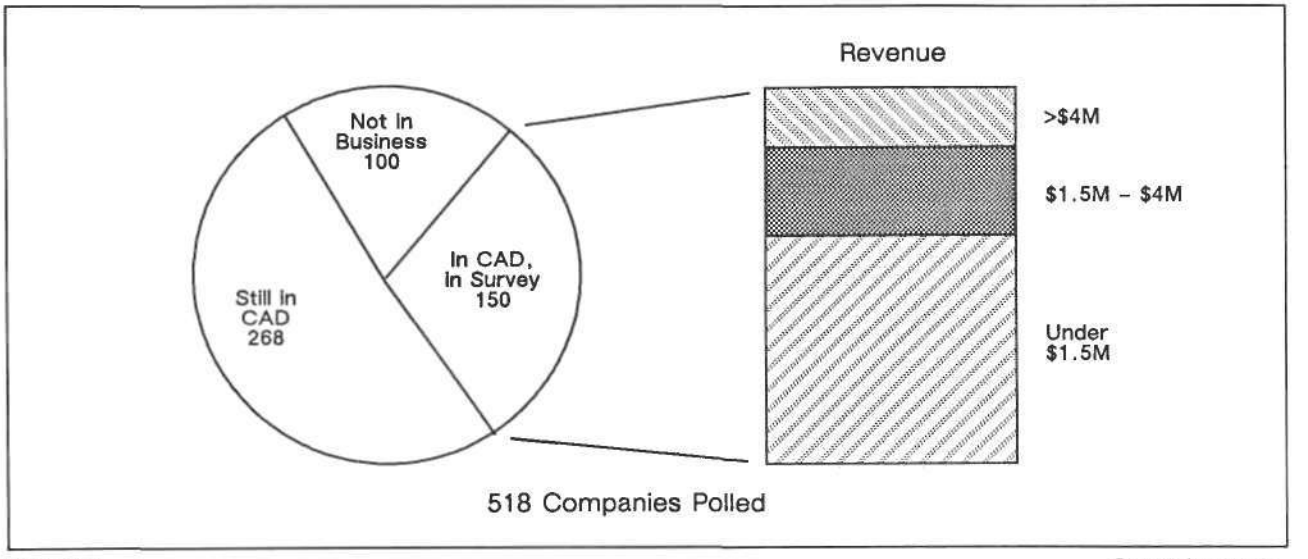
FIGURE 1
CAD/CAM/CAE VAR/Dealer Survey



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Source: Dataquest March 1990

TABLE 1
Product Mix Comparison—CAD Dealers versus CAD Industry (Percent of Revenue)

	Dealers	Industry
Hardware	47%	59%
Software	35%	27%
Service/Support/ Training	18%	14%

Source: Dataquest March 1990

Most dealers carry more than one computer brand, with 46 percent of dealers selling the market leader, Compaq (see Figure 2). Traditional workstation vendors have begun to make strong inroads on Compaq in this channel, with Hewlett-Packard and Sun each carried by 20 percent of the VARs.

The typical dealer sells to smaller enterprises than the CAD industry average, with 44 percent of sales coming from small companies with less than 100 employees (see Figure 3). With CAD vendors targeting the major accounts, these small sites are just the sort of customers that turnkey CAD companies are trying to reach through dealers.

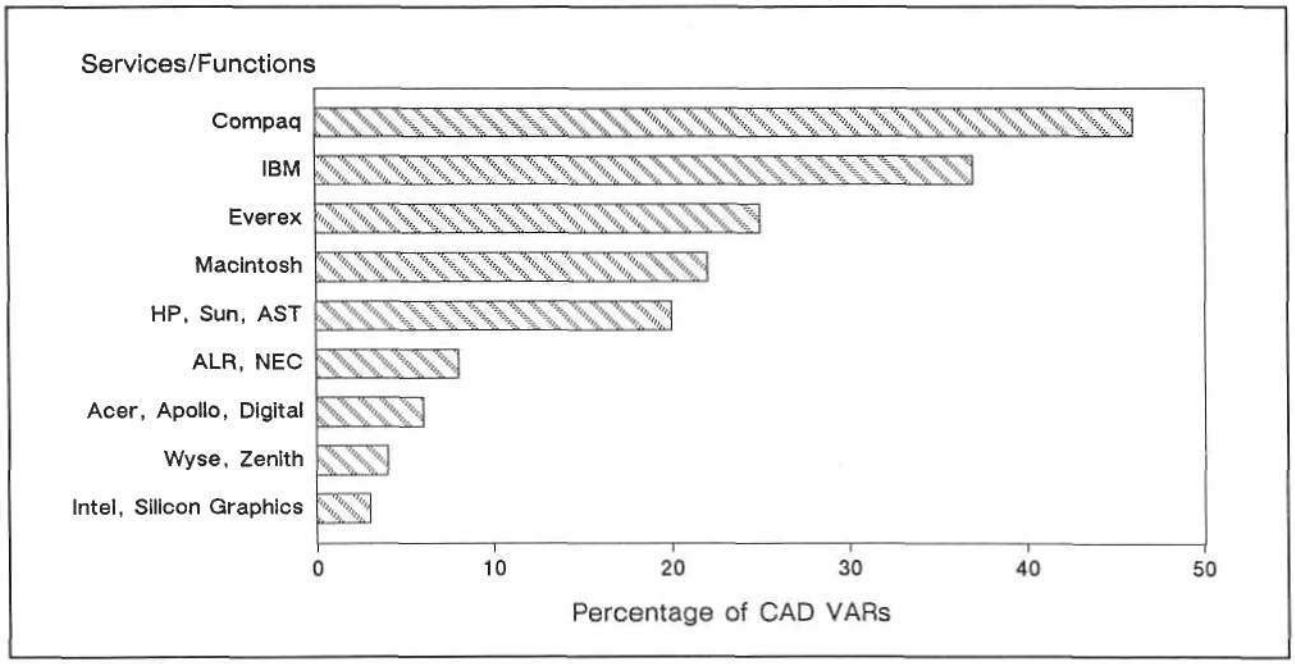
Dealers sell a broad range of CAD applications, but with greater emphasis on AEC (see Table 2). AEC, being less complex and lower in cost than other applications, captured 32 percent of dealer sales compared with 14 percent of the entire CAD market. Of course, dealer sales in all applications tend to emphasize less complex and lower-cost, PC-based solutions.

The typical dealer's favorite supplier is Autodesk. Dealers complain in chorus about competition in selling Autocad—in the next breath they report that Autocad is their favorite product, not only because of the vendor's good support structure, but primarily because customers want to buy the product. Market pull has created some very grateful dealers.

ANALYZING SUCCESS

We divided these dealers into three categories of success: "winners"—those with more than $3 million in revenue; "trying hard"—to represent the vast middle ground; and "limpers"—designating those who have been in business for several years and still have revenue of less than $500,000. A fourth group, "distributors," makes their primary business selling to other resellers. Figure 4 compares the number of businesses in each category with the revenue each category generates. The winners and distributors bring in 75 percent of the revenue, while making up 31 percent of the companies. These winners and distributors also sold 64 percent of the CAD software.

FIGURE 2
Computer Manufacturers' Lines Carried by CAD Dealers



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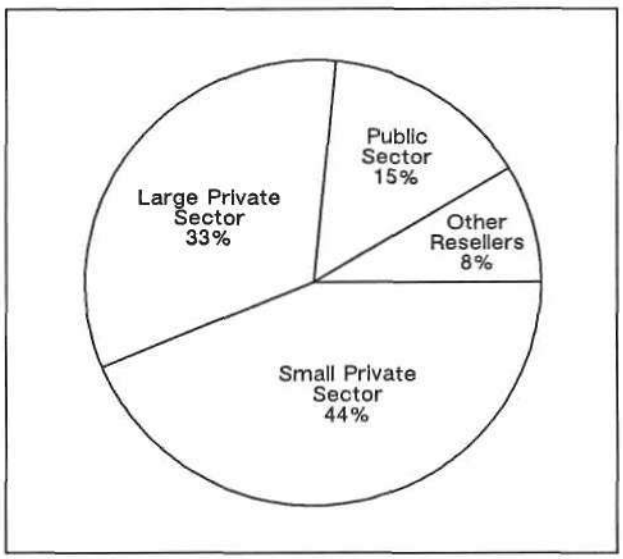
Source: Dataquest
March 1990

FIGURE 3
CAD VAR Customers



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Source: Dataquest
March 1990

Figure 5 shows that successful dealers are actually selling more brands of software. Often, considerable functional overlap exists among software brands sold, suggesting that vendors should expect good dealers to carry competing software.

On the surface, successful and unsuccessful dealers often look alike. Both appear to be operating their businesses in similar ways, and they subscribe to similar beliefs about how to sell CAD. For example, all dealers believe that service and support are keys to success, that their business is being ruined by other dealers cutting both prices and support, and that it is hard to keep up with the range and complexity of CAD products.

The single best objective predictor of success as a dealer turned out to be commitment to CAD/CAM/CAE, with winners reporting that 86 percent of their business is CAD, compared with the

TABLE 2
Application Comparison—CAD Dealers versus CAD Industry (Percent of Revenue)

	Dealers	Industry
Mechanical	41%	58%
AEC	32	14
EDA	16	22
Mapping	11	6
Total	100%	100%

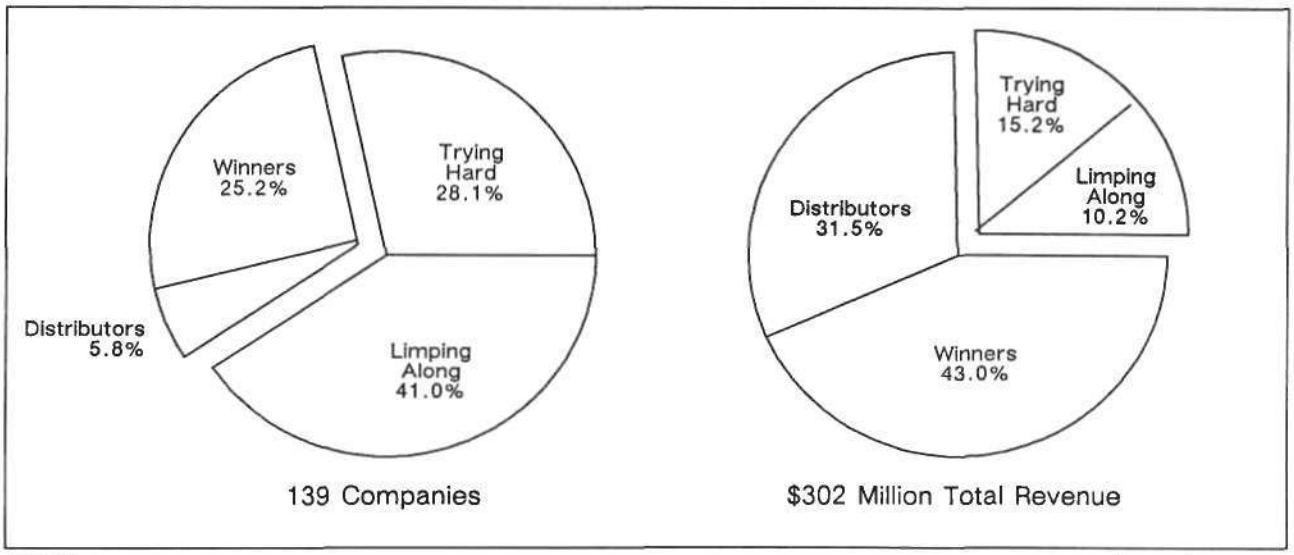
Source: Dataquest
March 1990

53 percent of CAD business reported by the limpers. Less objectively, we can say that in interviewing the most successful dealers, we would usually be talking to a focused, articulate, and ambitious personality—someone who was able to lead the company's growth personally.

THE CAD DEALER IN THE EARLY 1990S

We believe that the typical successful dealer in the early 1990s will be part of a regional or national enterprise. Many of the individual operators of today will either have left the business or

FIGURE 4
Distribution of Sales among CAD/CAE VARs



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Source: Dataquest
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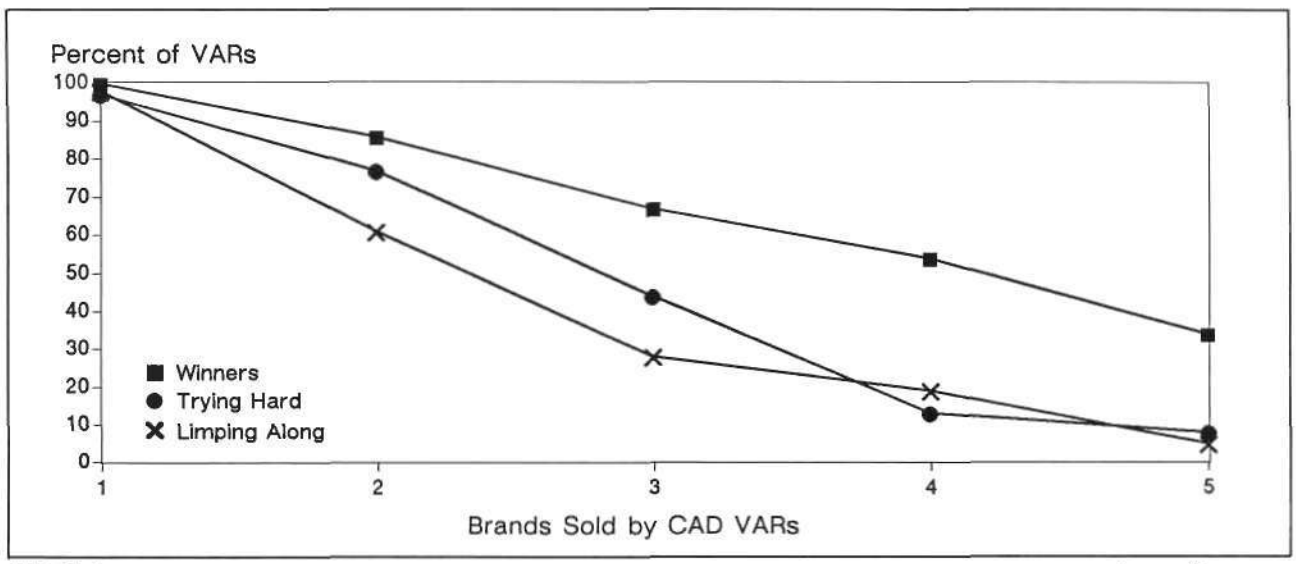
FIGURE 5
Software Brand Lines Sold



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Source: Dataquest
March 1990

have been acquired by larger dealers, usually because they lack the business acumen to operate independently. A steady stream of dealers are leaving the market; very few dealers are entering. Competition for the small group of successful dealers is intense and can only become worse. The undercapitalized dealer pool of today is the inadequate raw material for the dealers which will be available in the future, unless substantial investment is made by vendors or others.

Tomorrow's dealer also will be ruthlessly conscious of brand names—in terms of computers, software, and peripherals. A vendor's ability to generate market demand will become increasingly important, as dealers pare back offerings to focus further on meeting vendor quotas, simplifying an already complex business, and making every product offering profitable.

The more successful dealers will continue to focus intensely on products that improve margins. Several top dealers have committed themselves to workstation sales (typically sold with Autocad software), primarily because the shift improved their profit margins. Manufacturers of PC computers have begun to lose the attention of many of the best dealers.

In terms of specific applications, the most successful dealers told us they see their best growth opportunities in mechanical CAD and manufacturing environments, in addition to fairly strong prospects among architectural customers. These dealers appear to be relatively unaware of what Dataquest believes to be a good opportunity in desktop mapping CAD applications.

THE CHALLENGES AHEAD

Over the next few years, Dataquest expects to see significant increases in the complexity of methods to move CAD products from production to consumption. Success will depend on meeting key challenges—but the problems that need solving depend on where one is in the distribution chain.

The Hardware Vendor's Challenge

The computer manufacturer's challenge is to develop distribution programs that build in profits for dealers. We believe that, manufacturers must provide dealers with specific direction, increasingly, and that the most successful manufacturers will be telling their dealers exactly how to make a profit.

The second challenge facing computer manufacturers is to develop distribution programs that help their ISVs sell software. Compared with computer manufacturers, ISVs have far fewer resources for supporting a worldwide direct sales staff. Like manufacturers, ISVs must sell through resellers.

As computer manufacturers grow their volume sales channels, there is real danger that price-shopping users will increasingly bypass engineering resellers for hardware purchases, confining purchases from CAD VARs to software and support only. However, CAD resellers depend on hardware revenue for both cash flow and profit: we believe that they generally are unable to survive on software-only sales. Successful computer manufacturers will help create business models in which their engineering ISVs can sell software profitably—because, in the long run, there is a limited future in CAD markets for a computer that few companies make a profit writing or selling software for.

The Software Vendor's Challenge

The company that writes engineering software faces the challenge of building more training and support into the product itself. This investment is the best defense against both inept dealers and the spiraling costs of human-based technical support. We believe that there are three key product features here: easy to learn, easy to use, and bulletproof (hard to break and no bugs). These features are in demand from both sets of customers: the users and the dealers.

The CAD software vendor using resellers faces another significant issue: Autocad. Autocad has become the safe buy—the brand name buy—among the customers that CAD dealers usually encounter. Almost every dealer carries the product. Other software vendors must accept this and work to counteract the fact that their product will be compared with it, no matter how ludicrous the comparison seems.

The Dealer's Challenge

The CAD dealer's challenge is to adapt to certain change. Either the dealer will grow through acquisition or alliance to become a larger geographic presence, hide in a small but favored niche application, or go out of business.

The Challenge for Everyone

CAD/CAM/CAE has a somewhat lurid reputation of pushing market growth through a highly paid sales force selling, in some cases, more promises than delivery. In the maturing CAD/CAM/CAE market, there is a need for creating customer demand through regular publicity, through standardized and repetitive advertising messages, and through the urgency created by sales promotions. Dealers want to sell products profitably that customers already want to buy. There is a tremendous need for better cooperative strategies that enhance each contributor in any particular selling chain. Hardware vendors, software vendors, and dealers today are, through their interdependence, allies by necessity.

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A/E/C SYSTEMS '89—THE GOOD TIMES ROLL

SUMMARY

It was elbow-to-elbow crowds at A/E/C Systems '89, which was held recently in Anaheim, California. Apparently, everyone with any interest in either AEC or PC-based CAD was in attendance. The vendor-oriented "neighborhoods," application-oriented mini-shows, and concurrent conferences sprawled even wider this year. Attendance was up 8 percent, to nearly 29,000. Foot traffic still centered around Autodesk and its third-party family, the traditional attention-getters.

Since the buoyant Autodesk has blessed A/E/C Systems as a key trade show, the event has continued to grow, at a time when many other national shows either are holding steady or shrinking. Next year's show is back-to-back with Comdex, virtually guaranteeing an even bigger A/E/C Systems in 1990.

SHOW STANDOUTS

Every show has its memorable events, and the following are our nominations for distinction.

Award for Creative Product Direction

Based on the relatively complete display of Autodesk's wide range of future products, we see the company's direction as creative, constructive, and crowd-pleasing. Coming from a position of immense strength in the CAD industry, and armed with more than $100 million in cash, Autodesk is moving to create new software markets while providing core development for its existing markets.

Rather than adding application-specific enhancements to AutoCAD, Autodesk appears to be investing in just what every computer manufacturer needs: new kinds of software that make the system more useful and productive. Audtodesk's CA Lab, the Cyberspace project, Xanadu, and an imminent animation product all offer the potential

to do something new to leverage or extend the core CAD product line. Although we do not know if the elusive "killer application" is lurking within Autodesk, the territory appears to be fertile.

Autodesk also promises necessary and sensible improvements for Release 11: reference files, networking, support for worldwide drafting standards (ANSI, DIN, JIS, ISO), C language support (instead of requiring developers to write in Lisp), and further enhancements to the product's already open architecture. Longer term development include better surfaces/rendering and a common data base and user interface for AutoCAD and AutoSolid. All of these core improvements support, rather than compete with, the company's add-on suppliers.

We believe that Autodesk's apparent decision to rely increasingly on third parties for subapplication software is a very constructive approach. Rather than going head-to-head with workstation-based CAD companies by developing modules suitable only for niche markets, Autodesk seems committed to expanding to new lines of business while continuing to nurture its add-on vendors. However, both the potential risks and rewards are greater with this approach, and thus very few companies have the funds and determination to try it.

Class Act Award

The Dataquest Class Act award goes to Prime Computer. With two strikes against it—appearing at a PC CAD show lugging a product conglomeration from three separate high-end AEC lines (Calma, Computervision, and Prime) and trying to sell at the peak of a highly publicized takeover attempt—the booth should have been a debacle. Instead, the display hummed with serious prospects.

Prime's secret? Existing customers staffed the well-located booth, displaying their own designs. Prime's staff functioned smoothly as the glue, both supporting each workstation and directing attendees toward the most appropriate design example. Obviously, customers staffing a vendor's booth lend credibility to the product, but more importantly, there were real designs to explore.

The typical canned demonstration is designed to send information in one direction only and any design samples are just that—unidimensional examples. But, examining a product with a real design/designer involves prospective customers in extensive, interactive product exploration, creating a sales environment that is more a consultation than a pitch. The activities in this booth are sure to be the origins of several Prime sales a few months from now.

Award for Creative Effort in Booth Design

The A.I.A. contingent awarded Calcomp the distinction of Creative Effort in Booth Design, and we can only agree, since the structure was well aimed at this AEC-oriented audience. The booth resembled a two-story Tinker Toy, with balls racing on a track to nowhere, and attracted plenty of visitors just for the chance to study the construction.

THE GRASS ROOTS CONTINGENT STIRS

Apparently tiring of collective low revenue, several of the AutoCAD third-party developers have banded together, creating at least three new entities promising shared marketing expenses, and a shared product user interface and development environment. The most formidable is ASG of Sausalito, California, which was formed by two strong developers, Archisoft Corp. (the creator of the architectural and mechanical modules currently sold by Autodesk) and Chase Systems of Westerville, Ohio. Archisoft's growth has been boosted considerably by its royalties from Autodesk, which have more than doubled in the last two years, reaching nearly $2 million in the last fiscal year.

Other alliances include the merger of D.C.A. Engineering Software (Henniker, New Hampshire) and Acuware (Portland, Oregon), which considerably expands the D.C.A. product line, and the formation of Applications Publishing (Sausalito, California). Applications Publishing has signed up six developers and is seeking more.

Pooling development and marketing costs makes a lot of sense for the approximately 300 AutoCAD developers, each of which addresses a relatively small market niche. Whereas we expect Autodesk to aid all developers in such universal concerns as the transition to standard window environments, it makes economic sense to share many expenses through a developer's alliance. For example, it is unlikely that any developer could independently support an adequate number of regional sales offices.

The concept of multiple alliances is also far better from Autodesk's point of view. If Autodesk were to form one company-sponsored alliance itself to cover all these issues, developers would be likely to cry foul, charging favoritism, heavyhandedness, and incompetence—no matter what Autodesk did. It would be too much like having your mother tell you how to write software. Software developers, free souls that they are, will probably respond better to a choice of independent alliances. These alliances will also reduce the absolute number of developers with which Autodesk will need to communicate.

Although Autodesk's reputation with its developers appears strong, and despite the show of strength from these developers, this group does represent Autodesk's entire source of application-specific software. Autodesk will need to watch its flanks here, making sure that these developers are building as close to state-of-the-art software as is possible.

Smaller PC-based software companies are probably considering Autodesk's relative distance from its subapplication software developers as a weakness they may be able to exploit. The strongest challenger here would be Cadkey, which announced its acquisition of Microtecture at the show. Microtecture's DataCADD is the product formerly sold by the A.I.A. Cadkey can now claim a strong installed base of both mechanical and architectural users, with software tailored for each group.

PRESENCE OR PRODUCT?

As usual, this show highlighted vendor participation rather than product announcements, as witness the incongruous but unforgettable picture of a classroom of "AEC" trainees learning to draw pixel happy faces—on Sun Microsystem workstations. The principal product announcements actually came from plotter companies, which have adopted this event as a primary announcement arena.

Facilities Management: Needs a Great Communicator

Two CAD product areas were showing a large number of relatively new products: facilities design/management products and drawing conversion products. Judging by the number of facilities management solutions displayed, including many small PC-based products and fewer workstation-based offerings, a large number of vendors have tapped facilities design/management as a growing market. However, some of these booths were poorly attended.

Eye appeal may have been part of the problem. There were just too many CRTs displaying different words inside of different boxes, all claiming to be the solution to good information management. The presentation did nothing to facilitate comparing one product with another. We believe that better product demonstrations are needed here, ones that clearly communicate the basic concepts behind the work being done. Until then, attendees accustomed to visually appealing displays will probably walk right on by.

Raster/Vector Drawings: A Hot Spot

Although the subject is neither new nor particularly exciting, raster/vector products (also known as hybrid images or composite drawings) generated strong interest among attendees. The economics make good sense. Now that design services have driven the price of creating a raster image of a paper drawing to less than $10, and the prices of desktop scanners and storage devices have dropped dramatically, a "make-do" solution has emerged for working with a combination of old and new drawings.

Using hybrid drawing products, an architectural or engineering firm can bring a raster image (such as an existing site plan) into the CAD package, erase parts of the raster image that are not wanted, overlay the raster image with vectors drawn on a separate layer, and plot the hybrid drawing as a merged image showing both raster and vector information. Although it is offered by some workstation-based companies, this capability has not been available to PC users in the past, except at much higher prices.

Maintenance and rework as a percent of design work is increasing, which should cause increased demand for hybrid drawings. Many clients (government entities, particularly) enter into contracts with their own existing paper drawings, and vector conversion is costly. Other good uses for merged raster and vector images include zoning reviews and presentations before planning bodies. The ability to mix vector and raster

layers as a design progresses means that, on demand, decisions can be made about which drawings or portions of drawings to use as vector versus raster, as opposed to paying for a complete set of vector drawings. The users we talked to clearly understood that they do not require vector data all at once, and that data might most economically be built over time, line-by-line, as needed.

The proliferation of hybrid drawings could mean that manufacturers of high-cost scanners/digitizers could find themselves increasingly bypassed by lower-cost, but adequate, solutions in the AEC market. The situation is parallel to Autodesk's entry into the CAD market five years ago, when the company offered adequate performance at a dramatically lower price. To quote an A.I.A. spokesman commenting on incorporating existing paper drawings into a new design, "The cost just went down 99.9 percent."

On the other hand, as more composite drawings appear, the demand to print them will also increase. The favored plotter for these drawings is most likely to be one that supports a popular standard (such as PostScript), has a low cost, and is not painfully slow. It is reasonable to generalize that many small A/E offices are relatively disinterested in computers, and are leaning toward solutions that have been proven successful by others. We believe that architects would stretch to afford a reasonably priced output device that offers PostScript hardcopy for their composite raster/vector drawings.

DATAQUEST ANALYSIS

We believe that the majority of the architectural and engineering community has finally accepted computers as being necessary to their competitive business positions and that many of the non-believers tend to be near retirement age. Thus, strong growth in AEC CAD should continue. However, these same prospective customers also demonstrate a keen eye for cheap, "good-enough" solutions, such as PC-based hybrid drawings, which makes them continue to be the CAD/CAE buyers most difficult to entice into high-profit, high-ticket sales.

We also see potential stumbling blocks for the emerging facilities design/management market, as many of the products shown at A/E/C Systems did not capture much interest. We can hope that the audience was not quite right, but the fact remains that these products need a better presentation of both what problems are being solved and how they are being solved.

And finally, for the remaining few who would like to believe that Autodesk is not a serious CAD competitor, or that the company is unlikely to get lucky twice with a major new product, or that it will surely stumble soon—it is time to discard those notions. We believe that the company's influence will grow.

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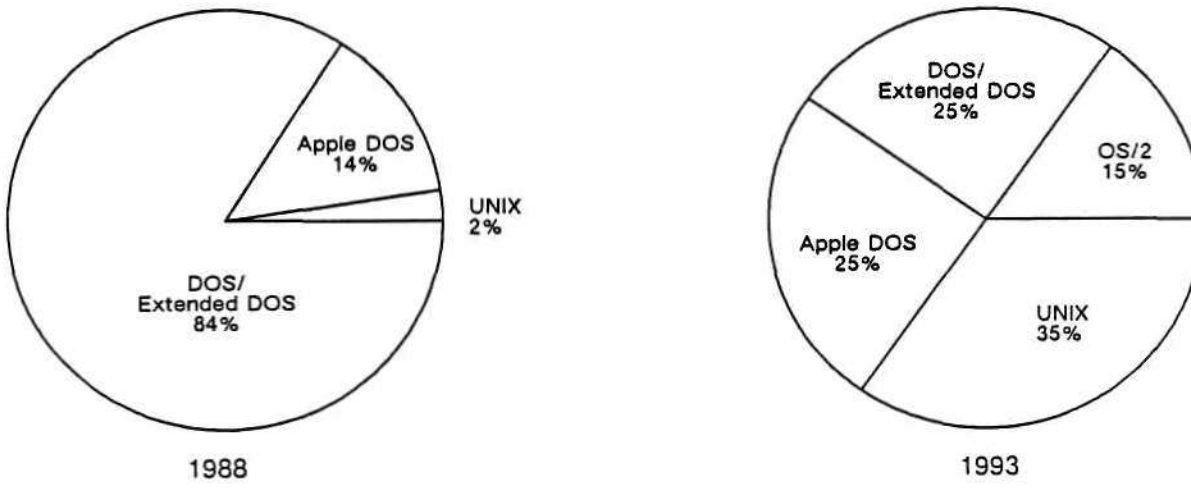
CHANGE AND CHALLENGE IN PC CAD OPERATING SYSTEMS

Some of the most important PC CAD software changes in the last year have had more to do with operating systems than with CAD/CAE features and functions. Because the future of low-end operating systems is vital to every participant in this market, Dataquest completed a forecast for low-end operating systems in CAD applications, and its results are shown in Figure 1. This newsletter presents our forecast and discusses some of the changes and challenges facing PC CAD operating systems.

Figure 1

PC CAD Operating System Forecast



0004003-1

Source: Dataquest
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THE FUTURE OF LOW-END CAD OPERATING SYSTEMS

The anticipated success of several operating systems reflects our conviction that software vendors that commit to one operating system are taking a significant business risk. Forecast growth in Apple DOS reflects our positive outlook for the Macintosh. The growth in UNIX indicates our expectation that, when engineering users leave the DOS operating system, they will go to UNIX, where their more computer-sophisticated peers are. OS/2 is generally perceived as a high-overhead office-oriented product that limits CAD performance. We believe that a single-user, lower-overhead UNIX will take hold among PC CAD users, and that Santa Cruz Operations' Open Desktop (a device-independent, standards-oriented UNIX for 386-based computers) will be the principal contender.

Dataquest believes that OS/2 will achieve virtually negligible penetration in PC CAD unless and until it first achieves compelling success in business application software, which is not available under DOS. This is unlikely to occur before 1992 or 1993. Although OS/2 is forecast to have the lowest penetration in CAD in our five-year forecast, IBM is holding the card that could turn the tables. OS/2 is seen universally as a product that is tied to the Micro Channel Architecture. If IBM were to drastically reduce or eliminate royalties on its Micro Channel Architecture, it is likely that the major developers would enthusiastically commit to OS/2. But as long as IBM continues to demand payment for a proprietary specification in a market that was built on an open bus, the thrifty, and the canny, are likely to find other alternatives.

TRACKING THE DOS TRAIL: AN EXPANDED FUTURE

While DOS use is forecast to shrink considerably in the next five years, this operating system will be tough to kill, because it still has much to offer. The gap across DOS, OS/2, and UNIX (and between PC and workstation) performance was quietly but considerably reduced in 1988 by two small bridge product suppliers, Phar Lap Software and A.I. Architects. These companies expanded DOS so that it functions as a demand-paged virtual operating system that runs programs of up to 4GB (the limit of the 80386 processor), while still appearing to the user as ordinary DOS.

Very few high-end DOS-based PC CAD programs exist that do not either offer, or have waiting in the wings, a product based on a DOS extender (including products from Autodesk, CAD Software, Cadam, Cadkey, Fluid Dynamics International, Futurenet, Hewlett-Packard, Integrated Silicon Systems, Intusoft, MacNeal-Schwendler, MCS, SMOS, SRAC, Swanson Analysis, Versacad, and Viewlogic). DOS programs larger than 640K first arrived in CAD/CAE, but will begin appearing in more mainstream software, such as Lotus 1-2-3.

To achieve the highest performance with a DOS extender, the typical application software developer rewrites the product to run in the 80386 32-bit protected (unsegmented) mode. Completing this task creates more portable software, thus reducing the amount of work required later that is ported to either UNIX or OS/2. In the meantime, programs can grow under DOS, and success stories are accumulating.

Cadkey represents a good example of a company that is upgrading its bridges one step at a time by first extending DOS performance for its mechanical CAD software, and then moving easily to the UNIX-based Silicon Graphics workstation. Cadkey is now able to offer a product with files that are compatible without translation across both operating systems, thus creating a cost-conscious, sophisticated product line where design and analysis tasks can be assigned to a Silicon Graphics workstation and drafting to a PC.

Conversely, Cadam is moving an increased percentage of its mainframe-based product down to the DOS-based Microcadam Plus, because space is now available. This move should significantly expand Cadam's presence among suppliers to the automotive industry, which now can buy more functional, but still low-cost, compatibility with Cadam.

THE MISSING LINK

By creating a bridge that allows DOS-based software to grow, Phar Lap and A.I. Architects helped the PC CAD industry evolve during a period of high uncertainty about the future of low-end operating systems. At the other end of the bridge, Santa Cruz Operations organized industry participants to specify a smaller, friendlier Intel-based UNIX that is primarily focused on the single user. However, there is an important—and needless—gap. Although almost all purveyors of UNIX tout their "DOS window," these windows will not accommodate a program written with DOS extenders. Thus, sophisticated DOS programs will not run in a UNIX "DOS window."

Unfortunately, users that buy extended DOS programs are the very users we would expect to move up to an Open Desktop-type product. While UNIX suppliers naturally have little interest in making DOS look good, accommodating only the lowest-level DOS products may prove shortsighted.

DATAQUEST CONCLUSIONS

Dataquest believes that it is a relatively simple matter for industry participants to create a specification allowing extended-DOS products (ideally in multiple windows) to run on Open Desktop. To ignore this issue will leave the leading-edge PC users only partway over an unfinished bridge, inviting them to jump to the traditional technical workstations, thus reducing the overall market for Intel-based products. Resolving the issue will help grow the PC CAD market.

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PC CAD HITS ITS STRIDE

THE PC CAD MARKET IN 1988

PC CAD flourished in 1988, continuing another year of record growth. Revenue rose 24 percent, which was above the industry average. (See Tables 1 through 9 at the end of this newsletter for a complete overview of the PC CAD market from 1988 through 1993). The 1988 market leaders featured well-known brand names: Apple, Autodesk, and Compaq. By the end of the year, Compaq had unseated IBM for the number one market position in two important categories:

- Total CAD/CAM/CAE revenue on the PC platform
- Number of seats shipped in the entire CAD/CAM/CAE market

In software, Autodesk's number one market position appears untouchable for the foreseeable future. Among the second tier companies, PC products from large traditional CAD companies grew faster than those from the small unknown vendors. Few companies entered the PC CAD market in 1988.

The revenue of PC CAD vendors of all sizes generally grew or held steady in 1988. Our PC CAD data represent revenue from a very large sample: 175 vendors and their subsidiaries, some of which are miniscule. While the CAD industry as a whole experienced mind-numbing consolidation, the small PC CAD software vendors generally neither left the market nor were acquired in 1988, with the notable exception of Autodesk's purchase of Generic Software.

Typically, vendors were busy either developing products for the Macintosh, or wringing higher performance from existing software. The scrappy, upstart nature of the PC CAD market has not vanished, but cost-conscious innovation has shifted from improving application software to wresting better CAD performance from hardware and system software.

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The PC CAD Platform

The Intel 80386 processor deserves significant credit for PC CAD growth in 1988, because its power was just what existing CAD software needed. More than any other PC-based application, existing CAD software provided the showcase for 80386 performance. Buyers saw existing PC software change from being a "make-do" product on the 286 CPU to being an "almost-workstation" product on a 386-based system. By midyear, it was clear that CAD is a key driver of the high-end PC market, and vendors of PC CAD system components began cooperating to produce more powerful systems.

During 1988, relationships strengthened among CAD software suppliers, computer manufacturers (especially Compaq), graphics hardware suppliers, and operating system suppliers. PC hardware manufacturers focused on CAD as a key driver of their high-end products and worked steadily to drive up product performance. Thus, the CAD software supplier is no longer working alone to deliver the highest performance on a PC system. Vendors supplying any component of a high-end PC CAD system typically tweak their products toward boosting CAD software performance.

Where Do PCs End and Workstations Begin?

PC and technical workstation vendors achieved significant overlap in 1988, with PC hardware vendors relentlessly driving up performance and options while technical workstation vendors pushed their products toward the commodity arena by lowering prices and adding DOS compatibility. For several years, Dataquest had been predicting the merger of the PC and low-end technical workstation CAD markets, and 1988 was the year it became measurable.

PC and Workstation Definitions

Personal Computer

This is a single-user computer that is distinguished from a technical workstation by its features and by the user's potential range of expansion on the platform. Features found in technical workstations (such as a virtual operating system, networking, high-performance graphics, and multiuser/multitasking capability) are optional, rather than integrated by the manufacturer. Many users reach a migration path ceiling at the high end of the PC product line, both in computer performance and sophistication of available application software (for example, a Mac II or Compaq 386 user is operating at the platform ceiling; the next move upward is to the technical workstation platform).

Technical Workstation

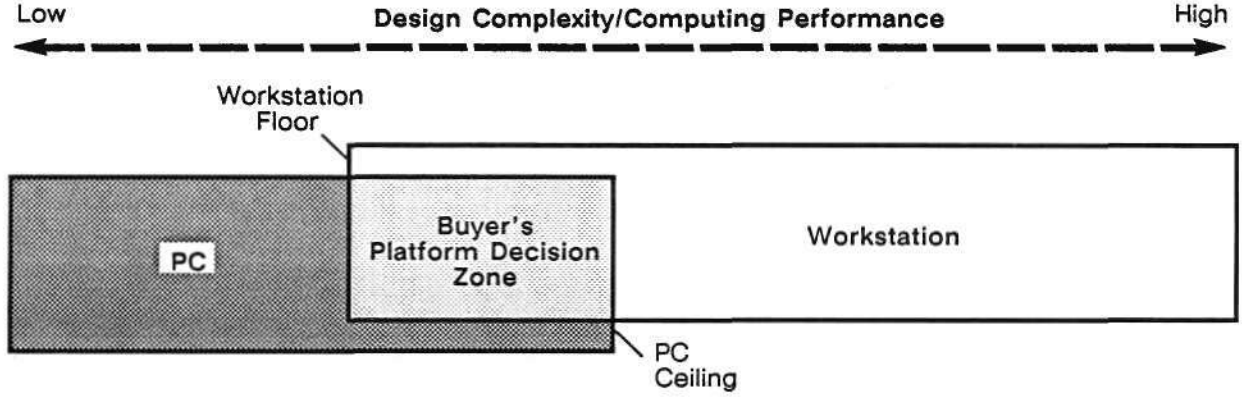
This is a single-user computer that is distinguished from a personal computer by its features and by the user's potential range of expansion on the platform. Its features include a virtual, multitasking operating system (UNIX, VMS, or DOMAIN). The computer is designed by a manufacturer to run high-performance graphic applications in a

multiuser/multitasking environment. Many users reach a migration path limit at the low end of the workstation product line (for example, the Sun 386i user is operating at the platform floor; the next move downward is to the personal computer platform).

Although Dataquest's glossary definition clearly distinguishes between the two platforms (see Figure 1), computer manufacturers are working overtime to claim every feature possible, and distinctions blur a little more each week. As a result, we expect long-term distinctions between the two platforms to eventually become more a function of intended use than of performance. "PC" will continue to describe a product bought by the price-conscious user to solve design problems limited to the lower end of the design complexity spectrum. "Technical workstation" will continue to describe a product bought by the user who must be able to solve—or grow to solve—the more complex design problems, at an admittedly higher cost per system seat.

Figure 1

Personal Computers versus Technical Workstations



PC Advantages

- Price-conscious image
- Wide range of low-cost business software
- Low system overhead cost
- Model upgrades easy to justify by passing castoffs downward throughout organization
- Future platform for software with "80% of the function at 20% of the price."

Workstation Advantages

- Prestige image
- Wide range of design and analysis software
- High graphics/computing power
- Integrated multitasking/ multiuser work-group environment
- Future platform for leading edge design software

0004004-1

Source: Dataquest May 1989

CURRENT INDUSTRY TRENDS

The trends driving the low-end CAD market in 1988 and 1989 are as follows:

- Moving up—Growth is occurring at the high end of PC systems, which means that the trend to grow or at least maintain average selling prices on this platform will continue.

- Wait and see—Uncertainty over the future of low-end operating systems appears to have discouraged entrants, innovation, and investments in both PC CAD/CAE software and third-party hardware.

- Lookalike PCs and workstations—Now that PCs and low-end technical workstations are converging toward becoming one market, they will start offering more and more of each other's features, much like diners at a potluck sampling one another's entrées.

- Maturing vendor distribution strategies—For CAD software suppliers, developing effective distribution strategies in a consolidating dealer channel will be as important as the product itself.

- Challenges for resellers—Technical workstations will start to actually ship through dealers and VARs, and may sorely test the resellers' abilities to grow to meet new and more sophisticated support requirements.

- Power for Apple—Increased market presence for Apple in 1989, as Autodesk's presence legitimatizes the Mac as a CAD platform.

MARKET SHARES

Table 4 illustrates the position of CAD/CAE in the overall PC marketplace. The percent of 386-based units shipped to CAD/CAE applications reaches as high as 20 to 25 percent for computers offering a brand name recognized for CAD performance (such as Compaq) or products packaged for dealer needs (such as Everex). Still, the industry average of 12 percent of 386-based machines shipped to CAD applications emphasizes the importance that CAD now has to high-end PC manufacturers.

Software unit prices stabilized and actually rose somewhat in 1988. Autodesk, which sets the pace, has driven its Autocad factory revenue up to a worldwide average of $1,550 ($1,400 in the United States) per unit during the past five years. These are now the price points against which other high-end PC CAD vendors negotiate.

Facing the fact that low prices produce low revenue, several vendors of software list priced at less than $500 also worked to boost factory average selling prices (ASP), with a small net gain in the marketplace. In 1988 the less than $500 software accounted for 8 percent of software revenue and 56 percent of the units sold, up from 6 percent of PC CAD software revenue and 56 percent of units sold in 1987.

Autodesk

Every year of Autodesk's existence has been remarkable, and 1988 was no exception. Autodesk's 20.7 percent market share in PC-based CAD software understates the company's influence. Autodesk, Mentor Graphics, and Prime/Computervision all have approximately equal software revenue. These companies also have approximately equal influence in CAD/CAE, but each in very different market segments.

Autodesk has no close, direct competition; instead, it has hundreds of small competitors worldwide. Today, Autodesk's financial strength, large installed base, and control of the DXF file format means that its products are perceived as the safe buy in many PC-based mechanical and AEC applications.

Despite its soaring revenue, Autodesk did experience frustrations in 1988, particularly with the delay in shipping Autocad for the Macintosh. Autodesk's push to move up in performance with AutoSolid was another disappointment, as the product captured little attention. However, Autocad itself is now so popular that 5 percent of Autocad revenue comes from workstation- and host-based products.

Compaq

Compaq, with its emphasis on system engineering, met market demand for PC-priced high-performance systems precisely. The company reaped its reward in revenue, unseating IBM for the number one position in total PC CAD revenue. It is now fair to say that both Compaq and Autodesk represent the leading vendors influencing PC-based CAD, even though Compaq only manufactures computers.

During 1988, Compaq drove its product line upward with its leading-edge 80386 systems. Just as important, the company also reached out to influence a wide variety of third-party developers. The company is now functionally operating as "glue" in the high-performance PC market by serving as an information and coordination resource to any supplier that can make the Compaq computer look good in high-end applications. Compaq's well-coordinated activity contributed significantly to the PC challenge to workstations.

IBM

IBM's position on its Micro Channel Architecture cost the company its number one position in PC CAD revenue in 1988. In 1988, demand in CAD was at the high end of all PC product lines, at a time when the high end of IBM's PS/2 line emphasized OS/2 and the Micro Channel Architecture, features for which there were no available CAD products. Although IBM shipped slightly fewer personal computers in 1988 than in 1987—in all applications—the drop was especially acute in CAD.

Apple

In 1988, Apple shipped record numbers of Macintoshes into technical and engineering environments (19 percent of Mac IIs, at last count), and established a clear market awareness of its potential as a serious CAD platform. However, few CAD software vendors actually shipped packages for the Mac in 1988. Thus, we place much of Apple's revenue in the general-purpose technical application category, rather than in the CAD category.

However, after a year of frantic development by independent software vendors, Apple is exquisitely positioned this year for a drive in CAD. A reasonable selection of CAD software is finally available, and the product is already selling briskly into engineering environments. The Mac has enormous potential to meet the demand from the legions of architects, engineers, and designers who either do not like computers or want the machine to explain itself.

MARKET OUTLOOK FOR THE 1990S

Major growth opportunities we see in the low-end CAD market over the next five years include the following:

- High-end, PC-based CAD systems will continue to win price-conscious buyers by offering low-end workstation performance at a substantially lower system cost per seat.
- Products will incorporate ease of learning for casual users (the Macintosh is the only example of this).
- Distribution channels will be developed as competitive weapons.
- AEC prospects will be more willing to make purchases now that CAD is a known quantity and as PC-based CAD becomes even easier to learn.

Application Forecast

AEC, mapping, and mechanical applications represent the best opportunities for growth during the next five years (see Table 5). Electronic applications on the PC have already begun to drop, and the future looks even dimmer. We believe that, because of both the current level of sophistication in the application and the demand for integrated design environments, technical workstations will be the machine of choice in most future EDA sales.

Regional Forecast

Dataquest's regional PC CAD forecast is shown in Table 6. Compared with the rest of the CAD/CAE industry, the North American market is forecast to remain substantially larger than the other regional markets, primarily because of the more developed CAD dealer channel in the United States and Canada.

Average Selling Prices

Dataquest's forecast for average selling prices of PC-based CAD products is shown in Table 7. PC prices in both hardware and software are expected to hold relatively steady during the next five years (particularly compared with the sharper drop in ASPs we predict for technical workstations).

Revenue Source Forecast

We expect PC CAD software to increase as a percent of system revenue, as software vendors continue to focus on moving workstation-based software features down to personal computers, in order to grow average selling prices (see Table 8).

Distribution Forecast

The last of the turnkey PC CAD markets crumbled in 1988, as the larger CAD companies became increasingly committed to selling PC-based products through dealers. The temptation to have the best of both worlds is strong, however. Vendors of both software and hardware still claim rights to sell direct to high-volume accounts, so a small amount of turnkey sales may persist for a few years (see Table 9).

Distribution is PC CAD's battle zone. The entire PC dealer/distributor industry appears to be entering a period of consolidation, and CAD applications will be taken along for the ride. Two factors are pushing this consolidation:

- The easiest way for a dealer to grow is through acquisition.
- The one constant in the vendors' shifting reseller policies has been a bias toward volume-based discounts, which rewards the biggest buyers in the distribution chain.

Generally, distribution of PC-based products has operated as a cutthroat business, and discounting—with its accompanying pressure on profits—will likely continue to plague PC CAD resellers. We believe that distribution in the 1990s will be much more competitive—for the vendors. Distribution of computers is at a much more rough-and-tumble state than distribution of more mature industries, such as foods or automotive. The early 1990s should produce considerable experimentation in the search for a stable and economically efficient division of labor in distributing personal computers and low-end technical workstations. One fact is clear: The pool of skilled technical application resellers is painfully small. Vendors will likely be forced to grant more concessions and give more support to distribution channels.

Kathryn Hale

Table 1

Personal CAD 1988 Worldwide Market Share
(Millions of Dollars and Actual Units)

	Revenue	Units	Revenue Share	Units Share
Compaq	250.0	48,000	14.0%	19.9%
IBM	170.6	26,966	9.6%	11.2%
Apple Computer	150.0	35,000	8.4%	14.5%
Autodesk	111.4	0	6.3%	.0%
NEC	93.0	9,978	5.2%	4.1%
Mutoh Industries	56.8	1,355	3.2%	.6%
Hewlett-Packard	50.0	10,000	2.8%	4.1%
Fujitsu	44.5	2,031	2.5%	.8%
Hitachi	38.5	700	2.2%	.3%
Prime Computer	35.8	257	2.0%	.1%
Makuto	26.2	298	1.5%	.1%
Zenith	23.6	8,000	1.3%	3.3%
Racal-Redac	22.6	0	1.3%	.0%
CADAM	16.9	0	1.0%	.0%
Olivetti	16.7	2,992	.9%	1.2%
Daisy Systems	14.8	265	.8%	.1%
Intergraph	14.2	0	.8%	.0%
Ziegler Instruments GmbH	14.1	0	.8%	.0%
Everex	13.5	6,750	.8%	2.8%
Futurenet	12.8	0	.7%	.0%
Other	605.3	88,531	34.0%	36.7%
All Companies	1,781.4	241,122	100.0%	100.0%
All U.S.-Based Companies	1,341.4	219,155	75.3%	90.9%
All Asian-Based Companies	326.6	16,672	18.3%	6.9%
All European-Based Companies	113.4	5,295	6.4%	2.2%
All Hardware Companies	989.8	225,519	55.6%	93.5%
All Turnkey & SW Companies	791.6	15,603	44.4%	6.5%

Source: Dataquest
May 1989

Table 2

Personal CAD 1988 Software Market Share by Revenue

	Software Revenue	Software Units	Revenue Share	Units Share
Autodesk	111.4	94,194	20.7%	19.8%
Prime Computer	28.7	15,880	5.3%	3.3%
Racal-Redac	22.5	5,760	4.2%	1.2%
Mutoh Industries	20.3	2,317	3.8%	.5%
CADAM	15.9	3,037	3.0%	.6%
Intergraph	13.4	8,645	2.5%	1.8%
Ziegler Instruments GmbH	13.3	1,000	2.5%	.2%
Hitachi	11.6	1,171	2.1%	.2%
Futurenet	10.8	3,613	2.0%	.8%
Fujitsu	10.6	2,760	2.0%	.6%
Hakuto	10.4	582	1.9%	.1%
CADKEY	10.3	7,360	1.9%	1.5%
Xilinx	9.7	1,900	1.8%	.4%
Daisy Systems	7.2	319	1.3%	.1%
Generic Software	7.1	66,000	1.3%	13.9%
View Logic	6.7	2,625	1.2%	.6%
Wacom	6.5	1,000	1.2%	.2%
Olivetti	6.4	901	1.2%	.2%
Andor	6.3	2,130	1.2%	.4%
EESOF	6.1	610	1.1%	.1%
All Companies	538.4	476,094	100.0%	100.0%

Source: Dataquest
May 1989

Table 3

Personal CAD 1988 Software Market Share by Units

	Software Revenue	Software Units	Revenue Share	Units Share
Autodesk	111.4	94,194	20.7%	19.8%
Generic Software	7.1	66,000	1.3%	13.9%
Evolution Computing	1.8	35,750	.3%	7.5%
American Small Business Comp.	3.3	21,667	.6%	4.6%
Innovative Data Design	2.5	18,000	.5%	3.8%
Prime Computer	28.7	15,880	5.3%	3.3%
Foresight Resources	3.1	15,500	.6%	3.3%
Orcad	4.9	13,514	.9%	2.8%
Micrografx	3.0	13,333	.5%	2.8%
Omation	3.5	11,666	.7%	2.5%
Superdraft	2.6	8,944	.5%	1.9%
Intergraph	13.4	8,645	2.5%	1.8%
CIVILSOFT	1.1	8,000	.2%	1.7%
CADKEY	10.3	7,360	1.9%	1.5%
Racal-Redac	22.5	5,760	4.2%	1.2%
ISICAD	5.2	5,200	1.0%	1.1%
Accel Technologies	2.0	5,000	.4%	1.1%
Strategic Locations Planning	2.3	5,000	.4%	1.1%
Robocom	4.1	4,925	.8%	1.0%
Design Automation	5.4	4,000	1.0%	.8%
All Companies	538.4	476,094	100.0%	100.0%

Source: Dataquest
May 1989

Table 4

PC CAD/CAE Share of Total PC Market
(Thousands of Units)

	All PCs	CAD Applications	Percent in PC CAD
80386-based	1,124	135	12%
80286-based	6,147	73	1%
Macintosh	878	35	4%
PCs in Scientific/Technical Applications	889	243	27%
All PCs (excluding home/hobby)	6,509	243	4%

Source: Dataquest May 1989

Table 5

Personal CAD Worldwide Forecast by Application
(Millions of Dollars and Actual Units)

	1988	1989	1990	1991	1992	1993	CAGR
All Applications							
Revenue	1,782	2,071	2,259	2,334	2,308	2,292	5.2%
Systems	242,037	288,650	324,610	348,300	362,200	369,390	8.8%
Workstations	242,037	288,650	324,610	348,300	362,200	369,390	8.8%
Mechanical							
Revenue	970	1,079	1,115	1,135	1,083	1,024	1.1%
Systems	143,354	164,320	177,310	188,970	192,810	191,920	6.0%
Workstations	143,354	164,320	177,310	188,970	192,810	191,920	6.0%
AEC							
Revenue	385	513	636	711	755	803	15.8%
Systems	61,867	83,730	104,870	121,970	136,730	150,940	19.5%
Workstations	61,867	83,730	104,870	121,970	136,730	150,940	19.5%
Mapping							
Revenue	78	118	168	214	256	310	31.7%
Systems	4,977	6,780	8,450	9,190	9,430	9,580	14.0%
Workstations	4,977	6,780	8,450	9,190	9,430	9,580	14.0%
Electronic CAE							
Revenue	179	178	163	127	95	63	-19.0%
Systems	15,873	15,830	16,000	13,420	11,240	7,530	-13.9%
Workstations	15,873	15,830	16,000	13,420	11,240	7,530	-13.9%
IC Layout							
Revenue	14	18	19	13	9	6	-14.4%
Systems	358	600	700	490	400	280	-4.5%
Workstations	358	600	700	490	400	280	-4.5%
PCB Layout							
Revenue	156	165	158	133	109	86	-11.1%
Systems	15,606	17,390	17,270	14,260	11,600	9,140	-10.1%
Workstations	15,606	17,390	17,270	14,260	11,600	9,140	-10.1%

Source: Dataquest
May 1989

Table 6

Personal CAD Worldwide Forecast by Region
(Millions of Dollars and Actual Units)

	1988	1989	1990	1991	1992	1993	CAGR
Worldwide							
Revenue	1,782	2,071	2,259	2,334	2,308	2,292	5.2%
Systems	242,037	288,650	324,610	348,300	362,200	369,390	8.8%
Workstations	242,037	288,650	324,610	348,300	362,200	369,390	8.8%
North America							
Revenue	826	971	1,079	1,132	1,146	1,162	7.1%
Systems	139,164	163,750	180,250	191,380	198,830	200,480	7.6%
Workstations	139,164	163,750	180,250	191,380	198,830	200,480	7.6%
Europe							
Revenue	455	545	595	605	591	575	4.8%
Systems	61,484	74,770	85,230	90,920	94,410	95,760	9.3%
Workstations	61,484	74,770	85,230	90,920	94,410	95,760	9.3%
Far East							
Revenue	475	528	553	559	530	510	1.4%
Systems	37,210	45,850	53,910	59,440	61,570	64,250	11.5%
Workstations	37,210	45,850	53,910	59,440	61,570	64,250	11.5%
Rest of World							
Revenue	26	27	32	38	40	45	11.6%
Systems	4,178	4,270	5,220	6,560	7,390	8,910	16.4%
Workstations	4,178	4,270	5,220	6,560	7,390	8,910	16.4%

Source: Dataquest
May 1989

Table 7

Personal CAD Worldwide Average Selling Price Forecast
(Thousands of Dollars)

	1988	1989	1990	1991	1992	1993	CAGR
Turnkey & Hardware-Only	5.3	5.1	4.8	4.5	4.1	3.9	-6.0%
Turnkey	18.5	18.8	17.3	16.1	15.1	13.7	-5.8%
Hardware-Only	4.3	4.4	4.3	4.1	3.8	3.6	-3.5%

Source: Dataquest
May 1989

Table 8

Personal CAD Worldwide Forecast by Revenue Sources
(Millions of Dollars)

	1988	1989	1990	1991	1992	1993	CAGR
Hardware	1,214	1,346	1,451	1,466	1,400	1,337	1.9%
Software	534	654	734	794	835	883	10.6%
Service	67	71	73	74	73	72	1.5%
Total	1,782	2,071	2,259	2,334	2,308	2,292	5.2%

Source: Dataquest
May 1989

Table 9

Personal CAD Worldwide Forecast by Distribution Class
(Millions of Dollars and Actual Units)

	1988	1989	1990	1991	1992	1993	CAGR
Total Hardware and Software Revenue							
Turnkey	280	306	250	227	202	173	-9.2%
Unbundled	1,468	1,694	1,936	2,033	2,033	2,047	6.9%
Total	1,748	2,000	2,185	2,260	2,235	2,220	4.9%
Hardware Revenue							
Turnkey	184	183	138	119	103	83	-14.8%
Unbundled	1,030	1,163	1,313	1,347	1,297	1,254	4.0%
Total	1,214	1,346	1,451	1,466	1,400	1,337	1.9%
Software Revenue							
Turnkey	96	123	112	108	99	90	-1.1%
Unbundled	439	531	622	686	736	793	12.6%
Total	534	654	734	794	835	883	10.6%
Workstation Shipments							
Turnkey	16,518	14,375	11,876	11,177	10,379	9,346	-10.8%
Unbundled	225,519	274,280	312,730	337,120	351,820	360,040	9.8%
Total	242,037	288,650	324,610	348,300	362,200	369,390	8.8%

Source: Dataquest
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MACWORLD EXPO 1989: CAD IN THE CROWD

SNAPSHOT OF THE SHOW

Approximately 60,000 attendees from mainstream America converged on the 500 vendors at the MACWORLD Expo held January 20 through 22 in San Francisco, California. Amid the crush, there was room for CAD/CAM/CAE, with more than 20 vendors showing design automation products. From a CAD perspective, the show highlights were:

- The Mac user interface—Its magic is still alive, introducing users to increasingly sophisticated applications with little training required.
- Vector from Micro Concepts of Fort Wayne, Indiana—The core 3-D software and development tools from this vendor offer a ray of hope for developers grappling with the time and expense of porting vector-based products to the Macintosh.
- Extend from Imagine That of San Jose, California—This design concept simulator fully leverages benefits to be gained from the Mac's look and feel. The company was able to attract high-level prospects from the crowd at this general-purpose show.

UPDATE ON PARTICIPANTS

The biggest disappointment for those continuing to wait for AutoCAD on the Mac is that the wait is not over. First shipments are now scheduled for the end of March 1989. Versacad has moved into this product vacuum fairly effectively and claims to have sold 13,000 licenses for the Macintosh in 1988.

A few promising tactics emerged. Schlumberger will be selling its MacBRAVO product exclusively through Apple Engineering Resellers, a move which should counterbalance the dealers' demands for reasonable product exclusivity, with the vendors' needs for viable resellers in all geographic areas. Both MacBRAVO and IGC Technology's Pegasys featured a running drawing log feature that should allow these companies to create strong demonstration packages for even the most inexperienced salesperson or trainer.

And finally, a baton has passed: industry veteran Tom Lazear has handed over management responsibility of Versacad to his son, Mike Lazear. As head of the Personal CAD/CAM independent business unit at Prime, the elder Mr. Lazear has been working on knitting together the management of Versacad's 750 resellers and Prime/CV's more-focused 50 dealers.

ARE MAC USERS SERIOUS ABOUT CAD?

We had no trouble locating serious and satisfied users of the less than $1,000 CAD products, particularly in the AEC markets. Users emphasized the benefits gained in placing a CAD workstation on every engineer's desk at an hourly cost of $5 versus the $40 per hour cost of workstation or host-based systems.

Apple user surveys confirm the Mac's toehold in engineering environments. Approximately 10 to 12 percent of all Mac users are working in scientific and engineering environments, and a new Apple survey shows that 22 percent of Mac II users identify engineering/scientific as their primary application. Clearly, the opportunity for CAD products is growing, considering that an estimated 190,000 Mac IIs were shipped in 1988.

In fact, in 1988, far more Macs were shipped to CAD-oriented environments than were CAD software packages. Conversely, far more CAD software packages were shipped in the DOS-based CAD area in 1988 than were computers destined for CAD use. We believe that the balance between CAD hardware and software shipments is in better equilibrium in the DOS world, and that good opportunities exist today to sell CAD software to the Mac installed base.

However, Mac users have been paying very moderate prices for their software—including their CAD software. The earliest CAD products available to Mac users were all in the less than $700 range, whereas many DOS-based product users are accustomed to paying higher prices. Driving the MAC application software prices up to the $2,000+ point may take some serious user education.

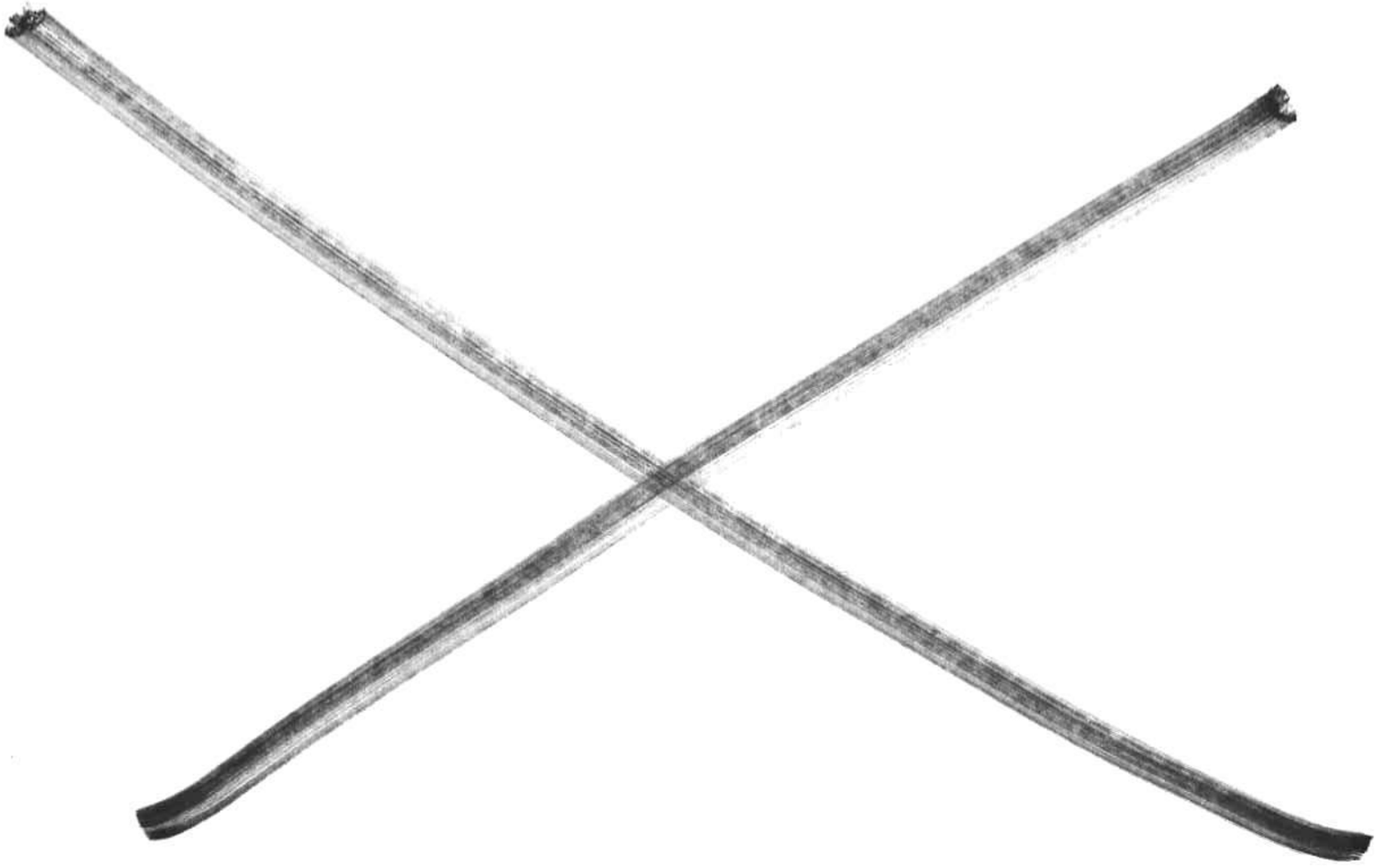
Autodesk, a key participant in this market, is probably up to the task, having sailed through a similar challenge in the DOS world. We believe that Autodesk's early sales will be to its traditionally heavy CAD users who simply want the product on a Macintosh. Experience with these initial users should allow the company to evaluate whether its break with the purist Mac interface is actually cutting into sales among the more casual but typical Macintosh users.

WHERE IS CAD GOING ON THE MAC?

Representatives from Autodesk, Claris, Engineered Software (PowerDraw), Gimeor (Mac Architrion), Infinite Graphics, and Innovative Data Design (MacDraft, Dreams) met to debate the futures of their products on the Macintosh. These vendors unanimously believe that the Mac market will continue to demand products that are easy to learn, no matter how complex the application. Opinions were far more divided on what it will take for the typically casual Macintosh user to move to 3-D design.

The Mac's allure is based on user accessibility, not price/performance. Dataquest believes that the Macintosh user's traditional expectation of easy-to-learn, low-cost software means that price-based market segments may develop quickly on the Mac. Low-priced CAD on the Mac is already established in retail and mail order channels. Higher-end products selling through VARs will be challenged to continue to develop the man-machine interface for increasingly sophisticated application software. To succeed in this market, developers must deliver on user requirements for instant product access, with training and support built into the product itself.

Kathryn Hale



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Research Newsletter

KNOWLEDGE-BASED ENGINEERING: A NEW WEAPON IN THE MCAD ARSENAL

SUMMARY

Knowledge-based engineering (KBE) is a relatively new tool in the mechanical CAD/CAM/CAE design arsenal. This technology allows users to complete work in minutes that, before KBE, took weeks. In addition to improving productivity, KBE can be used to optimize the design and manufacturing process, shorten the design cycle, improve product quality, cut costs, or allow more design iterations. With a KBE system, users capture both geometric and nongeometric information that defines design intent by building a "smart" model from engineering rules that describe how products and processes are designed. KBE incorporates the knowledge of company experts into rules that govern the entire design process.

KBE promotes design for assembly, design for manufacturability, and concurrent engineering by incorporating design, engineering, and manufacturing strategies into a product model. Although CAD/CAM/CAE is most often used in the design process, KBE may involve many areas of an organization, including engineering, manufacturing, sales support, and finance.

Dataquest believes that KBE is not merely another buzzword or marketing approach, but a valid and useful adjunct to computer-aided engineering. Large manufacturing organizations with complex design and manufacturing problems will benefit most from KBE. In general, KBE pays off best when the application is a design of a highly repetitious nature or a complex design requiring many iterations for optimization. To obtain broader market appeal, KBE will need to be easier to use and more completely integrated with other CAE applications.

This newsletter provides the following:

- A description of KBE
- A comparison of KBE with other design technologies such as parametric modeling and variational geometry
- A look at the market for KBE systems
- An analysis of barriers to growth of KBE
- A description of current KBE suppliers, ICAD and Wisdom Systems

MORE THAN GEOMETRY

KBE and CAD have been proven to complement each other. Manufacturers have surely discovered by now that CAD does a good job of defining part geometry and documenting the result of the design process. However, CAD is incapable of capturing design intent—the engineering that drives the design process. Moreover, although CAD often boosts productivity, there is still much repetitious and routine engineering that CAD cannot automate. As a result, engineers under tight time constraints tend to reuse old designs or design approaches that may or may not be optimized. CAD alone does not allow engineers to perform "what-if" analyses in a reasonable time frame.

KBE was created to address these issues. With a KBE system, users capture both geometric and nongeometric information that defines design intent by building a smart model from engineering rules that describe how products and processes are designed.

Like a spreadsheet, a KBE system needs definition. With a KBE system, the experience and knowledge of expert designers and engineers is captured in a "smart model" in the form of

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engineering rules that describe how products are designed and manufactured. Any descriptive statement that can be put into words can be translated into a design rule. Having built the model, users can quickly evaluate many design alternatives or create new designs by altering inputs to the model. Rules in the model evaluate the new inputs and generate new designs and output reports automatically. Some vendors, such as ICAD and Wisdom Systems, have developed high-level object-oriented programming environments using LISP for describing these rules for complex engineering applications.

Rules typically include product structure configuration, dependencies and relationships among parts, definition of descriptive attributes, geometric definition, decision criteria for extracting information from external databases, evaluation of analysis results, and transfer of data to and from CAD systems.

The actual collection of experts' knowledge and translation into rules is time-consuming, yet many companies agree that it is well worth the effort. Otherwise, when a key employee is lost, his knowledge is also lost. A key benefit of KBE is that it provides a way to capture the knowledge base of the expert, refine the design intent model as the experience base expands, and perhaps most important, allow the sharing of this information or procedure.

KBE provides a good foundation for concurrent engineering because rules in the model can express knowledge from many different engineering disciplines. Companies using KBE systems today have brought separate engineering groups, including manufacturing, together to describe the design and engineering process. Using manufacturing insight early in the design cycle can avoid many costly changes downstream in the process.

Users of KBE report that this technology allows them to complete work in minutes that took weeks using CAD alone. By automating repetitious tasks and using rules to create optimized product definitions, KBE has been responsible for some dramatic productivity gains. Some examples are as follows:

- Design and configuration of plastic molds reduced from 12 to 18 weeks to less than one day
- Design time for a boiler component cut from 1,000 to 100 hours
- Design time for jet engine turbine blade geometry reduced from 40 to 2 weeks
- Cost of the bid process reduced from 6 to 2 weeks

MORE COMPREHENSIVE MODELING

KBE differs from two other relatively new CAD/CAM/CAE technologies, variational geometry and parametric modeling. Unlike KBE, both these approaches are focused on geometry input or editing and have a primary benefit in enhancing the user-interface. A system driven by variational or parametric techniques develops a more valuable design model when compared with CAD, but the design intent remains in the brain of the designer. Because KBE uses engineering rules to describe the product design, it results in a more comprehensive description of a part than either variational geometry or parametric modeling.

Software based on variational geometry includes offerings from Automatix (formerly the Cognition product), Iconnex, and Premise. These programs allow a designer to sketch 2-D geometry and then constrain the geometry by linking it to equations. Variational geometry fits into the conceptual stage of the design process by permitting easy what-if analysis.

Parametric modeling systems operate best when a design task is well understood, such as variations of current designs to create families of parts. Parametric systems allow a user to specify variables instead of fixed values in the geometric description of an object. Once variables are assigned values, sometimes through use of a spreadsheet, part geometry is constructed accordingly. Vendors that offer parametric modeling systems include Parametric Technology Corp. and SDRC.

WHO NEEDS KBE?

Large manufacturing organizations with complex design and manufacturing problems will benefit most from KBE. In general, KBE pays off best when the application is a design of a highly repetitive nature or a complex design that requires many iterations for optimization. It is important to note that KBE is not limited to design-only tasks. Some applications are well suited to automation starting at the proposal-generation stage and can proceed quickly to a costing model or a full detailed product development plan. This quick turnaround gives

a salesman a potent weapon in fighting the competition, because KBE allows fast proposal generation with quality and accuracy guaranteed.

KBE vendors have targeted aerospace, automotive, consumer products, defense, and industrial equipment manufacturers. The typical designer in each of these industries has the right combination of complexity and need for optimization in the design and manufacturing process. Ford, General Motors, Motorola, and Combustion Engineering are good examples of companies that have implemented KBE systems, have found them to provide the benefits described, and are expanding its use.

A typical KBE user is Kodak, both its Film and Consumer Products Groups. Kodak has used the ICAD system along with Unigraphics to automate mold base design for plastic parts. Some of the problems in this complex application include time-consuming engineering calculations, scarce engineering expertise, tedious catalog lookup of standard parts, and an 8- to 12-week design cycle. The system implementation captures engineering tables, material properties, and standard part data with design rules. The resulting operation reduced design time from 12 to 2 weeks, optimized cavity design, and automated base and component design with many quality control-checking features.

Some large users involved with government programs are learning firsthand of the benefits of KBE. A strong interest in developing a better understanding of concurrent engineering technology and implementation is pulling KBE into the activity. The Department of Defense (DOD) has several programs, listed as follows, in progress to promote research in this area:

- DARPA Initiative for Concurrent Engineering (DICE)—General Electric has the contract.
- Manufacturing Technology Directorate (MANTEC)—A division of Wright-Patterson AFB, it has a series of programs initiated by the Air Force. All programs have a concurrent engineering "flavor"; one specifically is AAAP.
- Automated Assembly Planning Process for Aircraft Assemblies (AAAP)—NAVAIR and NAVSEA are Navy Sea Commands involved with a second generation CAD/CAM/CAE acquisition. Each RFP has included some form of rules-based engineering to support the engineering program.
- Rapid Acquisition of Manufactured Parts (RAMP)—RAMP is another Navy-sponsored project that is focused on time to market and on reducing time to service submarine parts.
- Computer-Aided Logistics Support (CALS)—CALS is perhaps the largest program. It ties in concurrent engineering and design for manufacturing to provide digital documentation for program support.

Companies bidding on these programs include Boeing, Lockheed, McDonnell Douglas, Northrop, Rockwell, and others. Each company is developing significant KBE experience and is expected to pursue the role of systems integrator in the KBE market model.

WHERE KBE FITS

KBE systems work in conjunction with existing CAD/CAM/CAE software, transferring model data via IGES in most cases. Data transfer is a two-way process. In some situations, information moves from the KBE system to a CAD package where manufacturing drawings are created, or to an analysis program for finite-element analysis. In other cases, geometry created with CAD may be transferred to a KBE system to form the basis of a model or the constraints for the design of a related part, such as the tooling associated with a given part design.

Both vendors of KBE systems have announced strategic partnerships or interface function with traditional CAD vendors such as Catia, Computervision, and McDonnell Douglas. Such arrangements ensure a working interface between CAD and KBE systems. In the long term, tighter integration—not simply IGES data transfer—should allow both CAD/CAM/CAE and KBE to work directly from the same database. Currently, ICAD and Unigraphics from McDonnell Douglas have the closest data integration, whereby a B-rep model can be accessed and manipulated directly by either software product.

Major corporate programs also are in progress. General Motors-EDS, Kodak, and others are working with KBE and CAD/CAM/CAE to better understand the benefits of an integrated approach. As the users prove the value of the combination, pressure will grow to make the integration tighter, easier to use, and less expensive. For the vendors involved, a strong alliance could easily create a marketable point of product differentiation.

Looking ahead, Dataquest expects KBE to become a required feature of any leading vendor's product offering. Many issues of cost, ease of use, and integration need to be addressed; as these issues are resolved, a growing population of users will find that KBE can play an important role in improving time to market, reducing costs of product development, and improving product quality.

MARKET OPPORTUNITY

The early KBE market has been driven by missionary sales by the KBE vendor direct to the end users. As the market has developed, several strategic alliances have formed between KBE vendors and large CAD/CAM/CAE partners. Longer term, value-added developers can take vertical application experience and package it with KBE and CAD/CAM/CAE to optimize the use of the system for a specific application. Many are looking for the magic combination of high value and untapped market for vertical market development. Systems integrators have the responsibility to make the whole process work. As the systems get more complex, the value of experience in attacking the integration problem becomes inestimable. Many large users have chosen to tackle the integration task for their own benefit. Dataquest expects a variety of companies to address this problem, from KBE vendors to CAD/CAM/CAE vendors to large manufacturing service organizations. Figure 1 shows the Dataquest model of the KBE market, illustrating product or service flow from the KBE developer to the end user.

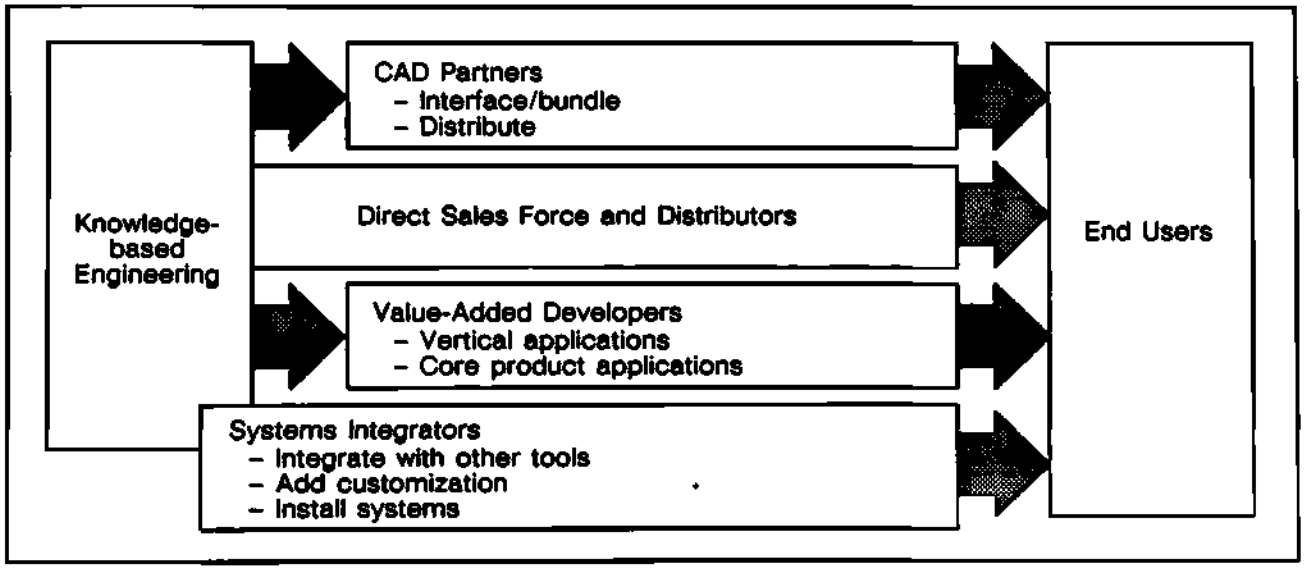
Dataquest believes that KBE is one of the key enabling technologies of the 1990s. As the market matures, moving from the hands of the experts to becoming more general and integrated, it will experience significant growth. A forecast of the KBE market is shown in Table 1.

BARRIERS TO GROWTH

Two factors will hinder the growth of KBE. First, the technology is complex, resulting in time-consuming implementation projects with significant expenses. Effective use of KBE requires lengthy interviews with many people to obtain the knowledge that underlies design rules. Creating rules is not simple either, although special training in object-oriented programming may not be necessary. Man-months of setup are required to reap the desired benefits. Dataquest expects the leading KBE vendors and CAD vendors to develop much more effective user interfaces in the short term to address this issue.

The second barrier to KBE growth is confusion in definition. In addition to being sometimes mistaken for parametric modeling and variational geometry, the perception that KBE is built on a type of artificial intelligence confuses prospective users even more. KBE vendors face the daunting challenge of educating several groups of people. Current CAD users need help in understanding the value of adding KBE technology. Non-CAD users face a larger hurdle because they must understand the potential benefits, learn how to do the value analysis, and learn to get comfortable with the

FIGURE 1
KBE Market Model



Source: Dataquest (August 1990)

TABLE 1
Forecast of Worldwide KBE Software Market
(Millions of Dollars)

	1989	1990	1991	1992	1993	CAGR (%) 1989-1993
KBE Vendors						
Direct to End Users	13.0	21.0	30.0	39.0	43.0	27
OEM Relationships	1.5	7.0	20.0	47.0	101.0	132
CAD Vendors						
Direct to End Users	4.0	18.0	52.0	124.0	262.0	131
Total						
Direct to End Users	17.0	39.0	82.0	163.0	305.0	78

Source: Dataquest (August 1990)

concept, believing that they can duplicate the grand success described in the latest testimonials. Perhaps the most important group that needs education in KBE, particularly within the next few years, is the sales force. If any KBE vendor is involved in developing a CAD vendor distribution channel, that vendor must help to define the message showing the value of the combined offering. To many users, the far-reaching benefits of KBE fall in the too-good-to-be-true category. As more and more success stories surface, the significant benefits will be better understood.

A SMALL FIELD

At this time, two vendors offer KBE systems: ICAD of Cambridge, Massachusetts, and Wisdom Systems of Cleveland, Ohio. Other KBE system developers are working to get involved with the CAD/CAM/CAE market. Dataquest expects several vendors with KBE experience and major CAD/CAM/CAE vendors to announce product offerings in this area in the next two years. Virtually all application areas will be affected.

ICAD was founded 1984 with a contract from CV to provide a design automation system for air-cooled heat exchangers. ICAD developed a generic tool to build the heat exchanger design system; that generic tool later became The ICAD System. At the core of the ICAD philosophy is creation of a smart model, a comprehensive representation of a product that includes design, engineering, and manufacturing process information.

Major components of The ICAD System include the following:

- ICAD Design Language—The component of the system that allows users to define rules that describe the design, engineering, and manufacture of complex products
- ICAD Solids Designer—Provides solid modeling function that can be driven from rules base. Announced at last year's Autofact, the solid modeler is based on the Parasolid modeling kernel, developed by Shape Data, which was acquired by McDonnell Douglas in late 1988.
- ICAD Surface Designer—Provides NURBS curve and common surface creation capabilities
- ICAD Drawing Tools—Includes an output interface tool kit with automatic drawing annotation
- ICAD Interface Tool Kits—Provides a variety of interface options for the transfer of information to and from CAD systems and external databases

The ICAD system runs on Sun SPARCstations, HP 300 and 400 series, the Symbolics MacIvory, and the Symbolics 3600 family. A port to the Digital DEC Station 5000 and IBM RS6000 is reportedly under development.

Over 350 systems are now installed at 50 sites, in 10 countries. Users include General Dynamics, General Electric, General Motors, Kodak, Lockheed, Northrop, and Pratt & Whitney.

ICAD has shipped $20 million in software systems and averaged an annual growth rate of over 100 percent in revenue and number of employees during its six-year existence. The company is privately held.

Wisdom Systems introduced its first product, the Concept Modeler, at Autofact '87, one year after the company was formed as an official business unit of McDermott International. McDermott has since sold Wisdom Systems and Bailey Controls Company to an Italian firm called Finmeccania, a unit of Istituto per la Ricostruzione

(IRI) located in Milan, Italy. Wisdom positioned the Concept Modeler as a tool for the conceptual stage of the engineering process and aimed advertising at companies that bid custom configurations of their products.

Wisdom Systems initially positioned its Concept Modeler as a tool for the conceptual stage of the engineering process, but as of last fall, the company has been touting the benefits of its system in automating simultaneous engineering. The company still focuses on the conceptual stage of the process, but emphasizes that it is at this point that the Concept Modeler integrates engineering, manufacturing, and marketing so that the resulting product meets everyone's needs.

Last fall, the Concept Modeler was expanded to the Wisdomwise software family, which includes the following:

- The Advanced Concept Modeler—Includes the Advanced Geometry Package, which enhances the capabilities of the modeling system to handle complex surfaces and solids
- Questa:Link software—A LISP development tool makes it possible to connect models to relational databases

Wisdomwise software runs on a variety of hardware platforms including Sun SPARCstations, VAX, Apollo, TI Explorer II, TI MicroExplorer, IBM PC-RT, and Symbolics. Although Wisdom has sold approximately 90 software licenses, the majority of its users are other McDermott subsidiaries. However, the Air Force recently selected the Concept Modeler for a simultaneous engineering project designed to cut turnaround time for machining aircraft metal parts to one day.

Wisdom has announced strategic partnerships with CV and Parametric Technology Corporation. With CV, Wisdom has agreed to jointly develop an interface between Wisdomwise software and CV's CADDS programs. Parametric Technology's Pro/Engineer package is being marketed as a geometry capture system for Wisdomwise products.

Wisdom Systems currently is an operating unit of Bailey Controls, which has sales of $400 million. Shipments for Wisdom Systems is estimated to be more than $7 million.

Both vendors supply development seats in the $50,000 to $100,000 range for software. Cost varies depending on modeling technology, training, and platform options. After development, the automated procedures can be moved to production seats that cost in the $20,000 range.

DATAQUEST ANALYSIS

Dataquest believes that KBE has much to offer. KBE captures design intent of expert designers and can be used to optimize product design and the flow of data to manufacturing. In the ongoing attempt to integrate engineering and manufacturing, KBE delivers a concrete and workable solution. The long-term benefits of higher product quality and optimized procedures in moving from concept to delivery are sorely needed in the competitive manufacturing environment. KBE is an essential ingredient of any program tackling concurrent engineering or design for manufacturability.

KBE is not a simple solution, however. It is a complex technology that requires a focused and dedicated effort in order to pay off. It multiplies the value of CAD/CAM/CAE systems, but, for now, at a high price.

The market for KBE systems currently is limited, but the best-case outlook is bright. As KBE systems become easier to use and more tightly integrated with CAD, they can be applied to simpler and more general applications. Eventually, KBE may become embedded in CAD. However, KBE vendors will need to educate the engineering community on the unique benefits of KBE systems if they want to see such growth. Dataquest expects KBE to be one of the fueling elements that propel the worldwide mechanical CAD/CAM/CAE market to $10.4 billion in 1994.

Michael J. Seely

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Research Newsletter

MECHANICAL CAD/CAM FUTURESHOCK: HERE COME 3D VIDEOLASER DIGITIZERS

SUMMARY

Just when everyone begins thinking that real innovation in CAD/CAM is a thing of the past, along comes something truly revolutionary. For example, in 1987, solid 3-D plastic prototypes from 3D Systems startled the market (see CCIS Research Newsletter 1987-9). In 1989, there is Vision 3D's 3D Videolaser. It can create digitized images in minutes (which leads to the consequent productivity gains); this capability is product innovation on a scale that will match and capture the popular imagination. As a development that potentially can open the market to many applications previously closed to CAD/CAM and can service retrofit, testing, and in-process gauging applications, the 3D Videolaser represents a technology—and a whole product class—that vendors need to watch.

HOW IT WORKS

3D Videolaser is an industrial system from France's Vision 3D that permits three-dimensional data acquisition. The product consists of a video camera and monitor, a 2-D laser, a linear or turntable mount, proprietary control modules, and a data acquisition and processing system based on an IBM AT or compatible.

The laser harmlessly illuminates the object to be digitized in order to describe a profile of the object (see Figure 1). Equipped with a parallax lens, the video camera then records the profile traced by the laser. A 3-D data acquisition card retrieves the laser trace from the camera image, and corresponding points are stored by their coordinates in a camera reference frame. By rotating or otherwise moving the object, the system records all the profiles defining its shape.

In this manner, the system generates a profile that contains several hundred points arranged in meridians that are known by their coordinates within the camera reference frame and the position of the meridian relative to the movement applied to the object. The number of points acquired depends on the camera resolution, the number of profiles required to scan the geometry adequately, and the object's location in the camera's field of view. Vertical resolution is camera-dependent, while x, y resolution depends on the number of points in the meridian and on the angle between the camera axis and the laser axis.

The optics that convert the laser beam into a planar beam can be internal or external. An interference filter tuned to the laser frequency relieves the user of any dependency on ambient light. A second camera, as well as a second laser, can be used to resolve hidden area problems.

POINT ACQUISITION

Acquisition accuracy depends on the width of the laser beam at the point of intersection with the object. According to the types of optics used, the width may vary from a few hundredths of a millimeter to 1 millimeter for common lasers. Although in some cases accuracy does not match direct contact measurement methods, it is usually within +0.15 to +0.02 millimeters.

The physical specifications of the table mount vary with the application. The table mount can range from a record-deck-size arrangement to a 10-meter diameter table that is capable of moving 10 tons.

Regardless of the mechanics of any individual configuration, the 3-D data acquisition card is at the heart of the system. When the card receives the

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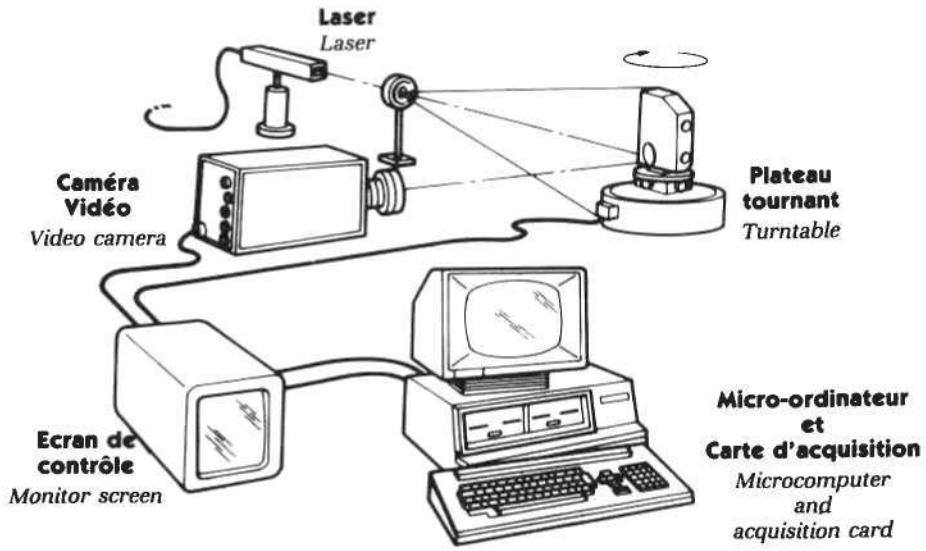
FIGURE 1
3D Videolaser System Configuration



The System Includes:
- 1 or 2 laser sources
- 1 or 2 video cameras
- 1 electronic acquisition card
- 1 IBM AT microcomputer
- All acquisition and processing software
- A system for moving the objects to be digitized:
  - Linear table
  - Turntable

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Source: Dataquest
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video signal, it performs signal windowing so that only the most useful signal points are retained. It digitizes the video signal, which sets threshold levels that pick up the laser trace. The laser trace coordinates are then transferred to the CPU.

The proprietary software consists of 7 modules:

- Autotest—The autotest module allows the user to test the main board functions.
- Configuration—The configuration module sets the parameters for motor-stepping changes and adjusts for varying conditions: interlaced or non-interlaced scanning, internal or external sync, internal or external clock, and European or U.S. video standards. This module also selects the threshold for meridian points.
- Calibration—The calibration module links camera pixels to points in space via the patented calibration process.
- Acquisition—The acquisition module ensures interactive operator acquisition of geometric data that relate to the object being digitized. It also handles meridian point reception, mass storage, and control of motor movement. Up to 100,000 points per minute can be captured.
- Raw display—The raw display module redisplays the file so that the operator can estimate the quality of meridian acquisition. The result of coordinate calculation is an ASCII file in which the points are arranged by meridians.

- Coordinate calculation
- Fast perspective—Using the fast perspective module, the operator can display an image of the digitized object from any angle. The module defines the line of sight and performs rotation (on all three axes), scaling, and windowing.

Optional software modules can be employed for data filtering, z-sampling, wire frame display, variable calculations (surface area, volume, inertia), file overlays (when more than one laser is used to capture data from hidden areas), downstream communications, and output drivers.

The system itself is a front-end acquisition and processing tool that is meant to be used in conjunction with other tools for specific CAD/CAM, robotics/dimensional control, animation, and other applications.

In a computer-integrated manufacturing (CIM) scenario, the problem usually is how to generate a CAD data base for physical models that have irregular shapes and curves (which are created by designers for esthetic reasons). After capturing the raw data, the 3D Videolaser system performs the smoothing, filtering, and surface and volume calculations needed for useful 3-D CAD input.

The system also can be used downstream in the manufacturing process to provide dimensional verification and shape control in space through either sampling or screening inspections.

For CAD applications, Vision 3D has developed two kinds of interfaces, by sections and subsampled points on the surface.

The data base of points is organized by sections along x, y, or z axes. In each section, points are ordered continuously and the number of points is reduced by intelligent subsampling of the section. This ordering allows the distance between the curve and polygon to be obtained independently of the curvature.

A detection of sharp edges is done on the surface, and a skeleton of edges is determined in order to split the complete surface in continuous surfaces without edges. Then, points in the subsurface are subsampled in a homogeneous network with regard to the curvature of the subsurface.

In either of the two cases, the result is an ASCII file of x, y, z points in a format acceptable by any CAD software.

Vision 3D already has systems linked with IEMS (Intergraph), UNIGRAPHICS (McDonnell Douglas), CADDS 4X (Computervision), STRIM 100 (Cisigraph), EUCLID (Matra Data Vision), CADKEY, IRIS (Silicon Graphics), and CUBI7 (Caption).

This technology is not unique to Vision 3D. Cyberware, a U.S.-based vendor, uses similar technology to produce "sculpted heads" by NC machining after first scanning the subject with a low intensity laser in this kind of fashion.

The 3D Videolaser is unique because it can be adjusted to the size of the object in order to optimize the acquisition. An object in a 400mm cube can be digitized in several ways, as follows:

- In 1 time, with the static field of acquisition being 400mm x 600mm. Accuracy will be 0.3mm.
- In 4 time, with the static field of acquisition being 120mm x 180mm. Accuracy will be 0.1mm and the number of points will be three times greater than with 1 time.

APPLICATIONS

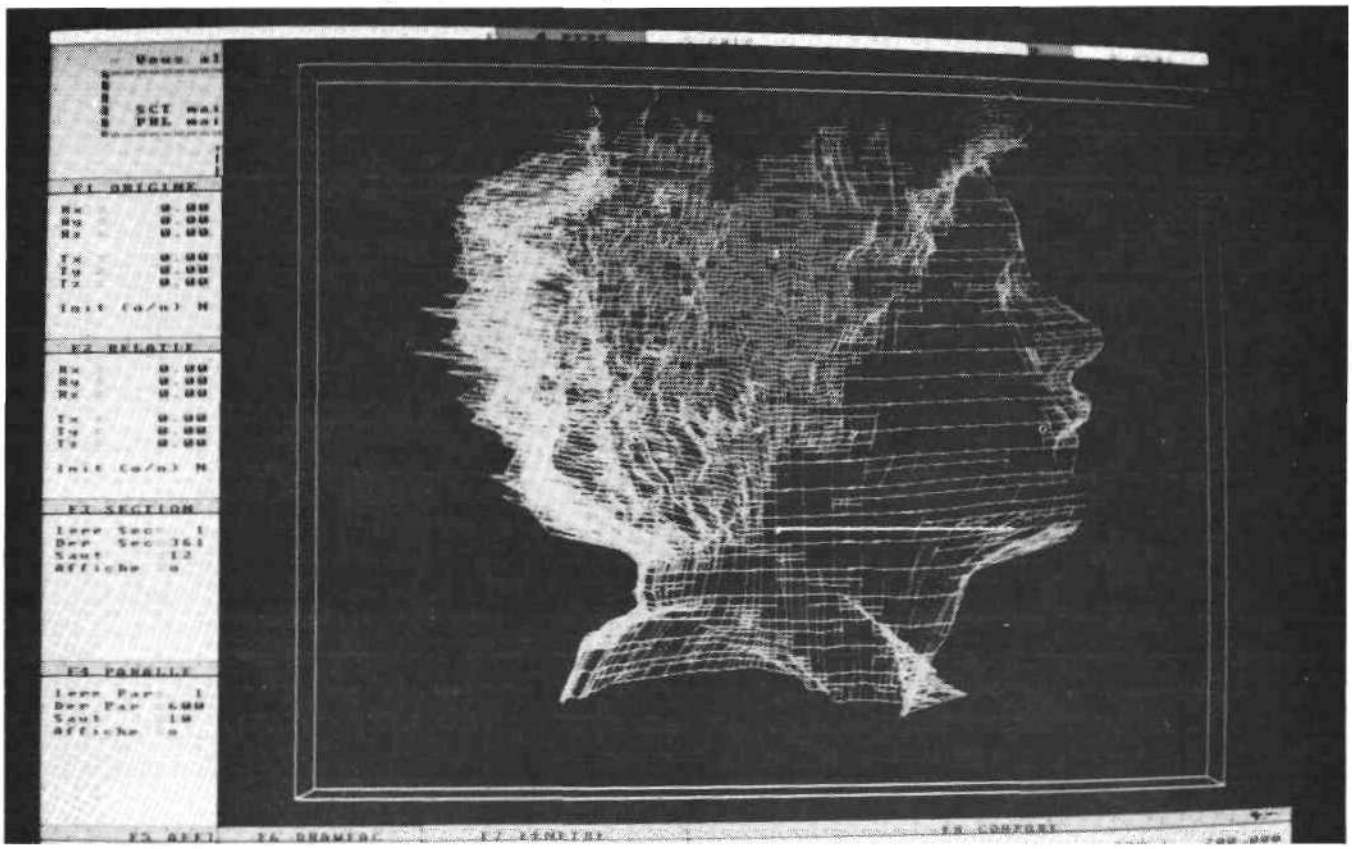
What is unique to Vision 3D's product is the range of applications provided. Key among these are the applications related to digitizing the human frame for use in both the fashion industry and the medical field (see Figure 2).

Rapid, noncontact digitization is essential when dealing with the relatively soft, resilient character of the surface of the human frame. These techniques have been used effectively in shoe design, the construction and fit of various types of safety helmets, and garment design.

In the medical field, whole body scans are possible and, using X-ray lasers, it is possible to establish skeletal geometry in CAD systems. With this and MCAE analysis techniques, it is possible, for example, to establish the optimum magnitude and direction of corrective forces for spinal deformities.

Other applications include scanning of the complex surface geometry used in the automotive industry, such as remedial testing for water erosion of turbine buckets. In the packaging area, establishing the envelope parameters of printed circuit boards can be done in minutes using this technique.

FIGURE 2
3D Videolaser 1/400/Head Output (Faceted View).



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Source: Dataquest
August 1989

DATAQUEST CONCLUSIONS

The 3D Videolaser provides an easy, fast, and relatively accurate noncontact digitizing technique and has broad applicability. It is important in digitizing the human frame and has a significant future in inspection and quality control applications. It provides a possible complement to Valysis verification and "in-process" gauging. And, coupled with the technology from 3D Systems, it may be possible to produce a copy in plastic of any object with minimum interaction on a CAD system, thus completely eliminating the need for a machine tool. Innovation in CAD/CAM is by no means dead. Judging by the 3D Videolaser introduction, it is just warming up.

Dr. Charles Clarke
Tony Spadarella

Don't Forget!

Register today for Dataquest's Technical Computing and Applications Conference, "Preparing for the 1990s," September 11–13, at the Doubletree Hotel in Santa Clara, California. To register, call the Dataquest Conference Department at (408) 437-8245.

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Research Newsletter

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MECHANICAL CAD/CAM 1988 MARKET AND 1989 FORECAST: STEADY GROWTH MASKS VENDOR TURMOIL

SUMMARY

The 1988 mechanical CAD/CAM (MCAD) market delivered a somewhat predictable performance, growing 16 percent in worldwide revenue. However, the market's steady, upward growth in total revenue belies the ups and downs of competing in this fast-evolving market. Changing buyer expectations, expanding market needs, technology enhancements, and world economics—all are the driving dynamics in today's MCAD market. Superstar performances by leading vendors and the underlying trends and issues in this rapid-pace market are discussed here.

This newsletter also presents the 1988 market highlights, gives Dataquest's forecast for 1989, and discusses in depth current industry trends and market leaders. Tables 1 through 6 at the end of this document show Dataquest's forecasts for this market.

1988 MARKET HIGHLIGHTS

- A 16 percent growth rate lifted the 1988 mechanical CAD/CAM market over the $5.9 billion mark in worldwide revenue.
- IBM and Prime split the top 30 percent of the MCAD market, with IBM taking $1.3 billion and Prime $685 million.
- Asian vendors captured four of the top fifteen market share slots in MCAD through primary sales activity in their local market.
- Europe became the leading consumer of mechanical CAD/CAM products.

1989 FORECAST HIGHLIGHTS

- Worldwide mechanical CAD/CAM revenue is expected to swell from $5.9 billion to more than $8 billion in 1993.
- It now appears that the demand for host-based systems peaked in 1987. In 1988, host-system sales began a downslide in revenue and shipments that will stabilize toward the end of the forecast period, at about two-thirds of 1987's high-water mark.
- Technical workstations dominate market share growth, and will jump from 34 percent of the market in revenue in 1988 to 65 percent in 1993.
- Sales of personal computers are expected to hover at around the $1-billion-per-year level, while unit shipment volume inches upward.
- Europe is forecast to remain the number one MCAD consumer.
- Asia will outpace total market growth in terms of revenue and units shipped.

INDUSTRY TRENDS

Steady worldwide demand for mechanical CAD/CAM products has set the stage for a wide variety of marketing strategies based on regional, platform, or niche application segmentation. But vendors are discovering, to their chagrin, that they continually must reposition themselves to hit a moving target, as both technology and user expectations are in constant flux.

The result is a predictably chaotic MCAD market and an administrative and marketing nightmare. Alliances are being forged simply to leverage installed user bases. Software porting to 12 or more platforms is common, with certain products offered on 100 platforms or more. Cheaper, faster hardware introductions are coming at increasingly shorter intervals. In such a market, vendors that can deliver doubled performance each year, while reducing prices 30 percent or more, are the perceived market leaders.

Analysis of the major trends driving the mechanical CAD/CAM market follows.

Strategic Alliances: A Fact of Life

Every major vendor announced alliances in 1988. With large users insisting on vendor commitment to win the business, we at Dataquest expect this trend to continue, as no single vendor has been able to deliver leading-edge functionality across the breadth of CAD/CAM applications.

Although a few vendors do a creditable job focusing in one industry or application niche, the user demanding mechanical, electronic, and facilities design functionality will most likely be using products from two or more vendors. Add the variability caused by local vendors in a worldwide market, and it is easy to understand the opportunity that exists for hundreds of vendors selling to thousands of user sites.

We believe that the most courted allies in 1989 will be those offering new technology based on advanced mathematical algorithms, object-oriented programming tools, and data base structures. ICAD, Object Design, Premise, Rasna, Ricoh, and XOX, among others, are examples of vendors fitting this category.

User Demographics

Roughly two-thirds of all technical professionals have some need for mechanical CAD/CAM applications. A third of this group has received some mechanical CAD training. We expect a doubling in the number of trained users in the next two or three years, with the remaining nonusers either becoming involved or retiring in the following five years.

New User Expectations Re: Ease-Of-Use

"Associative," "intuitive," and "consistent" are all words used to describe the latest releases of mechanical CAD/CAM products. To put it simply, buyer expectations are evolving. Buyers no long need to tolerate user interfaces with less sophistication.

New Level of Productivity at the High-End

High-end products are demonstrating a new level of productivity. High-performance 3-D computing, 3-D graphics, and 3-D software have evolved to new levels of performance and functionality. This combination is being promoted as the next major step toward improving user and enterprise performance.

Developers of high-end products must remember the current high level of user interest in well-integrated products. A blindingly fast display is worth little without a mathematical data base that can be used for design, analysis, and manufacturing. A fast 3-D modeler is worth little if it cannot be used to quickly generate detailed design information. A complete conceptual and detail design product is worth little if it cannot interface to the leading analysis tools and common manufacturing processes.

Penetration

Market penetration is a key driving issue in the MCAD market. The main-stream dynamics of this issue are focused on the experienced user. Many manufacturing companies consider CAD/CAM an indispensable component of the engineering information system. Moving this group of experienced users forward every five years will be a

significant challenge. Motivating change, minimizing training and retraining cost, and increasing productivity are the major barriers to managing system upgrades and expansion. The leading vendors will find ways to address these issues by improving the user/system interface and integration functionality and increasing the value of the CAD/CAM investment.

System Retirement

The rising retirement rate of CAD systems is presenting a significant market opportunity. Every year, systems are retired because of cost, lack of performance, or perhaps the vendor supporting the equipment goes out of business or gets acquired. The maintenance fees for some three- or four-year-old systems can be more than the replacement cost using a current product.

Our retirement model shows very little turnover in the first few years of system use. Beginning in the fourth year of service, approximately 25 percent of the personal computers sold for CAD applications are being retired or moved into other applications. Technical workstations follow a similar, but slower, retirement curve, reaching 50 percent retirement by the end of the fifth year of use. Host-based systems are expected to reach that level of retirement during the sixth year.

Currently, 40 percent of installed systems are more than 2 years old. By 1993, more than 60 percent of the installed workstations will be more than 3 years old. Dataquest expects the replacement market to be very active in the mid-1990s, assuming that the trends of improved price/performance and application integration continue.

MARKET FORECAST AND OUTLOOK

Software Lagging Hardware

Software vendors have been characterized as falling behind hardware vendors in developing state-of-the-art products. This view, although popularly held, belies the truth. Basic technology advancements are occurring on all fronts with increasing frequency and speed. More base technology of a revolutionary nature is being developed in hardware and software than at any point in the history of the CAD/CAM industry. Each month, new software products are introduced that present new data base structures, use the latest programming languages, and offer new mathematics that can solve the toughest geometric construction problems.

The real issue is not lagging software technology but package price. Software vendors will be very quick to take advantage of super high-performance hardware when the prices come down. They have been fighting the war of lower prices in response to the maturing PC market. They are reluctant to jump into a package price of more than $70,000 without very clear, quantifiable productivity benefits to the customer.

Software vendors that have been riding the decrease in hardware prices to offer cheaper and faster systems should beware. Aggressive software development is emerging that takes advantage of the latest in object programming and data base structures. Senior programming staff must be encouraged to understand and utilize these new programming tools effectively. Technology refreshment for the leading products must evolve using the best hardware and software available.

Regional Forecast

After a slight drop in revenue in 1988, the North American market is expected to grow 5 percent in 1989. The worldwide forecast for 1989 is 11.7 percent. Europe surpassed the North American market in total revenue for the first time in 1988, and it is expected to retain the largest regional market share. Asia also is gaining world market share, but not quite as fast as Europe. Europe should grow at a 16 percent rate in 1989, with Asia following at a rate near that of the worldwide average.

Platform Forecast

The expected flat growth rate for host-based systems turned out to be a bit optimistic. Host-based system revenue declined 7 percent in 1988. Similar revenue and shipment declines are expected in 1989 and beyond.

Host-based systems are not disappearing, however. The same incredible performance improvements in computing technology are being applied to multiuser platforms. These improvements are reducing costs and will help reduce the common complaint of performance degradation while maintaining integrated data and information management functions.

A critical driving issue in the next five years, related to the relative popularity of host-based systems, involves X-Windows. X-Window terminals are being developed that will provide low-cost access to engineering data bases held on host-based and distributed systems. One vendor recently reported the following challenge from a current user: "If you can get the cost-per-terminal down to $2,000, we will buy 600 units and put one near everyone in the factory." X-Window terminals do not make that price point today, but they are close.

Multiuser DOS systems are being advertised for office automation applications. Expect the low price tag and integrated environment to attract some low-end CAD/CAM applications. Some users do not want to worry about loading software, file backups, or system manager issues. They just want to use it, share it, make it part of their normal work day.

Technical workstations and personal computers are evolving at an amazing rate. Expect faster, cheaper machines with more memory, and perhaps most important, very significant improvements in the system architecture at the chip level. Intel's recent launch of the i860 processor is a prime example of the technology going into a processor chip

today. The full 64-bit, RISC-based processor has vector floating point and a 3-D graphics subsystem implemented on a 1-million transistor chip. With prices starting in the $750 range, this chip has 33 VAX mips performance with 10 mflops double precision Linpack, and graphics capability of 50,000 Gouraud shaded polygons per second. It will run a multiprocessing version of UNIX System V Release 4.0. The definitions used to differentiate technical workstations and personal computers are rapidly becoming obsolete. Expect to see DOS, UNIX, and other operating systems running concurrent on desktop computers in the near future. Dataquest will redefine platform segmentation in the next two years, reflecting these trends in technology evolution.

Average Selling Prices

Mechanical CAD/CAM system prices will fall an average of 10 percent per year for the next five years. Personal computer prices are holding steady or rising a bit as more memory and larger disks are required to support software with growing functionality. The latest high-end technical workstations are maintaining price tags above $75,000, but below the $100,000 pain threshold. Products offered in the $20,000 range are in the middle of a hot bed of competition. Several vendors are targeting this price point as the most important in gaining market share of the engineering desktop.

Some leading software vendors have effectively raised prices 10 or 15 percent per year for existing customers by switching to per-seat pricing. High-performance graphics and computing are being offered in innovative packaging for the benefit of users and software suppliers. We expect the trend toward better performance and lower prices to continue.

Revenue Sources Forecast

The trend in revenue distribution in the typical CAD/CAM system has not changed. Software is growing its share of total revenue, due partially to higher prices, but due also to a growing percentage of add-on software. Hardware is decreasing at the same rate that software is increasing, leaving service revenue at a fairly constant 14 to 15 percent of the total.

Distribution Class Outlook

"Bundled-versus-unbundled" has been a major strategic issue for many CAD/CAM vendors. There is just no easy solution. Both approaches have merit and risks. As the trend continues toward standardized platforms and platforms supporting a variety of operating systems, the transportability of software becomes easier, thus encouraging unbundled offerings. User demand for one-stop shopping and one-call service encourages the bundled approach. Large users want the integrated solution independent of product mix. Advances in application software, communications, and data base design are making the integrated environment easier to visualize. System upgrades, integrated scalable solutions, price, and distribution channel will be the primary driving issues in resolving the bundled/unbundled dilemma.

MARKET SHARE LEADERS

Number One: IBM

IBM grew 15 percent in 1989 to $1.3 billion, earning a respectable 22.1 percent market share, down from 22.9 percent of market in 1987. Workstation shipments, however, dropped from a 32.7 percent to a 14.5 percent share of the worldwide mechanical CAD/CAM market.

Normally, such a significant drop in shipped unit share would be accompanied by an even larger drop in total revenue. However, this was not the case in 1988 with IBM. It shipped more host-based products with a higher average selling price, but lost significant market share on the low-end PC products to Apple, and to Compaq and other DOS-compatible manufacturers.

IBM sold more than 22 percent of the mechanical CAD/CAM market in Europe. CATIA was a key ingredient in this growth, following a direct investment of the European car manufacturers, aerospace, and multinational manufacturers.

Worldwide, the numbers are amazing, considering the slowly eroding host-system sales. IBM software revenue grew more than 160 percent on the host-based platform, worldwide, representing an astounding 36 percent share of market.

Number Two: Prime

Prime, via its major acquisitions of Calma and Computervision, soared spectacularly from seventh to second place in the MCAD market. Revenue for the combined companies grew 9.5 percent over their individual 1987 revenue. The new Prime includes Prime Medusa, Computervision, Calma, and Versacad, and apparently remains on track in 1989, with its first-quarter sales having delivered more than 30 percent of the year's quota.

Number Three: Digital

Digital took a major turn in 1988, slipping into third place behind the new Prime. While the number of seats sold direct to end-users increased from 3,300 to 5,400 seats, Digital's revenue from those shipments dropped 32 percent, from $631.0 million to $429.0 million. This is due to the shift from VAX host systems to MicroVAX technical workstations, which have lower average selling prices. Additionally, the revelation that Digital's future workstation products will be UNIX-based, to allow higher performance, caused concern among the VMS workstation user base, where the MicroVAX has been extremely popular.

Number Four: Intergraph

Intergraph was number four again in MCAD. Revenue in 1988 increased 33.7 percent over 1987, from $180.0 million to $241.0 million. The EMS product for mechanical design with new high-performance hardware is causing the strong growth in this application area.

Number Five: McDonnell Douglas

McDonnell Douglas held onto fifth place in the market, with revenue of $181.1 million, up 10.6 percent from 1987. The announced interface with ICAD and the strategic alliance with EDS should be positive growth factors in 1989.

Number Six: Hewlett-Packard

Hewlett-Packard moved from tenth to sixth position, with $164.3 million in sales, representing 99.4 percent growth in revenue over 1987. The ME10, ME30, and unbundled hardware sales contributed significantly to the record-breaking year. European revenue was another area of rapid growth.

Number Seven: Compaq

MCAD was an extremely profitable market for Compaq in 1988, which had sales of $155.0 million. Compaq benefited from the overlap in markets where high-end personal computers vie with low-end workstations for the same customers.

Number Eight: Control Data

Control Data's revenue declined 8.9 percent from 1987, to $147.9 million in 1988. Control Data's market position slipped from sixth to eighth position. The big ticket mainframe systems have experienced a drop in average price per seat and have seen reduced unit shipments.

Number Nine: NEC

With nearly two thirds of its $226.4 million total revenue in mechanical CAD/CAM ($140.7 million), NEC ranks ninth in worldwide MCAD and number two in Asian MCAD. NEC has shifted away from mainframe-based systems to the technical workstation (i.e., the NEC EWS4800). NEC shipments were almost as high as IBM's total workstation shipments in Asia—largely due to NEC's unbundling of its own PC.

NEC has a strong application focus, offering all major CAD/CAM applications with the exception of IC layout. NEC's larger strategic plans include MIPS RISC chip manufacture, with production goals of 20,000 to 30,000 units per month.

Number Ten: Schlumberger (Applicon)

Schlumberger's MCAD revenue grew 10 percent in 1988, to $138.0 million, while its share of market declined two-tenths of one-percent, to 2.3 percent of total market. The recent introduction of Apple-based products should increase unit market share and open the PC market for Schlumberger.

The next three Japanese market share leaders—Nihon Unisys, Hitachi, and Fujitsu—ranked eleventh, twelfth, and thirteenth, respectively, in 1988. Like NEC, they all sell exclusively in Japan. Asian-based companies accounted for 14.5 percent of worldwide MCAD sales in 1988, up from 12.9 percent in 1987.

DATAQUEST CONCLUSIONS: EMERGING OPPORTUNITIES

Mechanical CAD/CAM is at the crossroads of computing technology. Every brand of computer, graphics display, operating system, and peripheral device is being utilized to support this application. This tremendous diversity has fueled steady growth and supplied a plethora of options for the user. We expect the high-end, advanced products to continue to lead the way for new technology applied to old problems. The mainstream of the market will ride the lower-cost, midlevel performance product line from choosing time-proven MCAD products. The low end is expected to continue to attract the MCAD novices and part-time users who have fueled the rapid growth of the PC-based market. Approximately one-third of the technical professionals in the United States have been trained in the use of some MCAD product. Several major users have stated growth plans that will double that number in the next two years. Ease-of-use, reliability, and productive operation will be essential for vendors competing at this market frontier.

Michael J. Seely
Tony Spadarella

Table 1

1988 Worldwide Mechanical CAD/CAE Market
(Millions of Dollars/Actual Units)

					Market Share			
Company	Total Revenue	Hardware Revenue	Software Revenue	Wkstns Shipped	Total Revenue	Hardware Revenue	Software Revenue	Wkstns Shipped
IBM	1,317.0	828.5	306.9	30,801	22.1%	22.4%	21.2%	14.5%
Prime Computer	684.7	313.0	185.5	6,309	11.5%	8.5%	12.8%	3.0%
Digital	429.0	353.5	.0	5,409	7.2%	9.6%	.0%	2.5%
Intergraph	240.6	139.7	51.0	2,636	4.0%	3.8%	3.5%	1.2%
McDonnell Douglas	181.1	83.8	51.5	2,417	3.0%	2.3%	3.6%	1.1%
Hewlett-Packard	164.3	106.8	33.5	7,712	2.8%	2.9%	2.3%	3.6%
Compaq	155.0	155.0	.0	29,760	2.6%	4.2%	.0%	14.0%
Control Data	147.9	102.2	19.7	1,658	2.5%	2.8%	1.4%	.8%
NEC	140.7	111.0	21.5	7,095	2.4%	3.0%	1.5%	3.3%
Schlumberger (Applicon)	138.0	57.5	40.5	1,880	2.3%	1.6%	2.8%	.9%
Nihon Unisys	128.8	90.2	29.6	653	2.2%	2.4%	2.0%	.3%
Hitachi	115.5	75.7	28.3	1,125	1.9%	2.0%	2.0%	.5%
Fujitsu	107.6	66.4	26.7	1,297	1.8%	1.8%	1.8%	.6%
Apollo	75.9	64.9	.0	3,958	1.3%	1.8%	.0%	1.9%
Sun	75.3	67.9	.0	3,585	1.3%	1.8%	.0%	1.7%
Apple Computer	75.0	66.0	.0	17,500	1.3%	1.8%	.0%	8.2%
Siemens	72.9	43.7	21.9	1,604	1.2%	1.2%	1.5%	.8%
Hitachi Zosen	69.3	34.8	27.6	846	1.2%	.9%	1.9%	.4%
Matra Datavision	67.0	42.1	14.8	571	1.1%	1.1%	1.0%	.3%
Silicon Graphics	55.6	50.6	.0	2,235	.9%	1.4%	.0%	1.0%
Autodesk	50.4	.0	50.4	0	.8%	.0%	3.5%	.0%
Mutoh Industries - No OEM	47.5	27.9	16.3	1,193	.8%	.8%	1.1%	.6%
Mitsubishi Electric	46.2	21.0	15.1	237	.8%	.6%	1.0%	.1%
Auto-Trol	44.6	18.7	11.1	624	.7%	.5%	.8%	.3%
SDRC	42.0	.0	42.0	0	.7%	.0%	2.9%	.0%
MacNeal-Schwendler	39.9	.0	39.4	0	.7%	.0%	2.7%	.0%
Unisys	38.6	8.7	24.5	617	.6%	.2%	1.7%	.3%
Norsk Data	36.5	18.5	10.4	484	.6%	.5%	.7%	.2%
Cimlinc	34.2	16.3	10.5	2,053	.6%	.4%	.7%	1.0%
Ferranti	31.1	20.1	5.8	266	.5%	.5%	.4%	.1%
Toyko Electron - No OEM	27.6	8.3	8.3	53	.5%	.2%	.6%	.0%
Gerber Systems	26.8	13.1	8.6	364	.5%	.4%	.6%	.2%
Toshiba - No OEM	25.4	10.9	5.5	520	.4%	.3%	.4%	.2%

Table 1 (Continued)

1988 Worldwide Mechanical CAD/CAE Market
(Millions of Dollars/Actual Units)

Company	Total Revenue	Hardware Revenue	Software Revenue	Wkstns Shipped	Market Share Total Revenue	Market Share Hardware Revenue	Market Share Software Revenue	Market Share Wkstns Shipped
PAFEC	25.2	.0	25.2	0	.4%	.0%	1.7%	.0%
Hakuto	24.3	12.1	9.6	540	.4%	.3%	.7%	.3%
Dassault	23.8	.0	19.5	0	.4%	.0%	1.3%	.0%
PDA Engineering	22.9	.0	22.9	0	.4%	.0%	1.6%	.0%
Cisigraph	20.8	10.3	8.7	400	.3%	.3%	.6%	.2%
Zenith	20.5	20.5	.0	6,960	.3%	.6%	.0%	3.3%
Info. Services Int'l. Dentsu	20.0	2.3	13.9	30	.3%	.1%	1.0%	.0%
Sharp System Products	19.5	8.6	9.0	54	.3%	.2%	.6%	.0%
Swanson Analysis	17.8	.0	17.8	0	.3%	.0%	1.2%	.0%
ISICAD	16.8	8.7	5.3	173	.3%	.2%	.4%	.1%
Manufacturing Consultants	16.6	.0	14.3	0	.3%	.0%	1.0%	.0%
Sumisho Electronics	15.4	8.3	5.5	392	.3%	.2%	.4%	.2%
CADAM	14.4	.0	12.5	71	.2%	.0%	.9%	.0%
Toyo Information Systems	13.2	6.4	5.4	120	.2%	.2%	.4%	.1%
Olivetti	12.0	4.7	5.1	1,963	.2%	.1%	.4%	.9%
STI-Strassle	12.0	9.6	2.4	16	.2%	.3%	.2%	.0%
Mitsui Engineering	10.9	7.2	1.7	133	.2%	.2%	.1%	.1%
ICL	10.6	7.4	1.8	198	.2%	.2%	.1%	.1%
Rotring euroCAD	9.6	4.2	4.4	120	.2%	.1%	.3%	.1%
ItalCad	7.8	3.5	2.7	132	.1%	.1%	.2%	.1%
Seiko - No OEM	5.3	2.4	2.4	296	.1%	.1%	.2%	.1%
Mentor Graphics	4.9	1.7	2.2	79	.1%	.0%	.2%	.0%
Zuken	.6	.3	.2	3	.0%	.0%	.0%	.0%
Sysscan	.1	.0	.0	0	.0%	.0%	.0%	.0%
Other Companies	673.0	566.6	148.8	65,905	11.3%	15.3%	10.3%	30.9%
All Companies	5,950.0	3,701.7	1,448.1	213,046	100.0%	100.0%	100.0%	100.0%
All U.S.-Based Companies	4,647.0	2,988.9	1,030.9	188,935	78.1%	80.7%	71.2%	88.7%
All Asian-Based Companies	864.9	502.4	248.0	15,976	14.5%	13.6%	17.1%	7.5%
All European-Based Companies	438.1	210.5	169.3	8,135	7.4%	5.7%	11.7%	3.8%
All Hardware Companies	1,507.5	1,473.7	.3	157,512	25.3%	39.8%	.0%	73.9%
All Turnkey & SW Companies	4,442.5	2,228.1	1,447.8	55,534	74.7%	60.2%	100.0%	26.1%

Source: Dataquest
June 1989

Table 2

Mechanical CAD/CAM Worldwide Forecast by Region
(Millions of Dollars/Actual Units)

	1988	1989	1990	1991	1992	1993	CAGR
Worldwide							
Revenue	5,950	6,623	7,250	7,461	8,042	8,578	7.6%
Systems	186,997	226,740	262,580	295,030	322,780	344,710	13.0%
Workstations	211,885	248,560	282,180	310,740	338,080	359,080	11.1%
North America							
Revenue	2,037	2,139	2,282	2,345	2,546	2,722	6.0%
Systems	98,016	114,890	126,910	139,690	152,160	159,780	10.3%
Workstations	106,753	121,840	133,010	144,590	157,080	164,530	9.0%
Europe							
Revenue	2,116	2,454	2,743	2,857	3,107	3,357	9.7%
Systems	54,817	68,340	81,500	91,790	100,340	107,470	14.4%
Workstations	63,948	76,470	88,780	97,520	105,770	112,520	12.0%
Far East							
Revenue	1,676	1,861	2,029	2,053	2,159	2,264	6.2%
Systems	30,931	39,800	49,280	57,110	62,920	68,680	17.3%
Workstations	37,199	45,640	54,680	61,530	67,130	72,640	14.3%
Rest of World							
Revenue	122	169	195	206	231	236	14.1%
Systems	3,234	3,700	4,890	6,440	7,360	8,780	22.1%
Workstations	3,984	4,610	5,720	7,110	8,110	9,380	18.7%

Source: Dataquest
June 1989

Table 3

Mechanical CAD/CAM Worldwide Forecast by Platform
(Millions of Dollars/Actual Units)

	1988	1989	1990	1991	1992	1993	CAGR
All Platforms							
Revenue	5,950	6,623	7,250	7,461	8,042	8,578	7.6%
Systems	186,997	226,740	262,580	295,030	322,780	344,710	13.0%
Workstations	211,885	248,560	282,180	310,740	338,080	359,080	11.1%
Technical Workstation							
Revenue	2,046	2,837	3,689	4,346	4,992	5,644	22.5%
Systems	37,541	56,340	79,130	100,680	123,940	146,180	31.2%
Workstations	37,541	56,340	79,130	100,680	123,940	146,180	31.2%
Host-Dependent/Server							
Revenue	2,934	2,718	2,453	1,987	1,973	1,916	-8.2%
Systems	6,923	6,770	6,700	5,960	6,590	7,120	.6%
Workstations	31,811	28,600	26,300	21,670	21,890	21,490	-7.5%
Personal Computer							
Revenue	970	1,069	1,107	1,128	1,077	1,019	1.0%
Systems	142,533	163,620	176,750	188,400	192,250	191,410	6.1%
Workstations	142,533	163,620	176,750	188,400	192,250	191,410	6.1%

Source: Dataquest
June 1989

Table 4

Mechanical CAD/CAM Worldwide Average Price per Seat Forecast by Platform (Thousands of Dollars)

	1988	1989	1990	1991	1992	1993	CAGR
Turnkey & Hardware-Only							
Technical Workstation	38.4	33.9	30.2	27.0	24.2	22.5	-10.3%
Host-Dependent/Server	340.7	310.4	281.7	254.0	225.5	200.2	-9.0%
Personal Computer	5.5	5.2	4.9	4.7	4.3	4.0	-6.0%
All Platforms	24.5	21.5	19.6	17.3	16.5	15.9	-8.2%
Turnkey							
Technical Workstation	51.7	48.7	45.9	43.1	40.8	40.0	-4.8%
Host-Dependent/Server	419.8	396.3	368.8	346.6	321.4	300.3	-6.1%
Personal Computer	20.9	20.0	18.7	17.1	15.8	14.4	-6.3%
All Platforms	85.8	75.8	67.5	57.1	52.4	49.7	-8.8%
Hardware-Only							
Technical Workstation	20.1	18.6	16.9	15.4	14.1	13.4	-8.0%
Host-Dependent/Server	220.7	194.5	176.5	162.5	149.5	136.3	-7.1%
Personal Computer	4.3	4.4	4.4	4.2	3.9	3.7	-3.5%
All Platforms	9.9	9.5	9.3	8.8	8.8	9.0	-3.3%

Source: Dataquest June 1989

Table 5

Mechanical CAD/CAM Worldwide Revenue Sources Forecast by Platform (Millions of Dollars)

	1988	1989	1990	1991	1992	1993	CAGR
All Platforms							
Hardware	3,711	3,950	4,194	4,177	4,349	4,502	3.9%
Software	1,451	1,719	1,996	2,181	2,484	2,769	13.8%
Service	867	954	1,060	1,103	1,209	1,308	8.6%
Total	5,950	6,623	7,250	7,461	8,042	8,578	7.6%
Technical Workstation							
Hardware	1,138	1,510	1,896	2,159	2,393	2,635	18.3%
Software	533	815	1,132	1,412	1,710	2,007	30.4%
Service	374	512	661	776	889	1,002	21.8%
Total	2,046	2,837	3,689	4,346	4,992	5,644	22.5%
Host-Dependent/Server							
Hardware	1,837	1,665	1,495	1,209	1,196	1,157	-8.8%
Software	694	642	590	482	487	481	-7.1%
Service	461	411	369	296	290	278	-9.6%
Total	2,934	2,718	2,453	1,987	1,973	1,916	-8.2%
Personal Computer							
Hardware	736	775	803	810	760	710	-.7%
Software	224	262	273	287	287	280	4.6%
Service	32	31	31	31	30	28	-2.3%
Total	970	1,069	1,107	1,128	1,077	1,019	1.0%

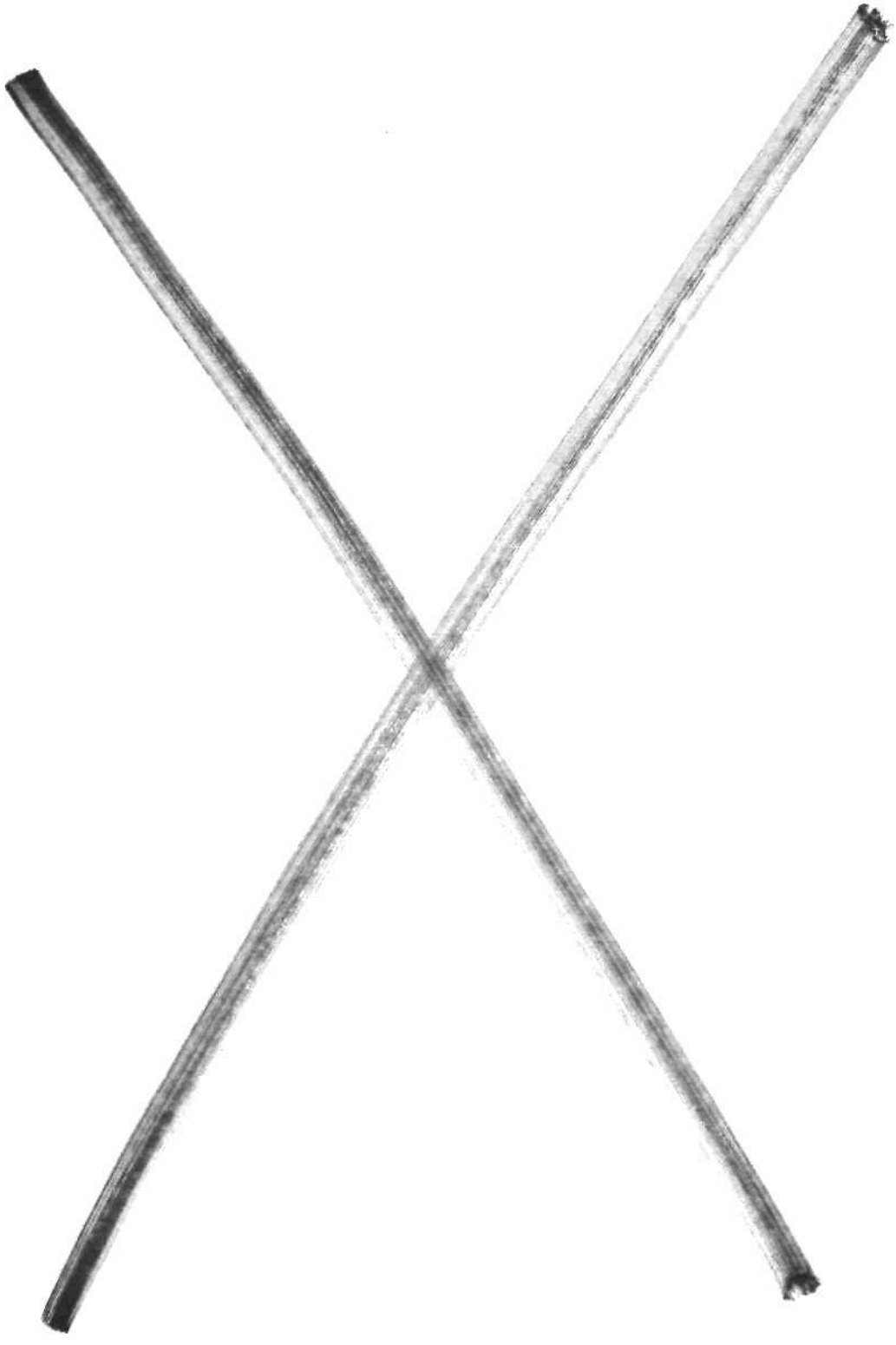
Source: Dataquest June 1989

Table 6

Mechanical CAD/CAM Worldwide Forecast by Distribution Class
(Millions of Dollars/Actual Units)

	1988	1989	1990	1991	1992	1993	CAGR
Total Hardware and Software Revenue							
Turnkey	3,071	3,180	3,229	3,058	3,073	3,046	-.2%
Unbundled	2,091	2,488	2,961	3,300	3,760	4,224	15.1%
Total	5,162	5,669	6,190	6,359	6,833	7,271	7.1%
Hardware Revenue							
Turnkey	2,237	2,262	2,270	2,125	2,109	2,063	-1.6%
Unbundled	1,474	1,688	1,924	2,052	2,240	2,439	10.6%
Total	3,711	3,950	4,194	4,177	4,349	4,502	3.9%
Software Revenue							
Turnkey	834	919	958	933	965	983	3.3%
Unbundled	617	800	1,038	1,248	1,520	1,786	23.7%
Total	1,451	1,719	1,996	2,181	2,484	2,769	13.8%
Workstation Shipments							
Turnkey	54,373	57,140	60,740	62,710	66,420	67,490	4.4%
Unbundled	157,512	191,420	221,440	248,030	271,660	291,590	13.1%
Total	211,885	248,560	282,180	310,740	338,080	359,080	11.1%

Source: Dataquest
June 1989



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Research Newsletter

THE HDL SHOWDOWN: VHDL VERSUS VERILOG HDL

SUMMARY

As top-down design moves into the mainstream of the application-specific integrated circuit (ASIC) and system design market, the engineering community faces a difficult task: choosing whether to use the VHSIC Hardware Description Language (VHDL) or the Verilog Hardware Description Language, or to continue using an internally developed proprietary language. Indeed, Dataquest's research indicates that the market is currently wrestling with this issue. This newsletter provides the following:

- An explanation as to why VHDL has yet to achieve widespread market acceptance
- An analysis as to how VHDL and Verilog HDL will fare against each other in the market over the next five years
- How the UDL/I "wild card" factors into the hardware description language equation
- Trade-offs associated with supporting Verilog HDL

AN UNCERTAIN HDL MARKET

Uncertainty in the EDA market over which language to select stems from a combination of factors. First, the viability of VHDL has not been adequately "validated" by the EDA industry. Despite the fact that many EDA companies have announced support for the language, only a handful have actually shipped products. Moreover, the number of products and licenses shipped by the larger EDA suppliers has been negligible.

In addition, although VHDL has received formal IEEE ratification, it is still not yet recognized as a truly viable standard by large segments of the market. Again, this is because the industry's stamp of approval has been heavy on form (that is, product announcements) and light on substance (that is, available products). Dataquest believes that effective validation of VHDL will require EDA companies wielding significant market power to begin shipping VHDL-based products in high volume.

A second reason for VHDL's weak market penetration is because its efficacy remains uncertain, as it has seen only scattered use in production design environments. In short, it has not achieved so-called "production-proven" status. Certainly there are pockets of design teams that have been using VHDL over the past few years, but the number is relatively small. Dataquest estimates that there are approximately 1,000 users of merchant VHDL tools and another 300 to 500 that use VHDL tools developed in-house.

A third reason results from the severe shortage of robust VHDL-based synthesis products available on the market. Only recently have such products been unveiled. Dataquest's research indicates that the top-down design market will gravitate toward those EDA vendors supplying logic synthesis tools. For vendors unable to provide synthesis products that can be easily integrated into the customer's design environment, it will be a difficult road ahead. In short, the market will be less willing to purchase other top-down design tools (for example, simulation, design entry, and test automation tools) from these vendors. It is thus clear that logic synthesis is becoming one of the cornerstone technologies in the top-down design environment. In assuming this role, it will act as a "market-pulling" catalyst for adopting other supporting design automation tools. (But it is important to note that it will be easier for users to interchange synthesis tools than logic simulators and, therefore, provide a less effective account control mechanism.)

Another reason is the nature of the language itself. Because it was originally designed to be

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a documentation language, VHDL is all-encompassing and thus somewhat unwieldy. But this is a double-edge sword, for VHDL offers users capabilities unavailable from other languages.

Further slowing market penetration is the fact that EDA vendors are supporting different subsets of the language, which continues to impede the VHDL standardization effort. Similarly, the actual VHDL specification is subject to interpretation, which also negatively impacts the standardization of the language. The result is that different VHDL tool developers construe the same part of the specification differently.

Finally, Dataquest's research indicates that users that have performed extensive comparisons between VHDL and Verilog have found the latter to be easier to use. But we believe that this is largely because the documentation supporting Verilog is better than most of the VHDL documentation, and Verilog users (that have compared Verilog HDL with VHDL) are less familiar with VHDL. The execution speed of VHDL simulators, especially at the gate level, according to users, is also questionable when compared with Verilog XL. This could pose severe problems for VHDL if it is not corrected. Indeed, a significant difference in price/performance ratio will be crippling to VHDL.

VHDL WILL FIND WIDESPREAD USE

The combination of these factors has dampened the anticipated penetration rate of VHDL. Indeed, in mid-1989 Dataquest surveyed over 100 EDA end users to determine when and if they would adopt VHDL. An overwhelming 77 percent said that they would adopt it by June 1991. The primary reason for adopting VHDL, according to this sample, was to keep pace with industry standards. Thus it is clear that adoption was contingent on VHDL being perceived as an industry standard, an event that has yet to occur.

In Dataquest's view there is no reason to believe that VHDL will not find widespread acceptance once it is recognized by the market as a standard, an event that will occur when VHDL-based products begin shipping in high volume. Also helping the cause is the increasing number of universities adding VHDL courses to their curricula.

Finally, our research indicates that the semiconductor, communications, and computer/peripheral industries will be the most aggressive in adopting merchant VHDL-based products. (The aerospace and military electronics segment plans to adopt VHDL, but suprisingly, the absorption rate into this sector will be slower than companies competing primarily in commercial markets.)

VERILOG AND VHDL: A TALE OF TWO HDLS

Unable to ship any substantive VHDL products between 1988 and 1990, the three major CAE suppliers (Mentor Graphics Corporation, Valid Logic Systems, and Dazix Corporation) contributed heavily, albeit indirectly, to the accelerated penetration rate of Verilog HDL. Certainly Cadence Design Systems Inc. (and previously Gateway Design Automation) deserves credit for both its Verilog HDL marketing effort and providing a logic simulator that has met the market's needs. Yet it is clear that the market has had few practical alternatives to Verilog HDL for performing top-down design. We believe that had any of the CAE market share leaders been able to ship a VHDL-based EDA environment, Verilog HDL's market penetration would have been significantly less.

The dearth of VHDL-based logic synthesis products together with VHDL's limited market presence has impeded the language's market penetration rate. Verilog HDL, on the other hand, has enjoyed exactly the opposite situation. When Synopsys Inc. unveiled its first Verilog HDL-based logic synthesis products in late 1988, the Verilog simulator had several thousand users and the language was readily available to all of them. The large installed base of engineers using the Verilog simulator plus the availability of Verilog HDL-based logic synthesis software combined with Cadence's marketing muscle to provide the critical mass needed to accelerate the market penetration of Verilog HDL over the past 18 months.

INSTALLED BASE, MOMENTUM, AND MARKET POWER

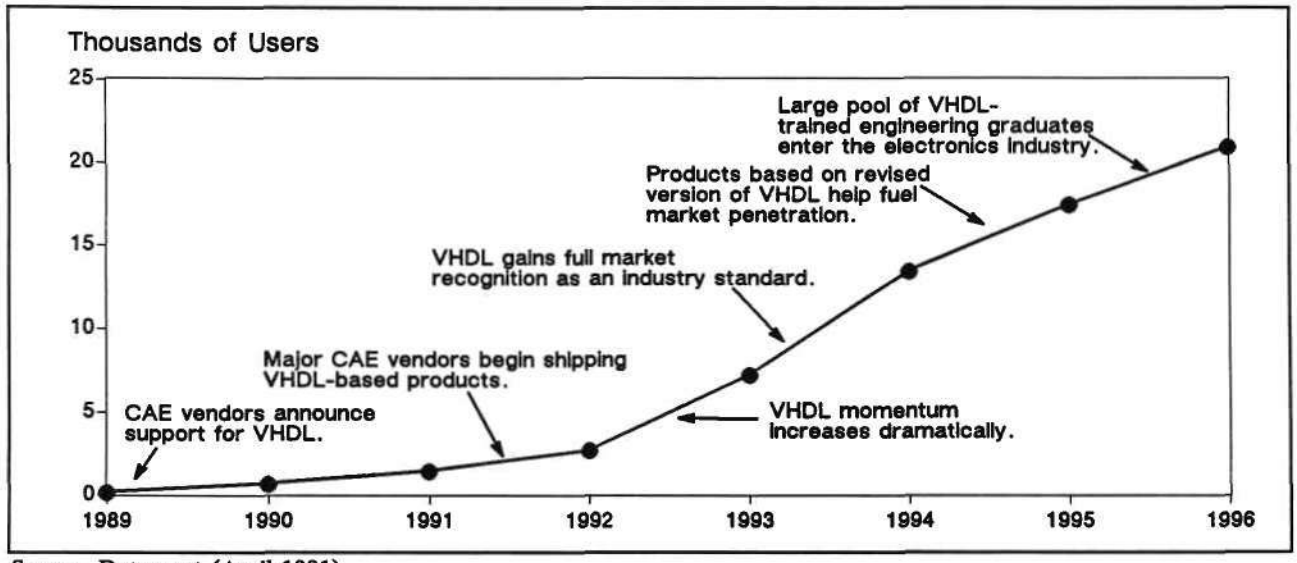
Although the number of VHDL users (approximately 1,400) is a relatively small figure when compared with the number of Verilog *simulator* users (7,000 to 12,000), the number of Verilog HDL users is somewhat deceiving. The installed base of Verilog simulator licenses is between 3,500 and 4,000. But many of these are multiuser licenses, which is why the total number of users ranges from 7,000 to 12,000. Certainly most, if not all, of these installations are using the simulation capabilities of the Verilog tool suite. But the more

important figure is the percentage of these engineers using the Verilog HDL as a modeling language as opposed to a mere simulation control language or for simple netlist generation. Dataquest's research indicates that approximately 15 to 20 percent of these users are using the Verilog HDL as a modeling tool. Thus, we believe that the number of Verilog HDL users is currently in the neighborhood of 1,800.

Despite the near parity that currently exists between the number of Verilog HDL and VHDL users, in Dataquest's view the number of VHDL users will soon surpass the number of Verilog HDL users. As Figures 1 and 2 show, our analyses indicate that this crossover will take place in early 1992.

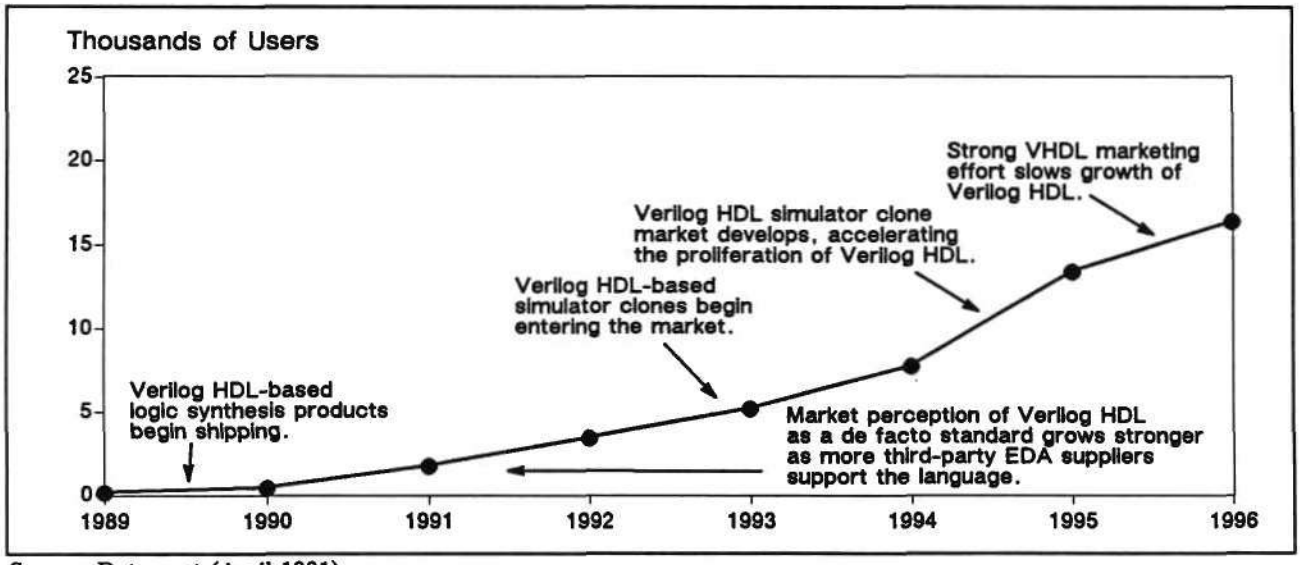
Nonetheless, we believe that Verilog HDL can solidify its position as a de facto standard over the next two to three years, *provided that second sources of Verilog HDL-based simulators emerge.* Whether this occurs depends upon Cadence's willingness to supply third-party simulator developers

FIGURE 1
Projected Growth Rate of VHDL User Base



Source: Dataquest (April 1991)

FIGURE 2
Projected Growth Rate of Verilog HDL User Base



Source: Dataquest (April 1991)

with the necessary technical specifications. Thus far, third-party developers indicate that Cadence has not been particularly forthcoming with the required technical data. We anticipate that this will change shortly.

In our view, just as widespread industry endorsement of VHDL forced Cadence to put Verilog HDL into the public domain, anticipated large volume shipments of VHDL-based products will force Cadence to facilitate the development of Verilog simulator clones. Indeed, a long-term monopolistic grip on the Verilog simulator market by Cadence will cause the market to migrate away from Verilog HDL in favor of VHDL, unless of course the Verilog simulation environment offers significantly better price/performance than its VHDL-based counterparts. Under the latter scenario, the market would naturally migrate to Verilog HDL, but we neither believe that Verilog will wield such a competitive edge over VHDL products nor that Cadence would take such a risk. As a result, we expect Cadence to disclose enough technical specification data to third-party developers within the next three to six months to allow them to build Verilog simulator clones.

By launching Verilog HDL into the public domain and establishing Open Verilog International (OVI), Cadence sought to mute the voices of EDA competitors that at one time labeled Verilog HDL as proprietary. Thus far, however, Cadence's opening of Verilog has been heavy on form and light on substance. For example, it has been approximately one year since the announcement was made and only now is an official Verilog HDL manual emerging. In addition, several issues have arisen that have slowed its acceptance among the EDA vendor community (for example, trademark rights in the Verilog name, validation of third-party tools based on Verilog HDL, and disclosure of technical specifications). As a result, only a few third-party EDA suppliers have charged forward to support the language.

However, opening the language has had a substantial impact on the market. Electronics manufacturers familiar with Cadence and HDLs in general have the perception that the Verilog HDL is equivalent to VHDL in terms of its status as an emerging/de facto industry standard. As long as this perception persists, Cadence will continue to enjoy its stronghold on the Verilog HDL market. And the longer major EDA suppliers delay in shipping VHDL-based products, the longer Verilog HDL will enjoy its relatively unfettered market reign.

In addition, the fact that a few key EDA suppliers are either planning to or currently support the language will help further the perception. Examples include Synopsys, Compass Design Automation (VLSI Technology), and Expertest Inc. But these third parties are not offering Verilog HDL simulators and thus we believe that their support will have only a limited effect on market perception once a range of VHDL-based products (for example, simulators) begin to ship in high volume and from different suppliers.

Moreover, the Verilog simulation environment has been in use since the middle 1980s and has clearly achieved production-proven status. It is also important to note that most of the current generation of Verilog HDL users are more experienced with using Verilog HDL as a vehicle for doing top-down design when compared with engineers designing with VHDL. In short, Verilog HDL has been in use as a production tool longer than has VHDL. Finally, we also believe that it currently has slightly more market momentum in North America and Asia than does VHDL, although it will take very careful planning by Cadence to sustain it.

THE EMERGING VERILOG CLONE OPPORTUNITY

Dataquest anticipates that a significant market opportunity for Verilog simulator clones will soon emerge. Our reasoning is twofold. First, we firmly believe that creating such an industry is in Cadence's best interest and that the company will pursue it, because doing so will sustain the momentum of Verilog HDL and expand the market for Verilog HDL-based EDA products. Second, market demand is very high for a Verilog simulator priced lower than that which Cadence charges. We believe that Cadence's current monopoly on the Verilog simulator market enables the company to charge prices well above those necessary to achieve acceptable profit margins.

Because we believe that Cadence will soon disclose all the necessary technical specifications for third parties to develop Verilog simulators, the first clones will reach the market by mid-1993. Thus, we believe that the number of Verilog HDL users will more than triple between 1993 and 1996.

Yet success in the clone market will not be easy. Cadence will become far more aggressive at improving the performance and functionality of its Verilog simulation product line. Spawning a clone industry forces Cadence to continuously improve the Verilog price/performance ratio.

It is also unlikely that Cadence will allow clone manufacturers access to the full Verilog intermediate format specification, thus preventing users from simply replacing the Verilog simulator with a clone. The user will be forced to purchase a compiler (that is, an analyzer and code generator) from the clone supplier.

AN INTERNATIONAL PERSPECTIVE

We believe that the Verilog HDL has the potential to achieve widespread use in Japan, as most of the major Japanese electronics manufacturers currently have Verilog simulator licenses. It will be a natural extension for these companies to adopt top-down design using the Verilog HDL. In fact, we believe that Verilog will outpace VHDL usage in Japan as long as the following conditions are present:

- The market perceives Verilog as a de facto standard
- An increasing number of third-party tool suppliers support Verilog
- VHDL wields no significant technical advantage over Verilog

In Europe, on the other hand, VHDL is clearly the preferred language. The reason is twofold. First, Cadence's European market position has been weak, resulting in limited market penetration of the Verilog simulator and HDL. Second, large European electronics manufacturers are convinced that VHDL is an undisputed HDL standard, whereas Verilog HDL is perceived as a mere candidate for recognition as a standard.

THE UDL/I WILD CARD

While the market grapples with Verilog HDL-VHDL dilemma, the UDL/I HDL development effort continues. UDL/I HDL was originally developed as a proprietary language primarily by NTT Laboratories in Japan. More recently, however, NTT has initiated a process aimed at injecting the language into the public domain. We believe that there is a strong likelihood that UDL/I will capture HDL market share when it competes against Verilog HDL and VHDL, provided that its capabilities greatly exceed those of VHDL and Verilog HDL.

Unlike VHDL and Verilog, which were developed to serve the limited purposes of documentation and simulation, respectively, UDL/I is targeted specifically at both logic simulation and logic synthesis applications. Thus, its goal is to meet the broad needs of engineers performing top-down design. For example, all constructs within the language are synthesizable.

At the same time, both Verilog HDL and VHDL will undergo revisions to enhance their respective capabilities. In fact, VHDL will undergo a revision in 1992 that will include a resolution of inconsistencies within the language, improvements in usability, better support for synthesis, and improvements in its ability to support timing descriptions. The resulting enhancements will likely make it more difficult for UDL/I to compete against Verilog HDL and VHDL.

In the absence of Japanese government intervention, we expect neither the Japanese industry nor the Japanese market to gravitate toward UDL/I simply because UDL/I's roots are Japanese. It will require much more than that by the time the first UDL/I compiler and simulator break free of the research laboratory (mid-1992).

Indeed, we believe that large-scale development of commercial EDA products based on UDL/I would not begin until the second half of 1992 and that these products will not reach the market until late 1993 or early 1994. By that time, there will be a myriad of VHDL- and Verilog HDL-based products on the market, with a combined user base of approximately 20,000 engineers. This will make market penetration extremely difficult for UDL/I-based tools.

Even supposing that UDL/I delivered capabilities far and above those of both Verilog HDL and VHDL, once UDL/I-based products reach the market it will take at least two years for the market to develop. As a result, we believe that the earliest possible opening of a significant UDL/I market window will be in the 1995 to 1996 timeframe.

MAKING THE DECISION TO SUPPORT VERILOG HDL

Whether to support Verilog HDL is among the most difficult decisions facing EDA vendors today. We believe that some vendors should support it whereas others should refrain. Determining in which camp a particular vendor resides demands the obvious kinds of assessments: size of the potential market targeted and market share that the supplier can reasonably expect to capture. This, of course, is a function of time to market, market window, market opportunity, cost of development, and product requirements, among others. Although

there are many variables that must be analyzed, Dataquest believes that there is at least one constant: a range of market opportunities will emerge for Verilog HDL-based products over the next five years. As a result, we believe that it makes sense for most EDA vendors to seriously weigh the tradeoffs associated with supporting Verilog HDL.

Certainly there will be a market for Verilog HDL-based logic simulators and logic synthesis tools. But suppliers attacking these markets will have to contend with not only product development issues, but also with the cost of competing against the marketing muscle of entrenched players such as Cadence in Synopsys. We believe that there is a range of other Verilog HDL-based products that entrenched EDA competitors are not likely to immediately pursue.

One problem with not supporting the Verilog HDL is that the market will soon be using an "HDL support" metric when comparing the EDA technology portfolios of different suppliers. This is not to say that an EDA supplier will necessarily lose business opportunities solely because of lack of Verilog HDL support, although it will undoubtedly occur in some cases.

With the number of Verilog HDL users steadily rising, the real penalty for not supporting Verilog HDL is preclusion from reaching a large pool of seasoned HDL users. And most of these users are employed by companies armed with large EDA budgets.

DATAQUEST PERSPECTIVE

Despite the initial leap that VHDL will take over Verilog HDL in 1992, the clear implication is that EDA suppliers cannot dismiss Verilog HDL. Cadence has a very strong interest in ensuring that the Verilog HDL is recognized as an industry standard. Similarly, many large electronics manufacturers using Verilog have made substantial investment in the language and simulator, and so they too have a very strong interest in ensuring that it is an industry standard. Moreover, electronics manufacturers in this category wield significant influence over Cadence, and we believe that these customers will demand that Cadence provide all of the technical specifications necessary for third parties to develop Verilog simulator clones. The unavoidable conclusion is that VHDL and Verilog HDL will share the market over the next five years.

To ensure that Verilog HDL solidifies its position as a de facto standard, Cadence must become very aggressive in establishing a Verilog simulator clone market. If Cadence takes a merely passive role toward this end, the company runs a very high risk of Verilog HDL opponents joining forces to smother Verilog. Indeed, EDA suppliers whose current plans include support solely for VHDL would like nothing better than to eliminate Verilog HDL from the landscape of the EDA market.

Ron Collett

Dataquest
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Research *Bulletin*

INTERGRAPH ACQUISITION OF DAZIX ADDS STABILITY TO EDA INDUSTRY

On January 3, Intergraph Corporation announced its purchase of DAZIX. Intergraph's electronics group has merged with DAZIX to form a new independent business unit known as DAZIX, An Intergraph Company. The purchase follows an abortive rescue of DAZIX led by the Bank of Suez in Paris. Dataquest believes that the purchase price of $14 million ($10 million in cash and $4 million in stocks) represents excellent value for the money, for the reasons outlined in this bulletin.

BENEFITS FOR EACH COMPANY

Intergraph gains the following from this acquisition:

- An installed base of 10,000 seats
- 150 to 200 ASIC libraries
- Valuable and proven core technology
- A substantial installed base of PCB layout systems
- An enhanced position in Europe, where DAZIX was particularly strong

DAZIX (and the DAZIX user base) benefits from the acquisition in the following ways:

- Considerable stability provided by a $1 billion parent
- An opportunity to target Intergraph's mechanical user base with EDA tools (Intergraph occupies the number-five position in MCAD total revenue worldwide.)
- Intergraph's strong management and company culture

The acquisition gives Intergraph a clear boost in EDA, an underdeveloped segment of the company's business, and offers the opportunity of combining Intergraph's MCAD strengths with DAZIX's EDA strengths. This overall CAD/CAM capability will appeal particularly to major accounts in the aerospace, automotive, and consumer electronics sectors. As a result, we expect to see a greater level of competitive activity in these accounts among IBM, Computervision, and Intergraph.

Dataquest believes that a partnership with Intergraph offers considerable synergy and interrelationships to both companies. We also believe that this acquisition is a strategically sound move by Intergraph in view of the company's goal of reaching the number-one CAD/CAM market position worldwide. The move also will enhance Intergraph's European visibility because of the increasing major account activity mentioned earlier.

MARKET POSITION

The acquisition will have little immediate impact upon Intergraph's market position in the overall CAD/CAM market. The company occupies the number-two position, trailing only IBM. Total 1990 estimated CAD/CAM revenue (preliminary figures) is $1,777.3 million for IBM and $1,002.9 million for Intergraph.

However, in the EDA segment, Intergraph rises from seventh position to fourth position in terms of EDA software revenue. The clear leader in EDA at this time is Mentor Graphics, followed by Cadence. We believe that Valid Logic, Racal-Redac, and DAZIX/Intergraph will fight hard for third place over the next two years before a clear winner emerges.

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PLATFORM ISSUES

Intergraph's EDA products will run on Sun SPARC machines, a break from the company's previous policy of offering all products exclusively on Intergraph's clipper-based stations. Intergraph's proprietary machines have proven successful in the company's traditional MCAD and GIS markets. However, standard platforms (especially Sun) are far more acceptable to the EDA community. Intergraph's platform decision further strengthens Sun's position in EDA.

DATAQUEST PERSPECTIVE

The financial problems of DAZIX following the merger of Daisy Systems, Cadnetix, HHB Systems, and SimuCAD threatened the viability of DAZIX as a leading EDA vendor. The resulting two-year slide in market share and the well-publicized bankruptcy declaration by DAZIX shook the EDA industry. The situation cast serious doubt on the future of DAZIX and implied risk for many other EDA vendors, who wondered which company would be next to stumble.

Dataquest believes that the Intergraph acquisition of DAZIX will be a stabilizing force for the entire industry. Intergraph's estimated total revenue for 1990 was $1,002.9 million, up 17.8 percent from 1989. The new DAZIX business unit will use this secure financial base to form its growth plans.

In spite of DAZIX's problems, Dataquest believes that the company lost very few accounts during the period just described. Although the status quo may relate more to the high costs of switching than to customer satisfaction and confidence in DAZIX, the fact remains that the new company has a solid foundation for growth. It is also interesting to note that Dataquest research indicates that the Cadnetix system (also part of the deal) was more popular with end users than any other EDA system.

Jim Tully
Ron Collett

Dataquest
a company of The Dun & Bradstreet Corporation

Research Newsletter

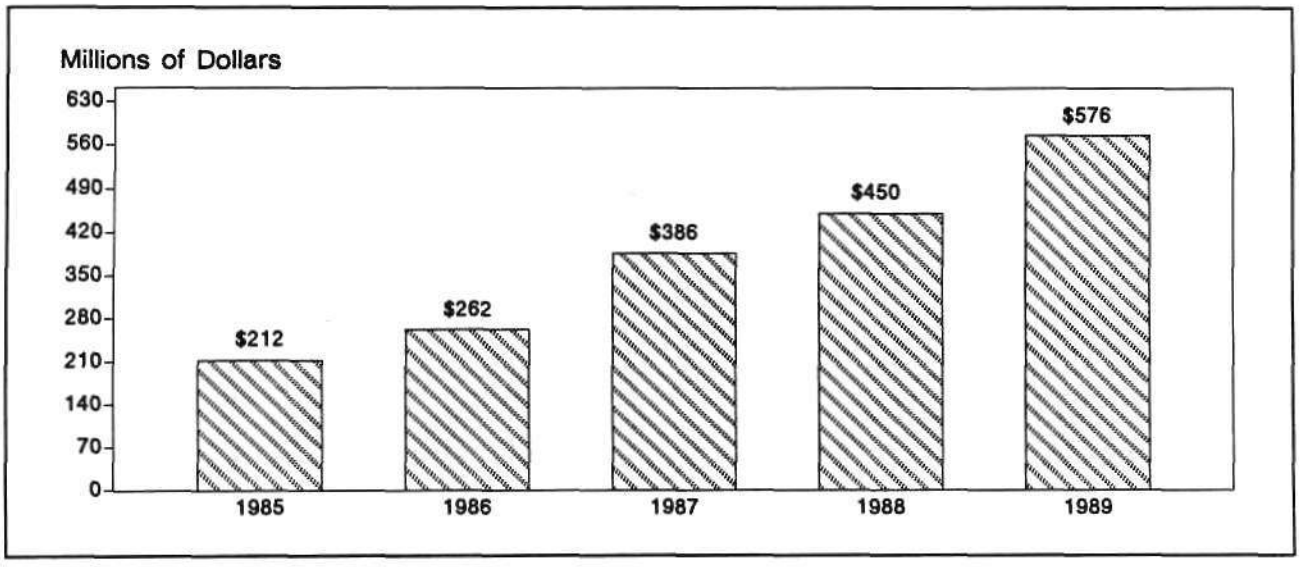
CAE: THE EDA MARKET OF GROWTH AND OPPORTUNITY IN THE 1990s

HISTORICAL GROWTH AND INSTALLED BASE

Of all of the markets comprising electronic design automation (EDA), the CAE segment has and continues to exhibit unabated vitality. Figure 1 illustrates the growth of the CAE software market from 1985 through 1989. During this period the market experienced a compound annual growth rate (CAGR) of 22 percent. Moreover, by the end of 1989 there were approximately 163,000 merchant CAE seats installed in the market. In North America, the installed base is approximately 83,000 seats; in Europe, it is approximately 49,000; and in Asia, it is about 28,000.

It is important to note that these penetration figures refer to CAE workstation penetration, not CAE software penetration. In fact, Dataquest believes that the high penetration in North America will help fuel CAE software market growth. Our conclusion is based on the fact that users of these merchant workstations wish to periodically equip their systems with new, more advanced CAE software, especially in light of the emerging framework standards that will facilitate integration. In short, the North American (and much of the European) *merchant* CAE market has been "developed" and conditioned over the past decade to use commercially available CAE tools. The situation contrasts sharply with the 1960s and 1970s, when most CAE tools in use in North America and Europe were either developed internally or time shared.

FIGURE 1
Historical Growth of the CAE Market



Source: Dataquest (December 1990)

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MARKET PENETRATION

Dataquest research shows that market penetration of merchant CAE seats is approximately 65 percent in North America, approximately 38 percent in Europe, and approximately 12 percent in Asia. Clearly, an enormous opportunity exists in Asia, and a significant market opportunity remains in Europe. On the other hand, the remaining opportunity in North America will be costly to capture, as most merchant CAE vendors are based in North America and thus have established strong distribution channels, high brand recognition, and solid customer support infrastructures. This established presence by a myriad of suppliers will make the competition fierce.

HIGH-GROWTH MARKETS

Meanwhile, the high-growth markets in CAE include design capture, simulation, synthesis, and test automation. For example, Dataquest forecasts that the ASIC logic synthesis market will experience a CAGR of 68 percent between 1989 and 1994. In 1989, the market was approximately $13.5 million (including maintenance). We expect this figure to cross the $30.0 million mark in 1990.

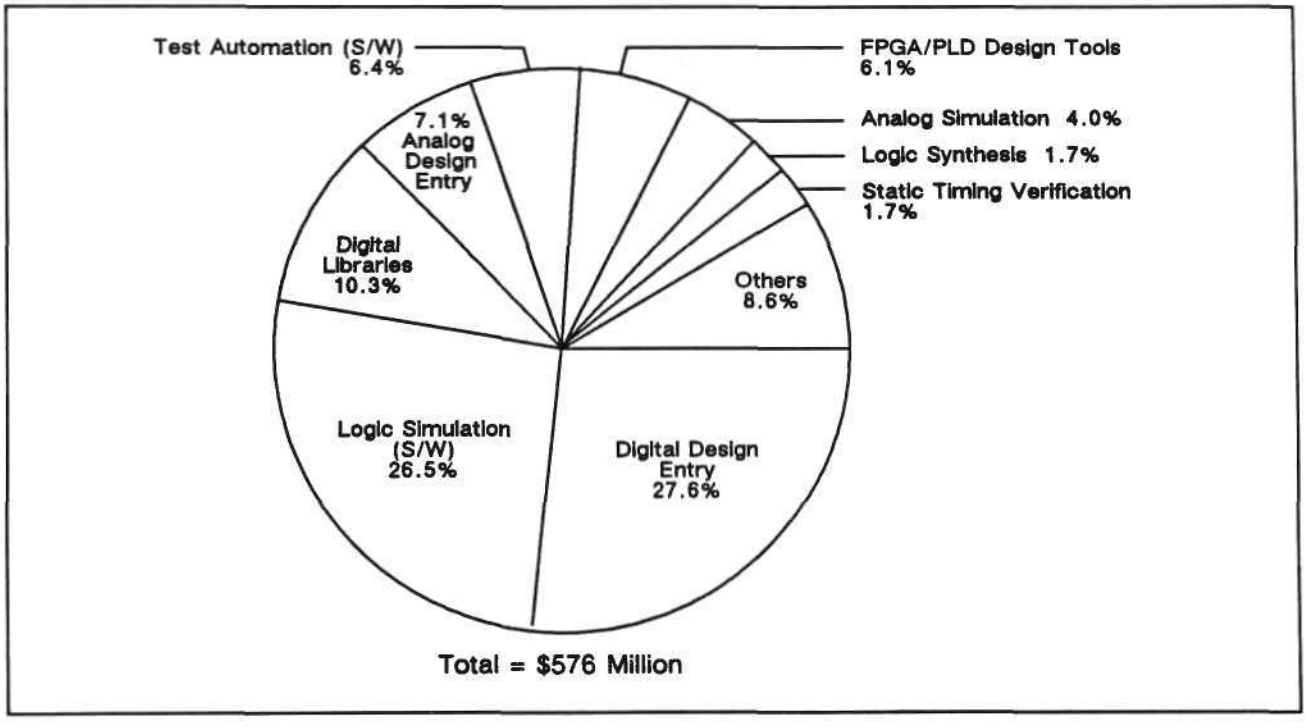
Similar growth can be seen in the HDL-based mixed-level logic simulation market, where the market was $29 million (including maintenance) in 1989. We anticipate that this market will reach approximately $50 million in 1990 and will exhibit a CAGR of 52 percent from 1989 through 1994. Other markets, such as test logic synthesis and automatic test vector generation (ATVG), will also experience very healthy growth over the forecast period.

CAE SUBMARKETS

Figure 2 shows the sizes of the various submarkets comprising the 1989 CAE software market. As the figure indicates, 64.4 percent of the market consists of digital design entry software, libraries, and logic simulation.

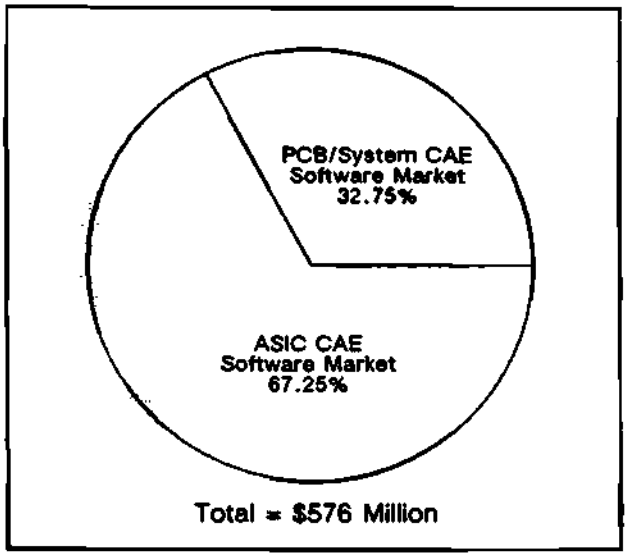
Figure 3 shows the split between CAE tools shipped into the ASIC design market and the PCB/System design market. Dataquest expects the PCB/System CAE market percentage to grow significantly over the forecast period, such that by 1995 its size will be within a few percentage points of the ASIC design CAE market.

FIGURE 2
1989 Worldwide CAE Software Submarkets



Source: Dataquest (December 1990)

FIGURE 3
1989 Worldwide CAE Software Market, Distribution between ASIC Market and PCB/System



Source: Dataquest (December 1990)

DATAQUEST PERSPECTIVE

From the foregoing data it is clear that significant CAE market opportunities remain in Asia, Europe, and North America. Dataquest believes that much of the opportunity will be in the top-down design EDA market (for ASIC and system design). Yet success in this market can be elusive for suppliers neglecting a key market requirement: compatibility with existing CAE tools, databases, and environments. CAD managers abhor complex integration duties, and users are often suspicious of the effectiveness of integration once a data translation error occurs.

It is also clear that success in the CAE market in the 1990s will demand a balanced distribution of CAE revenue among the various worldwide geographical regions. A broad international presence lends credibility and stability to the CAE supplier in the customers' eyes. Finally, establishing a strong international presence enables the CAE supplier to penetrate the early adopter market more easily, wherever it exists.

Ron Collett

Dataquest
a company of The Dun & Bradstreet Corporation

Research Newsletter

PCB LAYOUT INDUSTRY BRACES FOR CONSOLIDATION

SUMMARY

Dataquest believes that the PCB layout industry is ripe for consolidation similar to that which has occurred in the IC CAD industry over the past seven years. Indeed, it has already begun, as evidenced by the consolidation of ASI, Cadnetix, Calay, Daisy Systems (with perhaps Intergraph), as well as Hewlett-Packard's recently announced exit from the business. In short, the PCB layout industry is highly fragmented, with the top 12 vendors sharing 71.9 percent of the 1989 market. Moreover, there are over 50 vendors competing in a software market that totaled $313 million in 1989.

In addition to the impending consolidation, there are a range of emerging market trends that will significantly impact the industry. Suppliers able to adapt to the changing market conditions will be able to weather the impending consolidation and turmoil. Those unable to do so will be forced to merge with, or get acquired by, competitors or exit the business altogether.

This newsletter includes the following:

- PCB layout market statistics and analysis
- PCB layout market trends and issues
- Signal integrity EDA tool market analysis
- New battlegrounds in the PCB layout industry

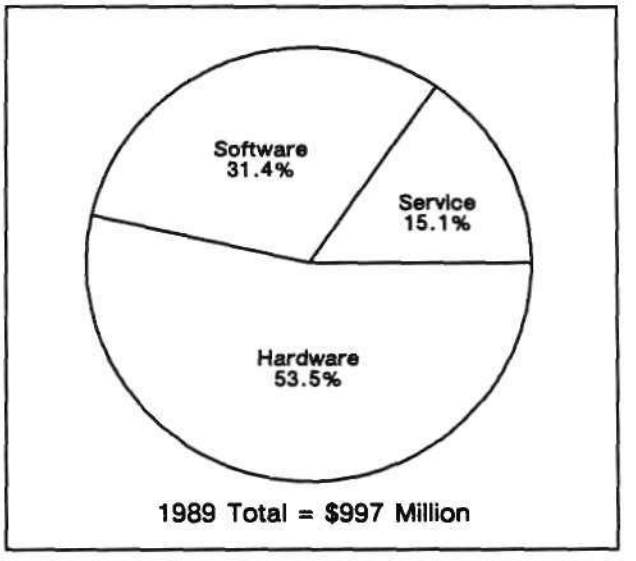
MARKET STATISTICS AND ANALYSIS

In 1989, the total PCB layout market was $997 million. This figure includes computer hardware (and peripherals when sold as part of a turnkey system), software, and maintenance revenue. Figure 1 shows the relative percentages. Figure 2 shows the PCB layout market sizes among the various geographical regions.

The worldwide PCB layout software market grew by only 2.6 percent in 1989. Dataquest's research indicates that the following reasons were behind this lackluster growth:

- Dazix's total PCB layout software revenue fell 59 percent between 1988 and 1989; Dazix's software revenue dropped 32 percent.
- Large segments of the market indicated that existing PCB layout tools did not need to be replaced.
- High switching costs associated with replacing Dazix systems made it difficult for PCB layout competitors to encroach upon the Dazix installed base.

FIGURE 1
1989 PCB Layout Market Size, by Segment



Source: Dataquest (December 1990)

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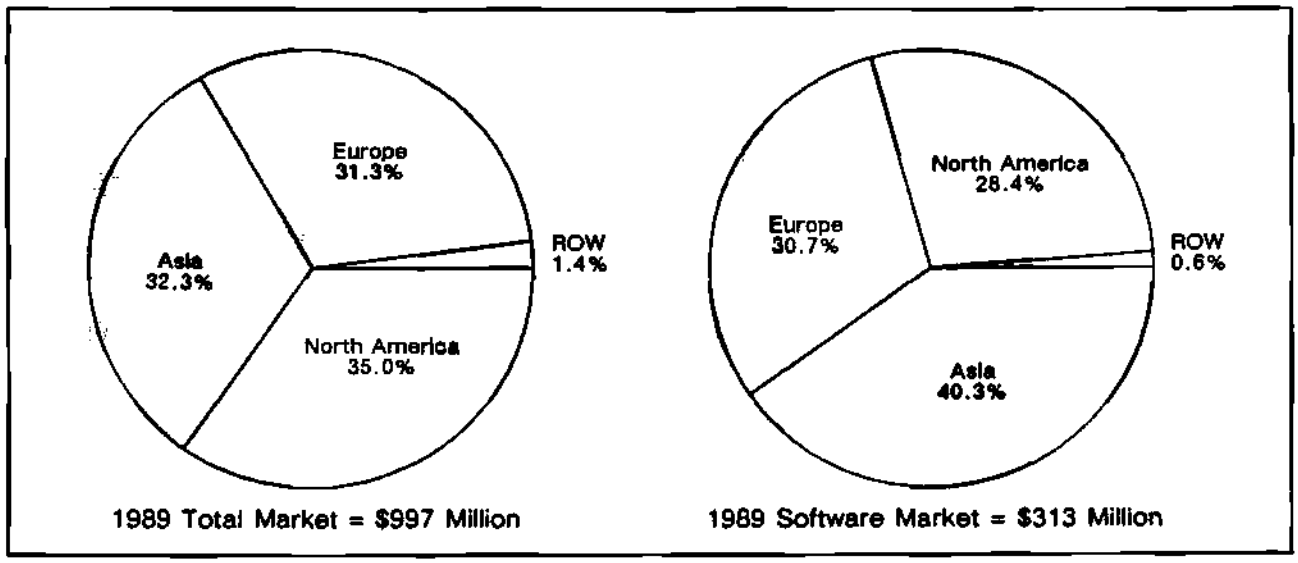
FIGURE 2
1989 PCB Layout Market Size, by Geographic Region



Source: Dataquest (December 1990)

- Dataquest's market research showed that users of the Cadnetix products were the most satisfied among all users of merchant PCB layout software in the market, thus making replacement even more difficult for competitors.
- Many users of PC-based PCB layout systems did not believe that the dramatic cost difference between PC-based systems and the "high-end" workstation-based PCB layout systems could be justified and thus did not replace their existing products.

Worldwide

Racal-Redac remained the market leader in the PCB layout sector with software revenue of $51 million and 15.9 percent of the worldwide market, up from 13.9 percent. Mentor Graphics captured the number two slot with its PCB layout software revenue reaching $42.3 million, giving the company 13.2 percent market share. This figure too was up from 1988, when the company had 9.3 percent market share. Zuken was the number three player with 8.9 percent market share, up from 1988 when it had 6.1 percent market share. Valid picked up significant ground in 1989, boosting its market share from 2.5 percent to 6.3 percent. This performance made Valid the fourth largest supplier of PCB layout software.

Asia

Figure 2 illustrates that Asia, accounting for 40.3 percent of the worldwide PCB layout software market, was the largest consumer of PCB layout tools in 1989. Indeed, the Asian market grew by 22.3 percent in 1989, from $103 million in 1988 to $126 million. This growth coincides with the region's dominance in consumer electronics goods. Such products have relatively short life cycles and require continuous replacement with newer, enhanced models. They also demand a great deal of up-front attention to layout and other manufacturability issues in light of the large manufacturing quantities involved. A constant demand for new and reliable PCB designs therefore exists.

Zuken, which has focused on developing PCB layout products for the analog PCB layout market, captured 23.1 percent of the software market in 1989. Racal-Redac, which has built a solid distribution channel in the Asian market, was the number two player with 10.3 percent market share. Both companies have been focusing primarily on the Japanese market, but each has begun to aggressively expand into other parts of Asia. Table 1 breaks down the 1989 Asian PCB layout market share.

Europe

Europe accounted for 30.7 percent of the PCB layout software market, a market that is being fueled by the region's strong telecommunications, consumer products, automotive, and industrial electronics industries. Although these industries remain

TABLE 1
1989 Asian PCB Layout Market Share

Company	Software (%)	Hardware (%)	Total* (%)
Zuken	23.1	12.1	16.2
Racal-Redac	10.3	3.6	6.3
Dazix	7.8	2.8	4.8
Sharp	7.7	5.4	6.4
Fujitsu	6.2	8.6	7.6
Cadix	6.1	3.7	4.7
Valid Logic	5.5	1.5	3.1
Others	33.3	62.3	50.9
Total	100.0	100.0	100.0

Note: All figures based on revenue share.
*Total includes software, hardware, and maintenance revenue.
Source: Dataquest (December 1990)

relatively healthy, total PCB layout software sales fell by 3 percent in 1989 to $96 million.

Racal-Redac dominated the European market in 1989, capturing 28.5 percent of the market. The next closest competitor was Mentor Graphics, with 13.5 percent market share. Despite Racal-Redac's commanding position in 1989, throughout 1990 the company has been feeling significant pressure from competitors such as Mentor Graphics. Dataquest expects the competitive pressures to intensify in 1991, as most of the major EDA vendors and PCB layout suppliers have set their sights on the European market. Table 2 shows the European PCB layout market share breakdown.

North America

The North American market accounted for 28.4 percent of the worldwide PCB layout software market. Certain PCB layout markets, such as the workstation and personal computer industries, remain strong. But others, such as the defense,

TABLE 2
1989 European PCB Layout Market Share

Company	Software (%)	Hardware (%)	Total* (%)
Racal-Redac	28.5	0	11.6
Mentor Graphics	13.5	4.6	8.7
Calay	6.3	2.6	3.9
Cadam	5.5	0	2.0
Computervision	5.0	6.3	6.7
Valid	4.3	1.4	2.5
Scientific Calculations	4.1	1.2	2.6
Dazix	4.1	2.1	3.2
Others	28.7	81.8	58.8
Total	100.0	100.0	100.0

Note: All figures based on revenue share.
*Total includes hardware, software, and maintenance.
Source: Dataquest (December 1990)

consumer electronics, and service bureau industries, remain soft. As a result, the North American PCB layout software market contracted by 10.9 percent in 1989, falling to $89 million. The slowdown was also due in large part to Dazix's tailspin.

Mentor Graphics was the dominant player in the PCB layout software market in 1989, capturing 26.1 percent market share. Valid Logic was the next closest player with 9.8 percent. Table 3 shows the 1989 North American market share breakdown.

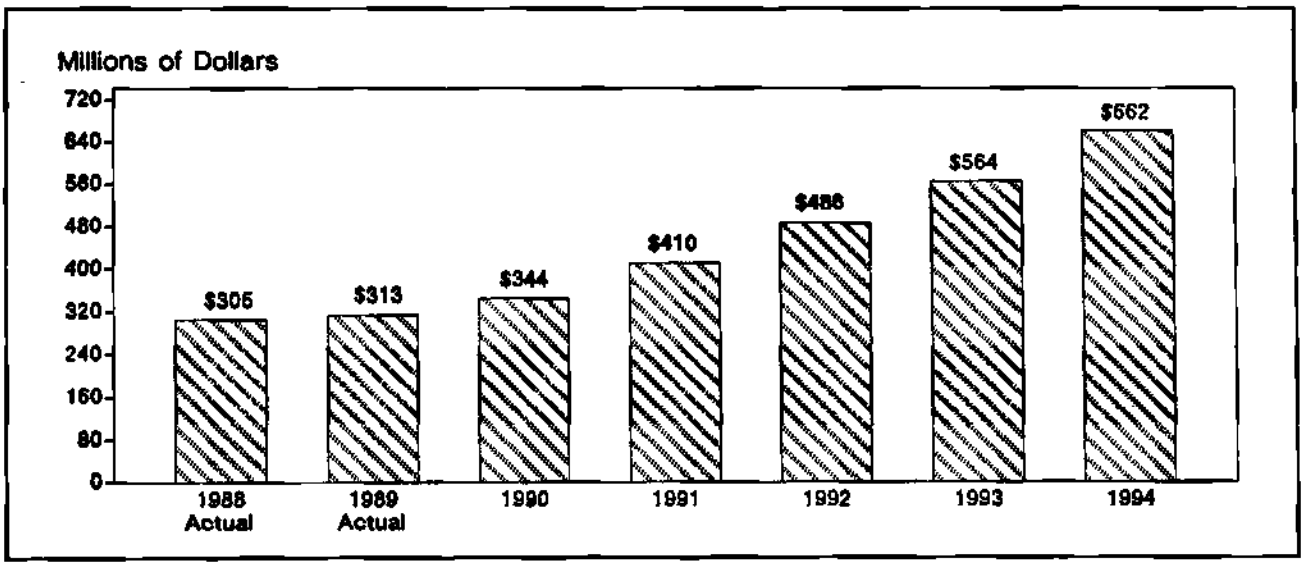
Despite the softness of the PCB layout software market in 1989, Dataquest expects the market to experience fairly healthy growth over the next five years. Figure 3 shows that PCB layout software market is expected to grow at a compound annual growth (CAGR) of 16 percent between 1989 and 1994.

TABLE 3
1989 North American PCB Layout Market Share

Company	Software (%)	Hardware (%)	Total* (%)
Mentor Graphics	26.1	7.9	13.4
Valid Logic	9.8	1.8	4.2
Racal-Redac	8.4	0.1	2.4
Intergraph	7.0	8.5	9.2
Calay	6.5	1.0	2.2
Scientific Calculations	5.8	1.0	2.6
Hewlett-Packard	4.9	17.1	13.7
Others	31.5	62.6	52.3
Total	100.0	100.0	100.0

Note: All figures based on revenue share.
*Total includes hardware, software, and maintenance revenue.
Source: Dataquest (December 1990)

FIGURE 3
Projected PCB Layout Software Market Growth



Source: Dataquest (December 1990)

MARKET FORCES DRIVING PCB LAYOUT GROWTH

Dataquest research indicates that the following forces will help fuel growth in the CAE market over the next five years:

- Increasing industry consolidation will lend stability to the market and provide a more healthy purchasing climate.
- Major EDA vendors are strengthening their PCB layout product lines and international distribution channels (e.g., Mentor, Racal-Redac, Valid, Zuken, Cadence, Intergraph, Scientific Calculations).
- A significant number of last-generation PCB layout systems are due to be retired over the next two years.
- Large segments of the market are retiring PCB layout systems that are not tightly integrated with their CAE tools, and these systems are being replaced with those that provide tight integration.
- New packaging technologies such as multichip modules will find increasing usage over the next five years, and these multichip modules (MCMs) will demand new layout tools.
- Surface mount devices will continue to displace through-hole packages (e.g., in 1989, 79 percent of all packages were DIP; in 1990 this figure dropped to 68 percent).
- Higher system clock frequencies are demanding PCB layout systems that ensure signal integrity is not compromised.
- An increasing number of electronic system manufacturers are bringing layout in-house to gain greater control over the design cycle.
- Users of DOS-based PCB layout systems will be looking to replace these systems with UNIX-based products.

ADVANCED PACKAGING TECHNOLOGY PUTS NEW PRESSURE ON PCB LAYOUT SYSTEMS

Advances in component and device packaging, as for example surface mount technology and more recently MCMs, are giving rise to higher-density PCBs. For example, it is becoming increasingly common to find 8-plus layer, double-sided boards containing components with 256 pins and 5-mil. line widths. The closer proximity of devices on the boards leads to the imposition of more stringent component placement rules in order to minimize the electrical and magnetic interaction between components.

Dataquest's research indicates that an increasing number of electronics manufacturers believe that such placement is best carried out by the design engineer in the CAE environment. Thus, design teams are anxious to equip their logic designers with CAE systems that enable users to perform a preplacement of the board. However, Dataquest's research shows that many of the existing systems offering this capability are difficult to use, and logic designers are submitting incorrectly preplaced boards that must be completely reworked by the layout designer.

In order for the market to adopt this new level of integration, EDA suppliers must provide systems that are easy to use and do not require the logic designer to become an expert in board placement. Most of the current generation of systems do not appear to satisfy this requirement.

The increasing interest in packaging at the enclosure level has led to the formation of a new EDA market: electronic packaging. These electromechanical applications are today used primarily by aerospace and consumer electronics manufacturers to facilitate the design of the enclosure (e.g., a missile nose cone or an injection-molded telephone handset) concurrently with the PCB outline shape. Clearly, the board must be designed to fit the space available (or vice versa), taking into consideration the board outline and three-dimensional component shapes. Because constant trade-offs must be made among the enclosure's shape, the PCB outline, and component positions, greater efficiency is achieved when PCB layout is carried out in-house.

Although some vendors such as Mentor Graphics, Intergraph, Computervision, and IBM are offering self-contained packaging stations, others such as Valid Logic and Racal-Redac remain focused on the layout applications and, thus, have formed strategic partnerships with mechanical CAD vendors. Dataquest expects most EDA companies choosing to not develop packaging tools to strike strategic partnerships with mechanical CAD vendors.

HIGHER-SYSTEM CLOCK FREQUENCIES SPUR SIGNAL INTEGRITY TOOL MARKETS

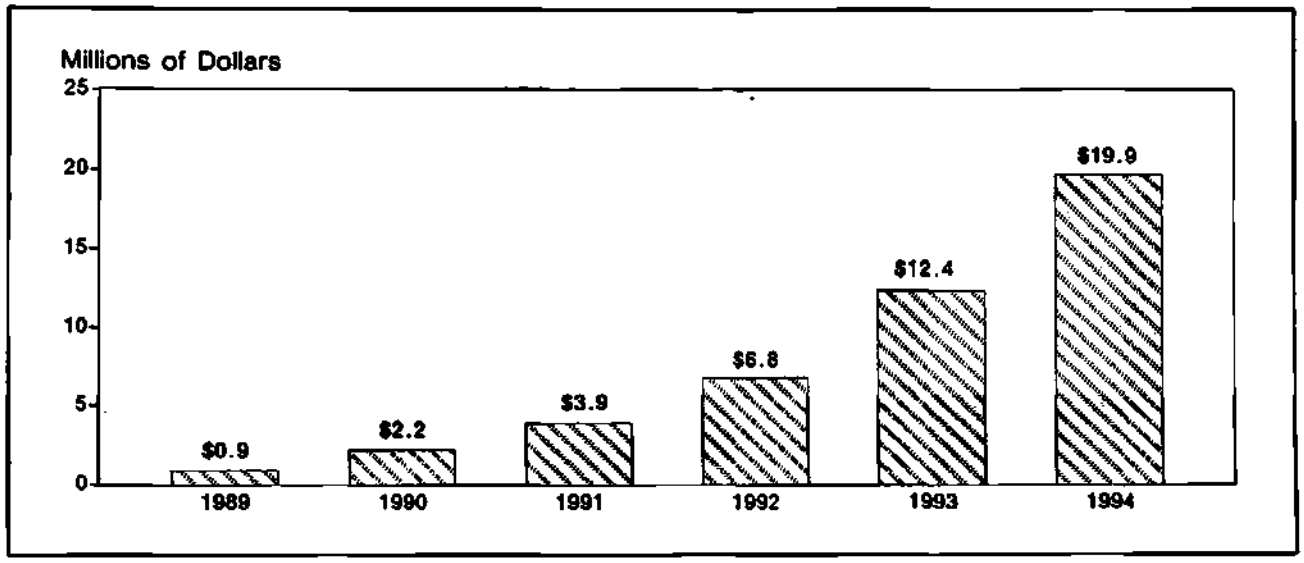
When the wavelength of an electrical signal on a PCB approaches the length of the metal trace,

the circuit behaves as an electrical transmission line and thus distorts the signal (e.g., causing reflection and degradation). In addition, when these higher frequencies are considered in combination with the reduced trace-to-trace spacing (implicit in the higher-board densities discussed earlier), the effects of crosstalk between traces will also negatively impact reliable circuit operation. It follows that there will be a significant demand for transmission line simulation and crosstalk analysis tools over the next five years. Figures 4 and 5 illustrate the projected growth of these markets.

A number of vendors are addressing this market, including market leader Quantic Laboratories, Quad Design Technology, Swift Logic, Contec, Dazix, Meta-Software, and several PC-based software vendors. Some of the large full-line EDA suppliers will provide this kind of technology to customers either by striking partnerships with any number of these niche suppliers, developing the technology internally, or acquiring the technology outright.

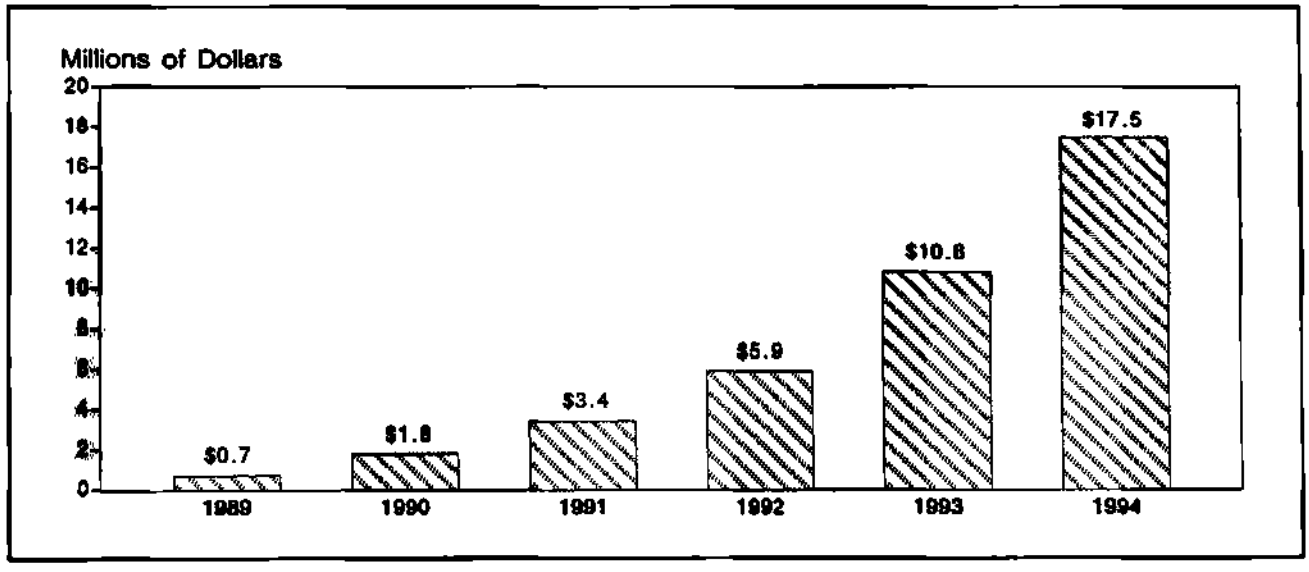
Dataquest's research indicates that few digital design engineers are familiar with transmission line

FIGURE 4
Projected Transmission Line Simulation Software Market Growth



Source: Dataquest (December 1990)

FIGURE 5
Projected Crosstalk Simulation Software Market Growth



Source: Dataquest (December 1990)

equations and their associated parameters. Thus, success in this market will require that the tools be very easy to use. In short, the tools must "speak" the engineers' language.

THE EMERGING BATTLEGROUND IN THE PCB LAYOUT MARKET

It is clear that PCB layout manufacturers will continue to compete by improving their systems' functional capabilities, as well as by improving placement and routing performance (e.g., improving algorithms and databases, and making better use of the base compute platform). Manufacturers will also compete by providing improved integration between the design environment and the layout environment. Indeed, this has been under way for at least the past eighteen months.

But PCB layout suppliers will also have to aggressively tighten the links among layout and manufacturing. Dataquest's research indicates that many large electronics manufacturers have antiquated links among engineering, layout, manufacturing, and sales organizations. Integration includes the links with photoplotters, NC drillers, NC routers/profilers, manual assembly systems, automatic assembly machines (e.g., pick-and-place, dip inserters, axial inserters, radial inserters, and semiautomatic light-guided assembly stations), bill of material (BOM) databases, engineering charge orders (ECO) databases, automatic test equipment (ATE) systems, order entry databases, and purchasing departments.

Dataquest believes that integration among engineering, layout, manufacturing, and sales will grow in importance throughout this decade as electronics manufacturers face increasing competition in the electronics market. Tool suppliers that are able to reduce these bottlenecks (at a minimum cost) through a combination of products and services will gain significant credibility in the eyes of the market. We believe that this credibility will in turn produce increased product sales.

DATAQUEST PERSPECTIVE

The PCB layout industry is among the oldest of the EDA industries. In the 1970s, it was consolidated, with only a few major players supplying the market. In the 1980s, many new players entered the market, and the industry fragmented. Dataquest believes that the industry will undergo a severe consolidation period over the next five to seven years. We anticipate a significant number of mergers and acquisitions, with some suppliers being forced to exit the business altogether.

Ron Collett
Jim Tully

Dataquest
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Research Newsletter

THE NEW BATTLEFIELD OF THE 1990s EDA MARKET: TOP-DOWN DESIGN

SUMMARY

In response to the increasing complexity of electronic system design, electronics manufacturers will be forced to make extensive changes to their organizations and design methodologies over the next five years. In our view, top-down design will become the preferred design methodology by 1994. As such, we believe that electronic design automation (EDA) tools supporting the top-down design paradigm will become a primary driver of the EDA market. These tools include mixed-level simulators, logic synthesis software, and test automation systems. Our research indicates that all these tools are gaining in importance and will become a staple in the designer's toolkit by 1995.

This newsletter provides the following information:

- An overview of the top-down design methodology
- Market signals of the top-down design revolution
- Gate complexity of the next generation of designs
- The impact of top-down design on the EDA market and industry
- Forecast for logic synthesis software and hardware description language (HDL)-based mixed-level simulation
- Strategies for penetrating the top-down design market

TOP-DOWN VERSUS BOTTOM-UP DESIGN

Top-down design is a species of design methodology. Together with the supporting tools, it allows engineers to perform architectural trade-offs by modeling and simulating a design first at the behavioral level and subsequently at the structural, or gate, level. Designing initially at the behavioral level permits the engineering team to determine the design's architectural viability without committing to any particular implementation. Upon selecting the optimal architecture, the design team implements a structural representation of the design that is equivalent to the behavioral representation. And with the addition of a mixed-level simulator, engineers can concurrently simulate the various levels of abstraction that model the different portions of the design.

Top-down design offers several advantages. First, it allows engineers to manage design complexity more effectively. Instead of proving the viability of the architecture at the gate level, the design team works at a higher level of abstraction. Second, it enables the design team to explore a range of architectural alternatives painlessly. Third, it permits more simulation and design verification, because behavioral models execute much faster than their gate-level equivalents.

When used in conjunction with a mixed-level simulator, top-down construction also allows the design team to simulate the *entire* system at any point in the design cycle, irrespective of the various levels of model abstraction that define the different parts design (e.g., gate, functional, behavioral). Thus, system integration and verification occur throughout the design cycle, as opposed to the end when a gate-level model is available. This enables the design team to uncover design problems throughout the design cycle.

Top-down construction contrasts sharply with bottom-up design, in which the engineer designs primarily at the structural level throughout the design cycle. In bottom-up construction, the architecture's viability is determined only by

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verifying the design's operation at the structural level, which requires a complete gate-level model of the architecture. Bottom-up construction provides only a limited, if any, opportunity for architectural exploration, because the designer's focus is almost exclusively on implementation, as opposed to behavior. Making architectural changes and performing design verification at the structural level is typically time-consuming and costly. Moreover, the bottom-up approach often produces inefficient architectures that do not conform to system requirements. To make matters worse, nonconformance frequently is uncovered late in the design cycle, when it is prohibitively expensive to make major changes.

THE TOP-DOWN DESIGN REVOLUTION IS COMING

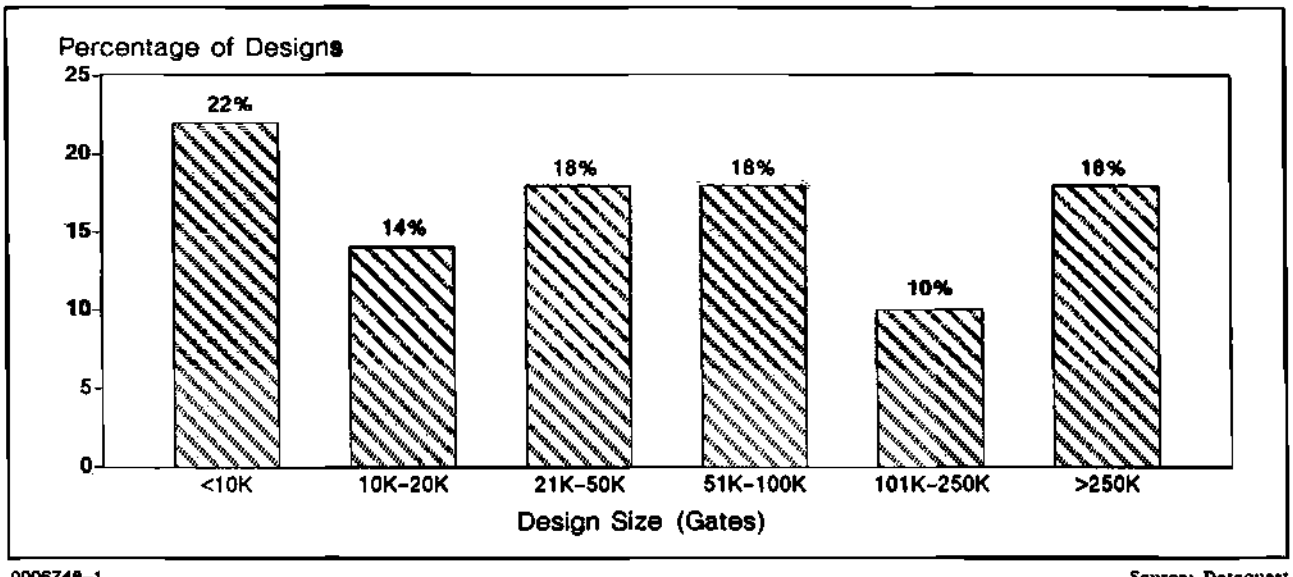
Several indicators point to the impending shift toward top-down design. For example, in 1988 a survey of design teams performing top-down design showed that 67 percent of the design cycle was devoted to structural-level design, while 33 percent was allocated to the behavioral level. Today the time spent designing at the behavioral level averages 40 percent. Another indicator derives from the market's purchasing plans—56 percent of the market preparing to adopt commercial mixed-level simulation tools plans to do so for the purpose of performing top-down design. A third indicator from Dataquest's research shows that more than 50 percent of the market believes that logic synthesis tools are an essential ingredient of the ASIC design toolkit. We believe that the combination of these signals marks the beginning of the top-down design revolution.

Increasing circuit complexity is driving system designers toward the top-down paradigm. Figure 1 shows the distribution of gate complexity for the upcoming generation of logic designs (i.e., those initiated over the next three to six months). The chart indicates that 46 percent will comprise more than 50,000 gates, and more than half of those will be greater than 100,000 gates. This compares with Figure 2, which illustrates a distribution of the largest designs performed in the past. A comparison of Figures 1 and 2 shows that the number of designs below 10,000 gates is on the decline.

MARKET PULL FOR TOP-DOWN DESIGN

The market clearly believes that an effective way to tackle design complexity is to increase the time spent designing at the behavioral and architectural levels and decrease the time spent at the structural levels. Leading-edge electronics systems manufacturers have begun using the top-down approach more earnestly over the past 12 to 18 months, but current EDA tools and interfaces still do not yield an unfettered top-down design flow. For instance, lack of behavioral-level logic synthesis precludes a smooth transition from the

FIGURE 1
Gate Complexity of Upcoming Generation of Electronic Designs



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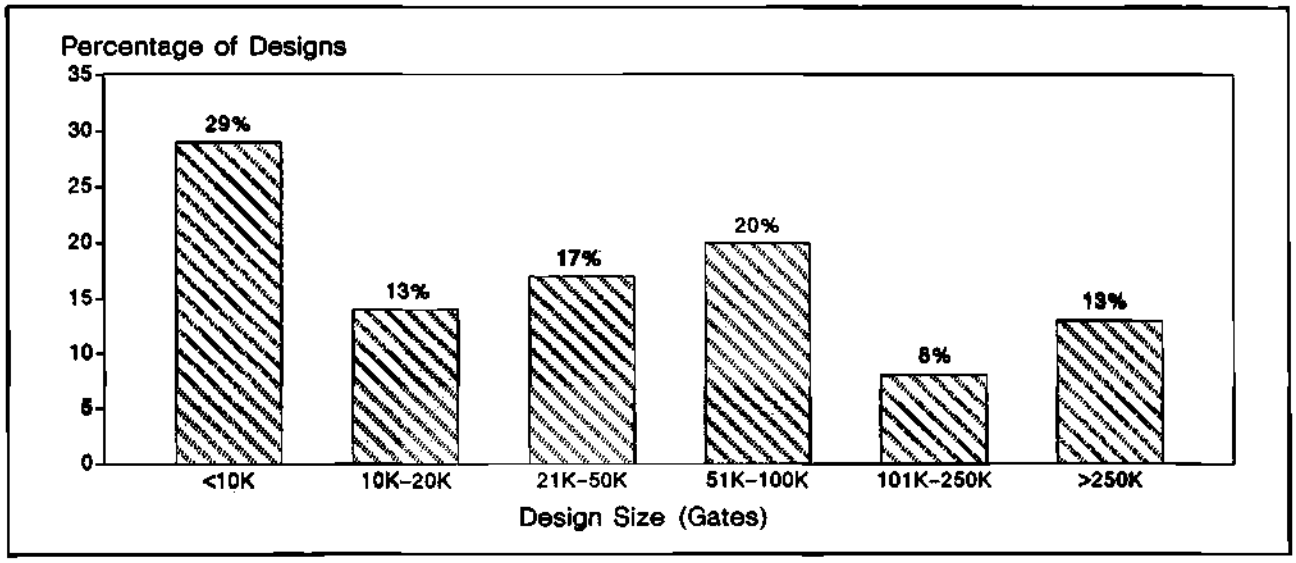
Source: Dataquest
April 1990

behavioral description to the logic implementation. Design teams need a suite of EDA tools that allows them to design by developing an HDL specification that is both executable (for simulation) and synthesizable.

Despite the increasing migration toward the top-down approach, today's predominant design paradigm remains the bottom-up methodology. In fact, as Figure 3 illustrates, behavioral-level design is not done at all in 20 percent of today's designs. And in 11 percent of the designs, no more than 10 percent of the design-cycle time is spent designing at the behavioral level. Thus, in nearly one-third of today's designs, engineers are spending minimal, if any, time at the behavioral level. Further evidence of the widespread use of the bottom-up methodology can be seen in the fact that 73 percent of the users of commercial mixed-level simulators are using these tools for gate-level simulation, while only 54 percent are using them for behavioral simulation.

FIGURE 2
Gate Complexity of Largest Electronic Design to Date



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Source: Dataquest
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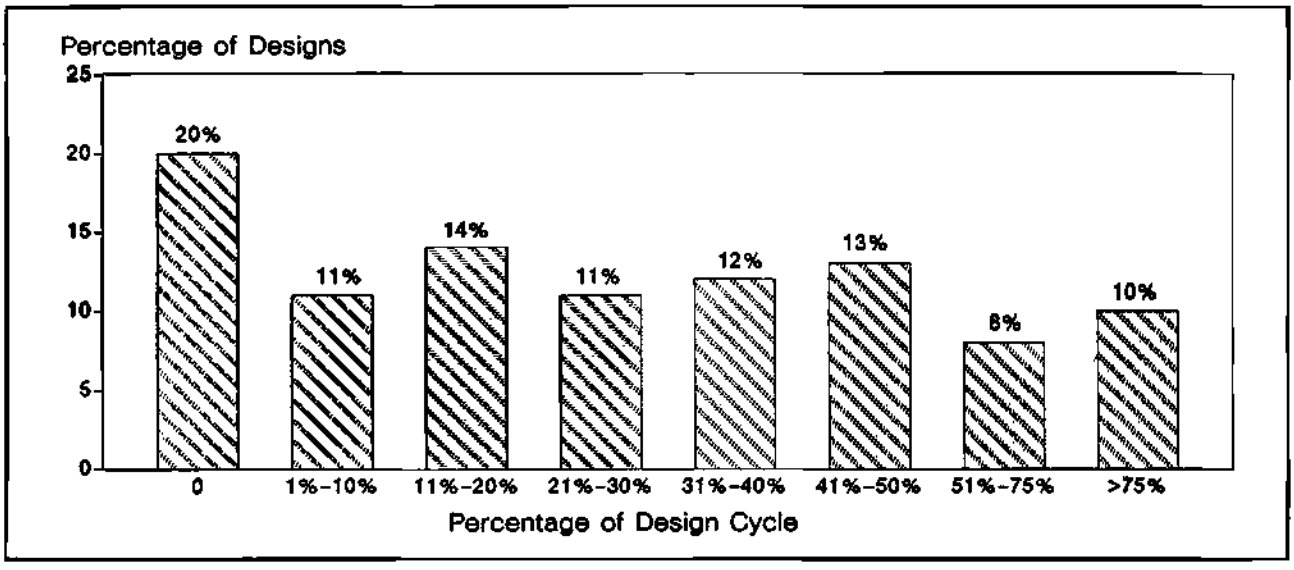
FIGURE 3
Time Spent Designing at the Behavioral Level



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Source: Dataquest
April 1990

Dataquest believes that these percentages will change dramatically over the next three years. We anticipate that 90 percent of all designs will be implemented with at least 20 percent to 25 percent of the design cycle devoted to architectural- and behavioral-level design by 1994. Our forecast is based on the following trends:

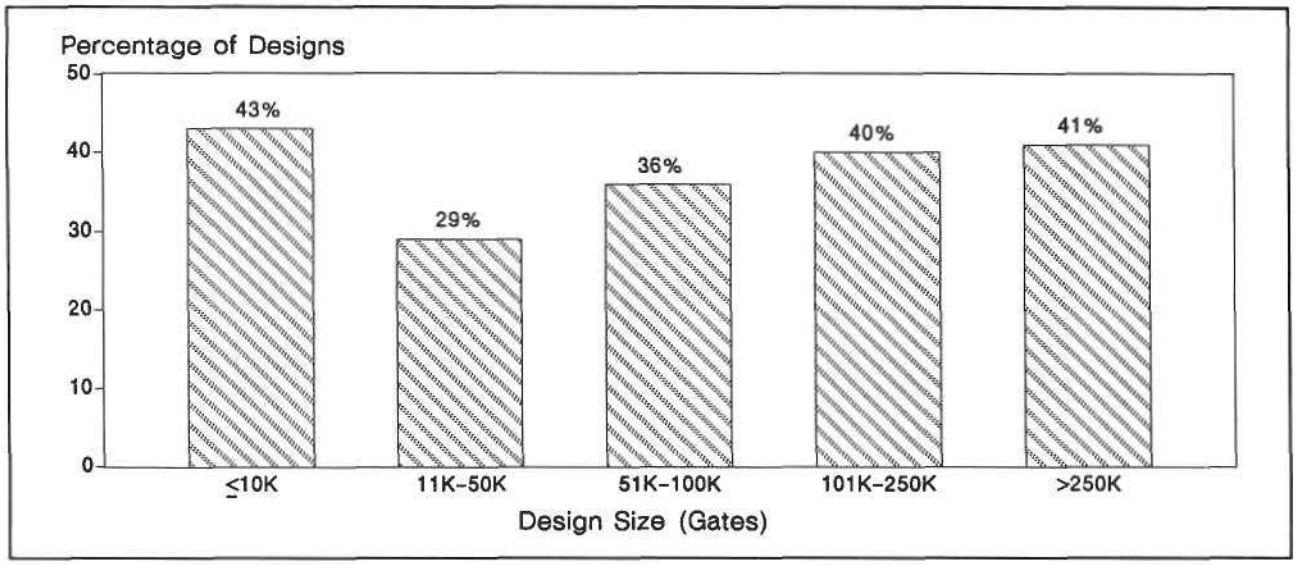
- Increasing design complexity
- Growing time-to-market pressures
- Emerging production-proven logic synthesis tools
- Improving mixed-level simulation products
- Growing penetration of hardware description languages (HDLs)
- Increasing model availability and improved modeling tools

A striking characteristic of the data in Figure 3 is its nearly normal distribution. That is, across the spectrum of design sizes, the amount of time spent at the behavioral level varies almost uniformly among the categories 10 percent to 75 percent. This wide range in times allocated to behavioral-level design can be explained by the data in Figure 4, which shows that as design complexity rises, so too does the amount of time engineers spend at the behavioral level.

Yet a seemingly anomalous data point of Figure 4 is the percentage of time spent at the behavioral level for designs of 10K or less. The 43 percent figure is larger even than the most complex designs. We believe that this percentage reflects the pressure on design teams to develop products within tight time constraints. For example, a less complex design (e.g., below 10K gates) described behaviorally can be converted into its gate-level equivalent fairly quickly and with little difficulty. There is little risk of spending too much time at the behavioral level and not leaving enough time for translation to the gate level. This contrasts with complex designs, which require more time and effort to translate from a behavioral representation to a corresponding gate level implementation. Too much time spent at the behavioral level could leave an insufficient amount of time for gate-level implementation, causing the design cycle to stretch out. In sum, we believe that designers are spending less time performing architectural trade-offs because they feel pressured to commence work on the gate-level implementation as early as possible.

This raises a question as to the optimal amount of time that design teams should allocate to behavioral-level design. Ideally, the time spent should equal the time needed to develop the most efficient architecture. Unfortunately, pressure always exists on the design team to ensure that the design is completed on time. So, engineers often jump prematurely to the gate-level implementation phase, without performing adequate architectural exploration. This, of course, typically yields a less than optimal architecture.

FIGURE 4
Behavioral-Level Design as a Function of Design Size



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Source: Dataquest
April 1990

LOGIC SYNTHESIS: THE CATALYST OF TOP-DOWN DESIGN

In our view, the reason behind the premature launch into the gate-level design stems from the dearth of behavioral-logic-synthesis tools on the market. Lack of behavioral-logic-synthesis tools necessitates manual translation of the behavioral representation to the structural representation.

We believe that design teams will continue limiting the amount of time spent performing architectural trade-offs until both the behavioral synthesis tools are available and the designers are comfortable following a top-down design methodology using HDLs and logic-synthesis software. Once designers adopt behavioral synthesis tools, they will have the luxury of relying on the tools to transform the behavioral description into a gate-level implementation. This automatic translation, of course, will allow design teams to bypass the manual task of converting the behavioral-level specification into logic, permitting more time to be spent at the behavioral level exploring architectural alternatives.

A handful of leading-edge electronic manufacturers recently have begun to use internally developed behavioral synthesis tools, but the technology has yet to penetrate the mainstream. We believe that behavioral-level synthesis will gradually move into the mainstream design groups over the next five years, with 18 percent to 22 percent of all ASICs implemented with commercial synthesis tools by 1994. Indeed, we anticipate that logic synthesis will be an integral driver of the top-down design paradigm. As Figure 5 shows, Dataquest forecasts the logic synthesis market to exhibit a compounded annual growth rate (CAGR) of 68 percent from 1989 through 1994.

Commercial EDA companies currently are focusing on expanding the capabilities of their register-transfer-level (RTL) synthesis products to include synthesis of higher-level behavioral. RTL-based top-down design allows engineers to perform more architectural exploration than a pure bottom-up, gate-level design methodology but not as much as a behavioral-based top-down paradigm.

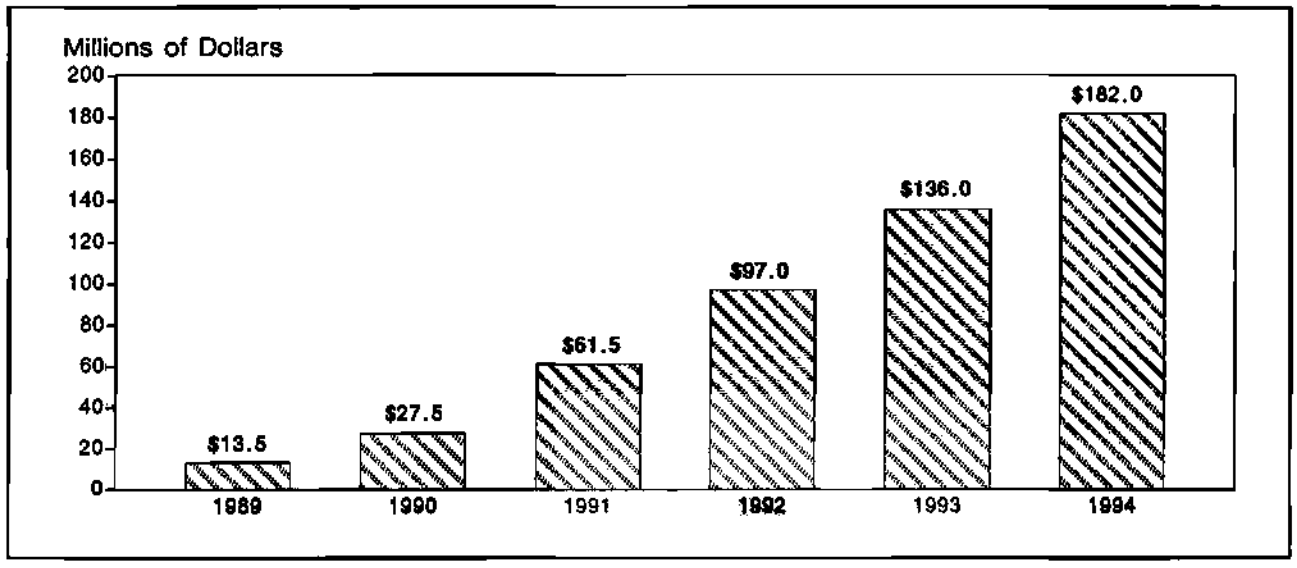
Because the current generation of synthesis products synthesize predominantly from RTL descriptions, designers wishing to use a synthesis-based top-down design methodology will most likely choose to design and simulate at both the RTL and behavioral levels, manually translate the behavioral descriptions into a combination of structural-level logic and RTL constructs, and rely on the RTL-logic-synthesis system to convert the RTL description into logic.

MARKET AND PRODUCT STRATEGY IN THE TOP-DOWN DESIGN ERA

Top-Down Design Education

Although the increasing adherence to top-down design techniques portends to have enormous impact on the EDA market, design methodology

FIGURE 5
Growth of Logic Synthesis Software Market



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Source: Dataquest
April 1990

changes will create several new challenges for EDA vendors. For example, education, training, and customer support relating to top-down design will become critical as engineers attempt to embrace the new methodology. Dataquest's research confirms that the primary reason for not adopting HDL-based top-down design is because it is perceived as being too sophisticated. This sentiment resounds across all industries, from data processing to semiconductors. Indeed, very few undergraduate electrical engineering programs offer courses in top-down design. Thus, we believe that success in the top-down design market requires education to be offered simultaneously with the new EDA environments, and the quality of education must be commensurate with the sophistication of both the top-down methodology and the tools.

Displacing the current design methodologies that electronics manufacturers use with a true top-down design approach will be among the most difficult hurdles facing EDA vendors over the next five years. We anticipate that, just as in-house proprietary tools continue to be primary competitors of commercial EDA vendors, much effort will be required to overcome the inertia embodied in existing design methodologies. Engineers will adopt commercial tools, but only after they feel comfortable with the methodology.

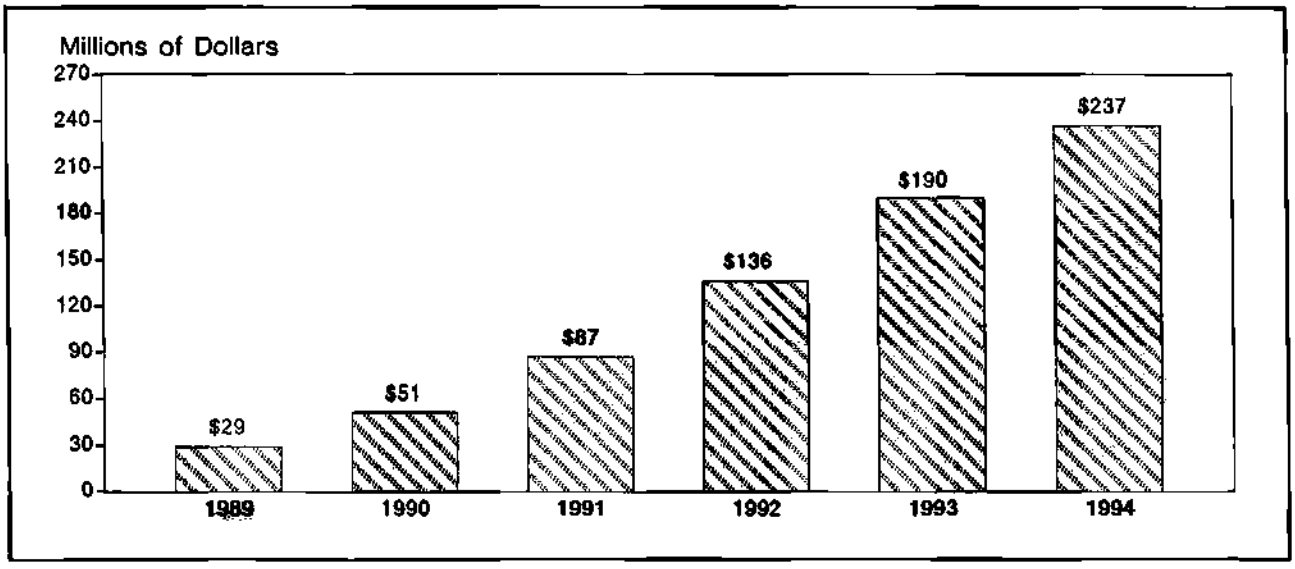
In addition, organizational changes within electronic-system manufacturers will be necessary to exploit the full value of top-down design. For example, it is unknown how much productivity improvement can be gained from the top-down paradigm. EDA vendors must be able to provide sound advice to customers regarding organizational issues relating to expected productivity gains.

Robust Behavioral Simulation

Dataquest's market research indicates that nearly all of the users of proprietary in-house digital simulators are using them equally for both behavioral- and gate-level simulation. This market segment already is convinced of the high value of top-down design and will evaluate commercial simulation products not only on their gate-level capabilities, but also on their behavioral-level capabilities. Support of VHDL will be mandatory, but other de facto standard HDLs also are likely to emerge over the next five years. As Figure 6 shows, Dataquest forecasts the HDL-based mixed-level simulation software market to experience a CAGR of 52 percent from 1989 through 1994.

Dataquest's market research indicates that industries that will be most aggressive in adopting mixed-level simulation include military/aerospace, data processing, and semiconductors. Within those industries, companies with more than 100 employees hold the most promise for EDA vendors.

FIGURE 6
Growth of HDL-Based Mixed-Level Simulation Software Market



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Source: Dataquest
April 1990

Product Line Mix

Competing in the top-down design market will require an EDA vendor to provide a tightly integrated environment that includes the following product suite:

- High-performance mixed-level simulation
- HDL-based logic synthesis
- A rich set of ASIC libraries supporting the synthesis and simulation environments
- Model debugging tools
- Test-logic synthesis software
- Automatic test vector generation (ATVG) packages

Dataquest believes that these tools are central to the top-down design methodology and must become part of, or easily integrated into, the full-line supplier's product line by 1992. Our market research also indicates that compatibility with existing EDA systems is the most important requirement of a new EDA tool. Also ranking high as important requirements are the tools' execution speed, functionality, and ease of use.

DATAQUEST CONCLUSIONS

Dataquest believes that conditions are right for a shift in the design paradigm. By 1995, we expect the majority of engineers to be following a top-down approach. Factors pointing to the impending shift include the following:

- Electronic system design complexities continue to grow.
- Simulation technology is improving.
- Logic synthesis is becoming more viable.
- HDL-based design is making inroads.
- Workstations now can handle the compute requirements of most EDA applications.
- Several companies are developing test-logic synthesis and ATVG systems to round out the top-down design environment.
- A handful of universities have begun including top-down design courses within the undergraduate curriculum.

In sum, the EDA market of the 1990s will look quite different from that of the 1980s.

Ron Collett

Dataquest
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Research Newsletter

STATE OF THE EDA INDUSTRY: AN UPDATE

SUMMARY

The turmoil that has become the earmark of the EDA industry through the mid-1980s continued unabated through 1989 and 1990: more mergers and acquisitions, new players displacing onetime industry leaders, new standards emerging, the accelerating trend toward open systems, and changes in market conditions that demand revamped business models and strategies. This newsletter discusses and analyzes the following topics:

- EDA market growth in 1989
- EDA market share leaders
- EDA trends and future directions
- EDA industry structural changes
- EDA market opportunities

EDA MARKET GROWTH AND ANALYSIS

Worldwide EDA Market Growth—1989

The total EDA market grew by 12.6 percent, reaching $2.90 billion. This figure includes hardware (including peripherals when shipped as a turnkey system), software, and service for the CAE, PCB layout, and IC layout markets. The EDA software market expanded by 14.4 percent, equating to $1.06 billion. The following summarizes the 1989 growth of the individual markets making up EDA:

- The CAE market grew to $1.53 billion, which represented an increase of 21.3 percent over 1988. The software component of the CAE market reached $576 million, a 28.0 percent increase over 1988.
- The PCB layout market grew by 4.3 percent to $997 million. The software component of the PCB layout market reached $313 million, which was a 2.6 percent increase over 1988.
- The IC layout market grew to $381 million, representing a 5.0 percent increase over 1988. The software component of the IC layout market grew by 5.6 percent to $171 million.

The overall EDA market grew slightly less than Dataquest forecast in 1988. (We forecasted that the market would grow by 16.6 percent.) We believe that the slower than expected growth was due to the following factors:

- Dazix revenue dropped by approximately $40 million in 1989.
- EDA vendors were unable to fill the void left by Dazix, which was a result of the enormously high switching costs associated with exchanging Dazix tools with another vendor's products.
- The market had major concerns about the stability of other EDA companies in light of the Daisy/Cadnetix merger.
- There was a tremendous amount of confusion in the market regarding which EDA products and companies are providing the best technology—all companies positioned their products as the best available, and it is difficult for the market to separate the "wheat from the chaff."

The result of all this was that many segments of the EDA market adopted a "wait and see" attitude when it came to purchasing EDA products.

North American EDA Market Growth—1989

The North American EDA market grew by 13.1 percent, reaching $1.25 billion. This figure comprises hardware (including peripherals when

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shipped as a turnkey system), software, and service for the CAE, PCB layout, and IC layout markets. The North American EDA software market expanded by 15.4 percent, equating to $456 million. The following summarizes the 1989 growth of the individual North American markets making up EDA:

- The CAE market grew to $722 million, representing an increase of 9.5 percent over 1988. The CAE software market reached $294 million, a 29.5 percent increase over 1988.
- The PCB layout market grew by 3.9 percent to $349 billion. The PCB layout software market fell to $89 million, a 13.5 percent decrease from 1988.
- The IC layout market grew to $177 million, which was a 17.2 percent increase over 1988. The IC layout software market grew by 7.5 percent to $72 million.

Dataquest believes that the following factors contributed to the growth of the North American EDA market:

- The market participants began taking a strategic view toward EDA and, thus, believe that remaining competitive in the 1990s clearly demands a significant investment in EDA technology. Fewer and fewer electronics manufacturers are questioning the necessity of sophisticated EDA tools.
- Buying was conservative in the defense industry.
- CAE software tools experienced tremendous growth because they are viewed as productivity accelerators (e.g., design entry, simulation, and logic synthesis).
- Slow growth occurred in PCB layout software because of existing tools that did not yet require replacement and the decline of Dazix's PCB layout business—the company's PCB layout revenue dropped by 50 percent in 1989.
- Slow growth occurred in IC layout software as a result of most suppliers' inability to execute their strategies and provide the right set of products to the market.

Asian EDA Market Growth—1989

The Asian EDA market grew by 17.9 percent, reaching $796 million. This figure includes hardware (when shipped as a turnkey system), software, and service for the CAE, PCB layout, and IC layout markets. The Asian EDA software market expanded by 32.0 percent, equating to $338 million. (Note: This does not include the 7.0 percent depreciation of the Japanese yen.) The following summarizes the 1989 growth of the individual Asian markets making up EDA:

- The CAE market grew to $338 million, which represented an increase of 39.7 percent over 1988. The CAE software market reached $141 million, which was a 54.9 percent increase over 1988.
- The total PCB layout market grew by 4.5 percent to $323 million. The PCB layout software market reached $126 million, for a 22.3 percent increase over 1988.
- The IC layout market grew to $136 million, representing an 8.8 percent increase over 1988. The IC layout software market grew by 14.5 percent to $71 million.

The following factors contributed to the strong growth in the Asian EDA market:

- The Asian market views merchant EDA tools as indispensable. Large electronics manufacturers recognize that they cannot remain competitive without them.
- Major EDA vendors strengthened their Asian distribution channels.
- Mergers, acquisitions, and EDA vendor stability continue to concern the market. (In the presence of this uncertainty, higher growth can be expected.)
- Strong growth occurred in EDA hardware because the market is complementing its predominantly mainframe-based environments with distributed processing (i.e., workstations).
- Strong growth in CAE was the result of the robust interactive capabilities of merchant CAE software, as well as the increasing capabilities of merchant verification tools.
- Modest growth in PCB layout was caused by a combination of Dazix's instability and the overall fragmentation of the industry, but this was somewhat offset by Zuken's growth.
- Strong growth in IC layout resulted from the pent-up demand in the semiconductor industry and the consolidation and stability of the IC layout industry.

European EDA Market Growth—1989

The European EDA market grew by 6.7 percent, reaching $823 million. This figure includes hardware (including peripherals when shipped as a turnkey system), software, and service for the CAE, PCB layout, and IC layout markets. The European EDA software market expanded by less than 1.0 percent, equating to $261 million. (Note: This does not include the 8 percent depreciation of the European currencies.) The following summarizes the individual European markets making up EDA:

- The CAE market grew to $449 million, which represented an increase of 16.7 percent over 1988. The software component of the market reached $137 million, a 6.2 percent increase over 1988.
- The PCB layout market grew by 3.7 percent to $312 million. The software component of the PCB layout market fell to $96 million, a 3.0 percent decrease decline compared with 1988.
- The IC layout market fell to $62 million, which was a 27.9 percent decrease compared with 1988. The IC layout software market fell by 18.2 percent to $27 million.

The following factors contributed to the growth of the European EDA market:

- Vendors that were most successful in Europe established strong distribution channels in countries with the strongest EDA markets (e.g., Germany).
- Dazix's problems translated to a decline in the European CAE market.
- Europe's quest for share in the electronic systems markets (e.g., telecommunication, aerospace, and consumer electronics) produced demand for advanced PCB layout systems.
- Europe's semiconductor industry remains weak because of strong international competition, which produced limited demand for IC layout tools; also, neither Cadence nor Mentor was able to make any significant inroads into the IC layout market.

EDA MARKET SHARE SCORECARD

Worldwide 1989 EDA Software Market Share

Table 1 shows that the leading EDA software players in 1989 were Mentor Graphics, Cadence, Valid Logic, Dazix, and Racal-Redac. As noted earlier, the total market size reached $2.84 billion, whereas software sales accounted for $1.05 billion. The top five are profiled in subsequent paragraphs.

Mentor Graphics

Mentor Graphics remained the EDA industry's market share leader with 14.6 percent of the overall market and 19.6 percent of the software market. These shares compare with 12.6 percent and 14.8 percent, respectively, in 1988.

Although Mentor Graphics experienced a very strong growth period in 1989, the company has been immersed in challenges in 1990 that have

TABLE 1
1989 Worldwide EDA Market Share Scorecard

Company	Total Percentage[1]	Software Only Percentage[2]
Mentor Graphics[3]	14.6	19.6
Cadence Design Systems	4.7	11.0
Valid Logic Systems	6.1	9.5
Dazix	5.4	6.5
Racal-Redac	3.2	6.5
Others	66.0	46.9
Total	100.0	100.0

[1]Market share based on revenue from hardware, software, and maintenance
[2]Market share based on revenue from software only
[3]Includes market share of Silicon Compiler Systems
Source: Dataquest (November 1990)

caused a slowdown in both revenue and earnings. These challenges include the following:

- Completion of Mentor's Falcon framework and the associated suite of EDA application software
- Absorbing Silicon Compiler Systems
- Porting Mentor's software to the Sun platform
- Attacking new markets such as CASE and electronic packaging

Mentor plans to begin shipping the production release of its Falcon framework and tools based on Falcon in the first quarter of 1991. Shipments of its software to the Sun platform are scheduled to begin in the second quarter of 1991.

Cadence Design Systems

Cadence became the second largest EDA software vendor in 1989, surpassing both Dazix and Valid Logic. Eighty to ninety percent of the company's revenue comes from sales into the ICDA market; the remaining revenue is from sales into the systems design market (i.e., ASIC and PCB design). Indeed, further penetrating the systems design market is Cadence's greatest challenge over the next three years. Most of the company's sales into this market thus far have come from the Verilog simulation product line, which was acquired via Cadence's acquisition of Gateway Design Automation in late 1989. Cadence clearly is aware that it must provide more than simulation products to be successful in the systems design market. Indeed, the company began shipping its more complete CAE solution, called Amadeus, at the end of the third quarter of 1990. We believe that the success of Amadeus is critical to the company's future.

Valid Logic Systems

Valid Logic made significant headway in 1989, increasing its revenue by approximately 23 percent. Valid's growth in 1989 can be attributed to the following:

- It was among the few full-line EDA suppliers shipping its products on the Sun platform (which has become the platform of choice over the last two years).
- Valid's PCB layout system—Allegro—experienced strong market acceptance, which also provided "pull-through" sales of CAE products.
- Valid's product line for high-speed design was among the most complete in the industry.
- Valid offers well over 100 ASIC design kits.

Similar to Mentor Graphics, Valid has slipped somewhat in 1990, reporting losses in the first and third quarters. Moreover, the company recently announced that it would exit the workstation hardware business. Valid joins an array of other EDA companies that have altered their business models to focus exclusively on software. Valid's major challenges over the next two years include the following:

- Provide a CAE solution that is competitive with those emerging from other EDA players, including Cadence, Mentor Graphics, Racal-Redac, Synopsys, and Viewlogic.
- Provide framework technology that allows users to integrate third-party tools easily and tightly into its environment.
- Demonstrate corporate and financial stability, as well as a competitive technology migration path, to the market.

Dazix

Dazix suffered such severe damage in 1989 that it was forced to declare bankruptcy in 1990. The company's problems stemmed from its merger with Cadnetix, which put the company into severe debt. The debt caused existing and potential customers to hold off on buying any significant quantities of products until the company demonstrated financial stability—an event that never occurred. The company's revenue fell from $208 million in 1988 (including Daisy Systems, Cadnetix, HHB Systems, and SimuCAD) to $153 million in 1990, and its market share dropped from 8.8 percent to 5.4 percent.

At this point, the issue for Dazix is whether or not the company can be successfully resurrected by its recent purchaser, Intergraph. Dataquest believes that Dazix has suffered such severe image damage that even if the company solves its financial problems, it will take at least a year or two for a reorganized Dazix to pose a competitive threat to other industry leaders. For Intergraph the challenges will be formidable. If Intergraph can successfully keep the Dazix installed base (approximately 10,000) from migrating away, Intergraph will pose a significant challenge to other major EDA players.

Racal-Redac

Racal-Redac has demonstrated over the past 15 months that it is expanding beyond its traditional PCB layout roots into the fast-growing CAE market. During this time period, Racal-Redac has purchased HHB Systems, an independent supplier of simulation products, and Silc Technologies, a logic synthesis company.

The combination of CAE and PCB layout products positions the company directly against Cadence, Dazix, Mentor Graphics, and Valid Logic—all of which are attacking the same market. Racal-Redac's market share fell slightly in 1989, as the company's revenue (including HHB Systems) was comparable to its 1988 figures, whereas the overall market grew by more than 13 percent. Racal holds a strong position in both Europe and Japan, but in North American it significantly lags the competition. For the company to succeed, Dataquest believes that it must establish a greater position in the North American market.

Worldwide 1989 CAE Software Market Share

Table 2 provides a comparison between 1988 and 1989 percentages of the CAE software market share captured by the top five EDA vendors. A complete listing of all vendors can be found in the CAD/CAM Industry Service's *Electronic Design Automation Applications* binder.

Table 2 shows that Mentor Graphics remained the CAE software market share leader in 1989, although the company's share dips slightly when compared with 1988. Mentor's inability to gain market share is indicative of the inroads made by the following CAE tool suppliers:

- Cadence, which acquired Gateway Design Automation, experienced very strong growth at Mentor's expense; Gateway's success can be attributed to the widespread acceptance of its logic simulators and the accompanying Verilog hardware description language.
- Viewlogic, which increased its revenue by nearly 80 percent in 1988, derived its success from the user friendliness of its products, support of both the PC and workstation platforms, and the affordability of its software products.
- Synopsys, which increased its sales from less than $1 million in 1988 to approximately $10 million in 1989, experienced growth as a result of its strong synthesis products and the limited competition it faced in the marketplace.
- Valid Logic, which increased its CAE market share several percentage points in 1989, can attribute its success to the factors outlined in the previous discussion of the company.

As Table 2 indicates, both Racal-Redac and Dazix lost market share. Racal's drop was primarily due to the severe turmoil that its CAE division (formerly HHB Systems) experienced in 1989. HHB Systems was purchased by Dazix in 1988 (as part of Cadnetix) and then sold in May 1989 to Racal-Redac.

TABLE 2
Worldwide CAE Software Market Share Scorecard

Company	1988 Percentage	1989 Percentage
Mentor Graphics[1]	21.6	20.3
Valid Logic Systems	8.6	12.1
Dazix	11.4	9.3
Cadence Design Systems	3.4	6.8
Racal-Redac	4.0	3.1
Others	51.0	48.4
Total	100.0	100.0

Note: All percentages are based on revenue share.
[1]Does not include market share from Silicon Compiler Systems, which was approximately 1.7 percent in 1988 and 1989
Source: Dataquest (November 1990)

Worldwide 1989 PCB Layout Software Market Share

Table 3 provides a comparison between 1988 and 1989 percentages of the PCB layout software market share captured by the top five EDA vendors. A complete listing of all vendors can be found in the CAD/CAM Industry Service's *Electronic Design Automation Applications* binder.

As Table 3 shows, Racal-Redac continued to occupy the top position in the PCB layout market in 1989, but the company's market share remained virtually flat. Meanwhile, Mentor, Zuken, and Valid each improved its market share. Dazix's PCB layout business, on the other hand, suffered as a result of the company's financial problems.

In order for Racal-Redac to maintain its leadership position, the company will have to gain a greater position in the North American market while preserving its existing customer base in Europe. In addition, now that all of the major PCB layout vendors, as well as Cadence, have set their sights on Europe, Racal-Redac will have to be more aggressive in its effort to capture new business in Europe. Racal-Redac holds a solid position in the Japanese market and, in fact, is establishing an R&D center in Japan.

Meanwhile, Zuken, which has sold its products almost exclusively in Japan and is the market share leader there, is preparing to move into both the North American and European markets, as well as to expand more aggressively into other parts of Asia. Zuken's strength derives from the fact that its products are tailored for analog PCB boards, which are used extensively in the consumer electronics market.

Both Valid and Mentor were able to increase their market shares by capitalizing on their full-line supplier status, the strength of their PCB layout tools, and the integration of their PCB layout systems with their CAE tools. Some of their gains came at the expense of Dazix, as both companies were able to penetrate accounts that formerly were the exclusive territory of Dazix (i.e., Cadnetix).

Worldwide 1989 IC Layout Software Market Share

Table 4 provides a comparison between 1988 and 1989 percentages of the IC layout software market share captured by the top five EDA vendors. A complete listing of all vendors can be found in the CAD/CAM Industry Service's *Electronic Design Automation Applications* binder.

Table 4 illustrates the firm grip that Cadence had on the IC layout market in 1989. The company's 44.2 percent market share in 1989 represents a 16.6 percent increase over 1988. Meanwhile, Mentor Graphics moved into the number two position in early 1990 via its purchase of Silicon Compiler Systems. The combined revenue of the two companies gave Mentor Graphics 23.0 percent of the 1989 market, which is a 1.0 percent increase over 1988 (consolidating the 1988 IC layout revenue of the two companies).

Both Seiko Instruments and Valid Logic picked up some ground in 1989, but each faces major challenges over the next few years. For example, Seiko is in the midst of sorting out its future relationship with Dazix. (Seiko is Dazix's distributor in Japan.) Seiko also faces stiff competition from both Cadence and Mentor, not only in

TABLE 3
1989 Worldwide PCB Layout Software Market Share Scorecard

Company	1988 Percentage	1989 Percentage
Racal-Redac	15.8	15.9
Mentor Graphics	8.3	13.2
Zuken	6.2	8.9
Valid Logic Systems	2.5	6.3
Dazix	7.6	4.9
Others	60.6	49.2
Total	100.0	100.0

Note: All percentages are based on revenue share.
Source: Dataquest (November 1990)

TABLE 4
Worldwide IC Layout Software Market Share Scorecard

Company	1988 Percentage	1989 Percentage
Cadence Design Systems	28.8	44.2
Silicon Compiler Systems	13.8	13.3
Seiko Instruments	10.0	11.1
Mentor Graphics	8.2	9.6
Valid Logic Systems	2.3	6.3
Others	36.9	15.5
Total	100.0	100.0

Note: All percentages are based on revenue share.
Source: Dataquest (November 1990)

Japan, but also in North America and Europe, as Seiko has yet to mount any significant effort to penetrate these markets.

Similarly, Valid's greatest challenge over the next few years will be to defend its installed base—most of which was acquired through Valid's acquisition of GE/Calma's IC layout business—against the attacks mounted by Cadence, Mentor, and Seiko. In an effort to create a more defensible position, Valid has been steadily introducing products aimed at demonstrating the company's commitment to the business, as well as providing technology that is competitive in the industry.

EDA TRENDS AND FUTURE DIRECTIONS

Forces Driving the CAE Market

Table 5 summarizes Dataquest's CAE market forecast for software, hardware, and service.

Forces driving the CAE market to purchase EDA products include the following:

- The need to reduce the number of design iterations and, hence, improve time to market
- The desire to improve design quality (i.e., performance, functionality, reliability)
- The desire to perform more architectural exploration
- The need to improve design productivity, so that more products can be offered to the market
- The need to enhance integration of design, layout, and manufacturing

Dataquest believes that the following CAE products, technologies, and factors will fuel CAE market growth:

- Faster and more accurate verification tools (simulation and timing)
- Improved logic synthesis
- More effective design entry systems
- Model development systems
- Test automation (i.e., test logic synthesis, ATVG, etc.)
- Concurrent engineering environments
- System-level design tools (e.g., those that enable h/w-s/w trade-off analysis, architectural analysis, etc.)
- Integration of computer-aided software engineering (CASE) with CAE
- Improved workstation performance

Forces Driving the PCB Layout Market

Table 6 summarizes the projected growth of the PCB layout market in terms of software, hardware, and service.

Forces driving the PCB layout market and the need for new layout systems include the following:

- New packaging technologies (e.g., SMDs, multichip modules, etc.)
- Higher system clock frequencies
- Tighter integration between design and layout

- Systems manufacturers bringing layout responsibilities in-house
- Advances in automatic placement and routing technology
- Increasing PCB complexity

Forces Driving the IC Layout Market

Table 7 summarizes the projected growth of the IC layout market in terms of software, hardware, and service.

Forces driving the IC layout market and the need for IC layout design tools include the following:

- Stability in the IC CAD industry (i.e., the industry becoming highly concentrated)
- Pent-up demand for next-generation IC design tools (e.g., module development tools, three-layer metal routers, layout synthesis, etc.)
- An increasing percentage of the ASIC design market performing back-end ASIC design (i.e., floorplanning, placement and routing, design verification, etc.)

TABLE 5
Projected CAE Market Growth (Millions of Dollars)

	1989	1990	1991	1992	1993	1994	CAGR (%) 1989-1994
Software	576	708	908	1,146	1,374	1,681	24
Hardware	727	833	947	1,057	1,165	1,295	12
Service	222	263	322	391	453	539	20
Total	1,525	1,802	2,177	2,594	2,992	3,515	18

Source: Dataquest (November 1990)

TABLE 6
Projected PCB Layout Market Growth (Millions of Dollars)

	1989	1990	1991	1992	1993	1994	CAGR (%) 1989-1994
Software	313	344	410	486	564	662	16
Hardware	533	601	651	734	828	934	12
Service	152	170	194	228	265	309	15
Total	998	1,115	1,255	1,448	1,657	1,905	14

Source: Dataquest (November 1990)

TABLE 7
Projected IC Layout Market Growth (Millions of Dollars)

	1989	1990	1991	1992	1993	1994	CAGR (%) 1989-1994
Software	171	225	290	354	425	521	25
Hardware	148	160	177	190	205	229	9
Service	62	75	90	105	122	146	19
Total	381	460	557	649	752	896	19

Source: Dataquest (November 1990)

IMPENDING STRUCTURAL CHANGES IN THE EDA INDUSTRY

Consolidation

Dataquest believes that the EDA industry will continue to undergo significant structural changes over the next five years. For example, consolidation, which has been a hallmark of the EDA industry for the last several years, will continue. Indeed, an average of nearly one merger or acquisition per month has occurred over the past four years. Table 8 illustrates the impact that these mergers and acquisitions have had on industry concentration.

From Table 8, it can also be seen that the EDA industry remains highly fragmented as the top ten companies have captured only 64 percent of the market in 1990. The result of such fragmentation is that the industry will continue to experience consolidation via mergers, acquisitions, and shakeout.

New Players Poised for Entry

Dataquest expects an increasing number of niche product suppliers to enter the market over the next few years. One reason will be the trend toward open systems and standards, both of which lower the barriers to entry. We also expect large systems manufacturers to begin commercializing in-house EDA tools. Indeed, this has already begun (e.g., Texas Instruments, NTT, Dassault Electronique, Siemens). We also expect an increasing number of niche suppliers to spin off from large EDA companies such as Cadence, Dazix, Mentor Graphics, Valid Logic, and Racal-Redac.

A Shift in Bargaining Power

Another significant structural change occurring in the EDA industry is the shift in bargaining power between EDA customers and EDA suppliers. In short, tools developed in-house are rapidly losing ground to commercial tools in terms of functionality, user interface capabilities, integration with other tools, and performance. This situation is the result of the huge research and development investments being made by merchant tool suppliers. Dataquest estimates that the combined R&D investment of merchant EDA companies in 1989 was approximately $300 million.

As a result of the improving capabilities of the merchant tools, the market has little choice but to purchase these commercial products. We believe that most large electronics manufacturers will continue to develop tools in-house, but the focus will be on developing tools and technologies unavailable on the open market.

TABLE 8
Market Share Captured by the Top Ten EDA Vendors—1986-1990

Year	Percentage
1986	50.0
1987	50.0
1988	55.2
1989	60.9
1990 (Estimated)	64.0

Source: Dataquest (November 1990)

Changing Distribution Channels

Dataquest believes that the distribution channels used by EDA companies, which were predominantly direct in the 1970s and 1980s, will include more use of the OEM channel. We believe that large EDA companies, as well as ASIC suppliers, will become OEM purchasers of niche products to help round out their product lines.

For OEM suppliers, including both large systems manufacturers and small niche product vendors, ASIC vendors, large EDA vendors provide a much-needed distribution channel. Indeed, this scenario has already begun to take place. For example, Racal-Redac Japan recently became an OEM purchaser of NTT's ADLINES transmission line simulator. Similarly, numerous OEM deals have been struck or are in the works between large EDA vendors and small niche suppliers.

EDA MARKET OPPORTUNITIES

Dataquest believes that a significant market opportunity exists for the following kinds of products and technologies:

- Tools supporting top-down design
  - HDL-based design entry systems
  - Model debugging tools
  - Mixed-level logic simulators
  - Logic synthesis systems

  - Test logic synthesis products
  - Automatic test vector generation systems
- System-level EDA design tools
  - Tools enabling hardware/software trade-off analysis
  - Tools enabling full-system verification (e.g., of software development environments with EDA)
- Tools that facilitate design partitioning, such that the design team can optimally partition a design to meet such constraints as performance, size, cost, reliability, testability, and manufacturability
- Tools that enable implementation trade-off analyses, such that the design team can make the optimal selection of ASICs, field programmable gate arrays (FPGAs), and programmable logic devices (PLDs)
- Tools supporting analog design automation
- EDA products supporting the design of high-speed electronic systems such as transmission line simulators and static timing verifiers
- Tools supporting the design of digital signal processing systems

DATAQUEST PERSPECTIVE

Dataquest believes that if the 1980s can be thought of as the EDA industry's consolidation phase, the 1990s will be a period of shakeout with several major players exiting the business or scaling down operations. We believe that the EDA industry is maturing but is still far from complete maturity—plenty of growth remains. And finally, we anticipate that the rules that guided EDA suppliers in the 1980s will be dramatically different in the 1990s, which will mean that suppliers will be forced to adopt new business strategies.

Ron Collett

Dataquest
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Research Newsletter

SUBMICRON PROCESS GEOMETRIES POSE NEW CHALLENGES FOR EDA VENDORS

SUMMARY

For electronic design automation (EDA) tool vendors, providing a full range of ASIC design kits is a key element to winning in the electronic systems design marketplace. It is a competitive weapon. The more ASIC libraries that an EDA vendor supports, the greater the choice of ASIC foundries the EDA vendor can offer its customer base. Indeed, ASIC libraries often are a critical benchmark used by the market when comparing EDA vendors. But as process geometries routinely fall below 1 micron, the support issues become more challenging for both EDA and ASIC vendors. Remaining competitive in the ASIC design market demands that EDA suppliers provide highly accurate models in their submicron ASIC design kits. This newsletter explores the following:

- The number of ASIC libraries supported by EDA vendors
- Third-party ASIC vendor library support
- The impact of submicron process geometries on EDA vendors
- The challenges facing EDA vendors in the ASIC library wars

ASIC DESIGN KIT WARS

Tables 1 and 2 provide a snapshot of the current ASIC library wars. Table 1 summarizes the number of ASIC libraries available to customers that use the EDA tools from these companies.

Table 2 lists the ASIC vendors with libraries supported on EDA tools from Cadence, Dazix, Mentor Graphics, Racal-Redac, Synopsys, Valid Logic, and Viewlogic.

Since the beginning of the ASIC revolution in the early 1980s, much of the success of the leading CAE vendors can be attributed to providing tool suites that support ASIC design for a myriad of ASIC foundries. In fact, this support was the primary force behind the rapid growth of Dazix, Mentor, and Valid in their early days. The EDA systems from these companies became the de facto standards for ASIC design, to the exclusion of most other competitors. Similarly, in the early days ASIC vendors recorded tremendous competitive advantage when they provided the customer with advanced EDA tools developed internally. However, over time, the market trends shifted in favor of standards, open systems, and nonproprietary tools.

The challenge for EDA vendors has always been to entice ASIC manufacturers to support their

TABLE 1
Number of ASIC Libraries Supported

Company	Number of ASIC Libraries
Cadence*	76
Dazix	169
Mentor Graphics*	200
Racal-Redac	53
Synopsys*	53
Valid Logic Systems*	139
Viewlogic Systems	50

*A small fraction of the company's library count is designated as being under development and becoming available during 1990.
Notes: PLD devices not included in these data. Approximately 40 percent of Mentor's library count comprises libraries that the company classifies as "Others." These kits have not been formally submitted to Mentor.
Source: Company Literature, Dataquest (September 1990)

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TABLE 2
Third-Party ASIC Vendor Library Support

	Cadence*	Dazix	Mentor Graphics*	Racal-Redac	Synopsys*	Valid Logic*	Viewlogic
ABB Hafo		X					
AEG			X				
AMCC	X	X	X			X	
Atmel					X		
AT&T	X		X		X	X	X
Austria Mikro Systeme			X				
California Micro Devices			X				
Custom Silicon			X				
DOD MOSIS					X		
Ericsson Components		X					
ES2			X				
Exar			X				
Fujitsu	X	X	X	X	X	X	X
GigaBit Logic		X	X				
Goldstar		X	X				
Gould Semiconductor		X	X	X		X	X
Harris		X	X	X		X	
Hitachi	X	X	X	X	X	X	X
Honeywell		X					
Hughes			X				
Intel		X	X				
International Microcircuits		X	X				
LSI Logic	X	X	X	X	X	X	X
Marconi Electronic Devices		X	X				
Matra Harris		X	X			X	
Micro Linear		X					X
Mietec		X					
Mikron			X				
Mitsubishi	X	X	X		X	X	X
Motorola	X	X	X	X	X	X	
National Semiconductor	X	X	X	X	X	X	X
NCR	X	X	X	X	X	X	X

(Continued)

TABLE 2 (Continued)
Third-Party ASIC Vendor Library Support

	Cadence*	Dazix	Mentor Graphics*	Racal-Redac	Synopsys*	Valid Logic*	Viewlogic
NEC	X	X	X	X	X	X	X
Oki Semiconductor	X	X	X	X	X	X	X
Panasonic		X	X				
Philips/Signetics			X	X	X	X	
Plessey		X	X			X	X
Qudos			X				
Raytheon Semiconductor			X				
Ricoh		X	X				
Rockwell			X				
Samsung		X	X		X		X
Sanyo		X					
Seiko Epson/SMOS	X	X			X	X	X
SGS-Thomson	X	X	X	X	X	X	X
Siemens	X	X	X		X	X	
Sierra Semiconductor		X	X				
Silicon Systems			X				
Sipex		X					
Sony		X	X				
Standard Microsystems (SMC)		X		X			X
Texas Instruments	X	X	X	X	X	X	
Toshiba	X	X	X	X	X	X	X
TriQuint Semiconductor		X	X				
United Microelectronics Corp.		X					
United Silicon Structures (US2)			X				
USC/Information Sciences Institute			X				
UTMC	X	X	X		X	X	
Vertex Semiconductors			X		X		
Vitesse	X	X	X		X	X	
VLSI Technology	X	X	X	X	X	X	X
VTC			X				

*A small fraction of the company's library count is designated as being under development and will become available during 1990.
Notes: PLD devices are not included in these data. Approximately 40 percent of Mentor's library count comprises libraries that the company classifies as "Others." These kits have not been formally submitted to Mentor.
Source: Company Literature, Dataquest (September 1990)

tools (e.g., porting the library to the EDA vendor's design entry system and simulator and updating the software when either the fabrication process changes or the EDA tools change). But ASIC manufacturers will support only those third-party EDA vendor tools that either have gained acceptance in the marketplace or show tremendous promise toward gaining such acceptance. In short, ASIC vendors view merchant EDA tools as vehicles for leveraging and selling their silicon to the marketplace. EDA vendors, on the other hand, view ASIC libraries as value-added technology for their EDA product line, to be used as leverage in the sale of their EDA tools. In the absence of ASIC vendor support, EDA vendors are forced to absorb the development and support costs associated with offering ASIC libraries.

Although developing ASIC design kits has not required much technological innovation, it nonetheless demands attention to detail and continuous maintenance by trained engineers. Thus, for both EDA tool suppliers and ASIC vendors, the issue over whether or not to support each other's tools and processes, respectively, depends on the development and support costs versus the return on investment. In the past, the data needed to develop an ASIC library have been modest. Moreover, third-party models have not had to match the ASIC's characteristics perfectly because enough margin existed within the ASIC's timing performance to rely on good approximations of parameters. For example, piecewise linear modeling could be used to approximate the timing delays across a broad fanout range. (Of course, the ASIC foundry's internal verification tools and models, which are used to simulate a design just prior to layout, exactly match the characteristics of the devices produced by the fabrication process.)

Yet as fabrication process geometries shrink to the submicron range, what once were insignificant delays that could be ignored by third-party models become critical. Examples of parameters that potentially have a far greater impact on the design of submicron ASICs include fanout loading, slew rate, and pin-to-pin interconnect delays. In order for designers to be able to rely on ASIC design kits, the models must closely mimic characteristics of the electronic devices being produced by the fabrication process.

DATAQUEST CONCLUSIONS

Dataquest believes that a major challenge for EDA vendors over the next two years will be to provide simulation and modeling technology that enables ASIC manufacturers to easily incorporate process-specific information into the simulation models. EDA vendors also must be mindful of the fact that although ASIC vendors will clearly gravitate toward supporting the most popular third-party EDA systems, they also will favor porting their libraries first to those popular EDA systems that require the least effort. For EDA vendors, being among the first to offer a particular ASIC library can yield a significant competitive edge.

ASIC vendors that market proprietary tool sets may be tempted to delay offering updated simulation models to third-party EDA suppliers in an effort to promote their own tool sales. However, such a strategy would be shortsighted. Dataquest believes that, in the long term, it would behoove ASIC vendors to support third-party EDA suppliers with updated libraries as soon as they become available. As ASIC densities increase, the ability of ASIC vendors to develop and support leading-edge tools becomes increasingly difficult. Instead of devoting massive resources to such development in the face of focused third-party EDA suppliers, ASIC vendors are likely to realize greater success if they concentrate on more specialized software tools that continue to provide value-added benefits that are unavailable through other sources.

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Research *Bulletin*

SYNOPSYS AND SIEMENS EXPAND THEIR EDA OFFERINGS WHILE HP CONTRACTS

SUMMARY

Merger and acquisition activity, which has been the hallmark of the electronic design automation (EDA) industry over the past few years, appears to continue apace as evidenced by the latest developments. Synopsys Inc. recently agreed to acquire Zycad's VHDL software simulation business, and Siemens announced its purchase of Calay Systems GmbH. Under terms of the agreement between Synopsys and Zycad, Synopsys will pay $5 million in cash, an undisclosed amount in Synopsys securities, and future royalties for full rights to Zycad's System VHDL. Siemens has disclosed plans to form a new EDA business unit by combining its in-house CAD capability with the PCB layout expertise of Calay Systems.

Meanwhile, Hewlett-Packard has decided to phase out development of the company's proprietary EDA software. Over the next two years, HP's Electronic Design Division (EDD) will make the transition away from its proprietary EDA software, but HP will continue to support the EDD products for five years thereafter.

DATAQUEST ANALYSIS

One of the clear implications arising from the merger and acquisition activity over the past few years is that the EDA market of the 1990s will be quite different from that of the 1980s. Success in the early 1990s demands that vendors provide open systems and support standards. The myriad of standards that vendors will be forced to support continued to grow in 1989, with VHDL topping the list.

Synopsys' acquisition clearly is part of the company's strategy to establish a strong foothold in the emerging VHDL-based top-down design market. Indeed, Dataquest believes that the acquisition marks a turning point in Synopsys' evolution where "Synopsys the synthesis company" is now "Synopsys the CAE company." Synopsys, which specializes in logic synthesis tools, experienced tremendous growth in 1989, with company revenue reaching approximately $10 million. The company expects to record revenue of between $20 million and $30 million in 1990. Although not immediately imminent, the company is likely to attempt further expansion into the broader EDA market if it successfully penetrates the simulation market.

Synopsys maintains that the company's commitment to being an integratable technology with a range of CAE vendors will not be adversely impacted by this deal. Zycad assessed its stance vis-à-vis the sale as a move that will allow the company to concentrate on its core hardware accelerator business. Also, the financial compensation received for the business presumably represents a welcome infusion of cash.

Meanwhile in West Germany, Siemens apparently took aim at the US-dominated EDA industry. According to Dataquest's market share estimates, Calay Systems' PCB layout software revenue of $14.2 million in 1989 made it the seventh largest company in its field, with its competition coming from such major EDA vendors as Mentor Graphics, Racal-Redac, and Valid Logic. If Siemens plans to set itself up as a major European full-line EDA supplier, it faces several major challenges, including the development of framework technology, further expansion of its product portfolio, and establishment of a robust EDA distribution channel. It also must position itself more aggressively as an EDA supplier in the marketplace.

HP rationalized its move by citing the momentum of the open systems movement in the industry, as well as the company's belief that this decision will allow it to focus on its workstation and mechanical CAD businesses. Dataquest believes that the company questioned a strategy of continuing to commit the substantial R&D resources needed to maintain a competitive and viable product in the EDA marketplace. In 1987, 1988, and 1989, HP's EDA software revenue remained constant at approximately $20 million, but its market share dropped from 2.6 percent to 1.8 percent during this time period. Furthermore, the company may have recognized an inherent conflict between its workstation business and its tools business. The company's orderly retreat from the EDA application software market provides its strong Japanese client base (approximately 1,000 licenses) with adequate notice to migrate smoothly from HP's EDA products to those of other vendors. It appears unlikely at this point that HP would sell the EDD unit to another EDA vendor.

TABLE 1
EDA Industry Concentration

Year	Market Share
1986	50.0 percent
1987	50.0 percent
1988	55.2 percent
1989	60.9 percent

Source: Dataquest (September 1990)

DATAQUEST CONCLUSIONS

Dataquest believes that the recent events in the EDA industry exemplify the continuing turmoil and volatility in the EDA industry. Table 1 shows the market share captured by the top ten EDA vendors over the past four years.

The consolidation and shakeout that has been occurring this year is likely to further increase the industry's concentration.

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Research Newsletter

IC DESIGN AUTOMATION MARKET: WHERE'S THE GROWTH?

SUMMARY

Dataquest's research indicates that revenue in the IC design automation (ICDA) software market reached $172.3 million in 1989, a 6.4 percent increase over 1988's $162.0 million figure. Despite the lackluster performance, we believe that the ICDA market is not in the state of decline that the numbers would appear to suggest. Rather, our analyses conclude that once the industry weathers the current period of transition and turmoil, the market will enter a strong period of recovery and growth and will experience a compound annual growth rate (CAGR) of 23.8 percent (software only) over the next 5 years. We believe that this transition period, which has been under way for the past two years, will wind down over the next 6 to 12 months. This newsletter discusses the following:

- 1989 market share data
- ICDA market forces, trends, and issues
- ICDA market forecast
- ICDA submarket analysis, trends, and issues

ICDA MARKET AND INDUSTRY OVERVIEW

Over the past decade, the ICDA industry has gone through four stages of evolution. The industry from the late 1970s to early 1980s can be characterized as an oligopoly, dominated by a handful of players such as Calma and Applicon. By the mid-1980s, the major players were running out of steam and were unable to adapt to the market's demand for new technology. A myriad of companies sprung up to fill the growing void. Indeed, no less than 20 companies were competing in the ICDA market by 1986. (Examples include SDA, ECAD, Silvar-Lisco, Seiko Instruments, Daisy, Mentor, Valid, Scientific Calculations, Caeco, VLSI Technology, Racal-Redac, Silicon Compiler Systems, Tangent, Silicon Design Labs, Seattle Silicon, and Control Data.) The result was a highly fragmented industry, which the market was both unable and unwilling to support. What followed was the industry's inevitable shakeout and consolidation period, which took place between 1985 and 1990.

Today's ICDA industry once again is an oligopoly, with Cadence Design Systems and Mentor Graphics (combined with Silicon Compiler Systems) together capturing 73 percent of the 1989 ICDA software market. Indeed, the top five companies held over 94 percent of the ICDA software market in 1989.

Table 1 illustrates Cadence's firm grip on the ICDA software market. The company's 44.2 percent market share in 1989 represents a 16.6 percent increase over 1988. Meanwhile, Mentor Graphics moved into the number two position in early 1990 via its purchase of Silicon Compiler Systems. The combined revenue of the two companies gave Mentor Graphics 23 percent of the 1989 market, which is a 1 percent increase over 1988 (consolidating the 1988 ICDA revenue of the two firms).

General ICDA Market Forces

Dataquest believes that the ICDA market is poised for strong growth. Supporting this growth will be a range of basic forces acting in concert. A series of additional forces is also acting on the individual submarkets comprising ICDA. These are detailed under the section entitled "ICDA Software Submarket Analysis."

Dataquest's forecast for ICDA software, hardware, and service, found in Table 2, shows that the ICDA market is expected to grow at a CAGR of

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TABLE 1
1989 ICDA Market Share

	Revenue ($M)			Market Share (%)		
	Total	Hardware	Software	Total	Hardware	Software
Cadence	88.0	0	76.2	22.8	0	44.2
Mentor/SCS	69.9	12.7	39.6	18.1	8.9	23.0
Seiko	38.4	5.8	19.1	9.9	4.1	11.1
Valid	17.4	4.2	10.8	4.5	2.9	6.3
VLSI Technology	8.5	0.5	6.7	2.2	0.4	3.9
Silvar-Lisco	7.5	0	4.9	1.9	0	2.8
ES2	7.3	1.8	5.5	1.9	1.3	2.8
Others	149.2	117.8	9.5	38.7	82.4	5.9
Total	386.2	142.8	172.3	100	100	100

Note: "Others" includes hardware-only vendors such as Sun, DEC, HP, and IBM.
Source: Dataquest (September 1990)

TABLE 2
ICDA Market Forecast (Millions of Dollars)

	1989	1990	1991	1992	1993	1994	CAGR (%) (1989-1994)
Software	172	219	280	342	409	501	23.8
Hardware	160	159	177	193	210	236	8.1
Service	65	70	84	98	114	135	15.7
Total	397	448	541	633	733	872	17.0

Source: Dataquest (September 1990)

17 percent from 1989 through 1994. The following forces will support strong ICDA growth.

Industry Stability

During the period from 1987 to 1990, the ICDA industry experienced enormous volatility, with an array of mergers and acquisitions precipitated by the industry's fragmentation. Dataquest believes that this fragmentation contributed heavily to the industry's slow growth in 1988 and 1989. Indeed, uncertainty and doubt surrounded the viability of many fledgling commercial ICDA companies, as well as their technologies. Not suprising, many buyers were reluctant to purchase large quantities of products. Moreover, as a by-product of acquiring and merging with other companies, many ICDA suppliers were sidetracked by the challenges of absorbing other companies (e.g., integration of product lines, distribution channels, facilities, and corporate cultures) and thus were forced to divert resources from product development, marketing, and sales.

Just as fragmentation and instability created ICDA market uncertainty, Dataquest anticipates that the ICDA industry's increased concentration and stability will contribute heavily to market growth over the next five years. This conclusion stems from our belief that the new oligopoly will instill confidence in the market and create an attractive climate for the market to buy commercial ICDA tools.

Pent-Up Demand

Dataquest's research indicates significant pent-up demand for next-generation ICDA tools, which will further fuel industry growth over the

next five years. Examples of tools and technologies in high demand include symbolic editing, compaction, floor planning, layout synthesis, three- and four-layer metal automatic placement and routing tools, advanced polygon editors, high-speed design verification tools, and module generation tools. Much existing internally developed ICDA technology is being rapidly surpassed by the capabilities of the commercial tools. And many chip suppliers will be unable to afford the development costs to develop these capabilities internally. Thus, many will have no choice but to turn to merchant ICDA products.

Workstations, Frameworks, Open Systems, and Standards

Also playing a role in the ICDA market's future growth is the skyrocketing integer and floating point performance of the new generation of workstations. Workstations churning away at 15 to 30 mips and 3 to 4 mflops are fully capable of handling most of the compute-intensive ICDA tasks. Thus, it is no longer necessary to purchase a mainframe to perform tasks such as design verification, automatic layout, and circuit simulation.

Frameworks, open systems, and standards also will play a role in whetting the market's appetite for ICDA products. The ability to integrate point tools more easily into the emerging frameworks and open systems creates a powerful draw for many potential buyers. And this draw promises to accelerate as framework standards emerge.

ICDA SOFTWARE SUBMARKET ANALYSIS

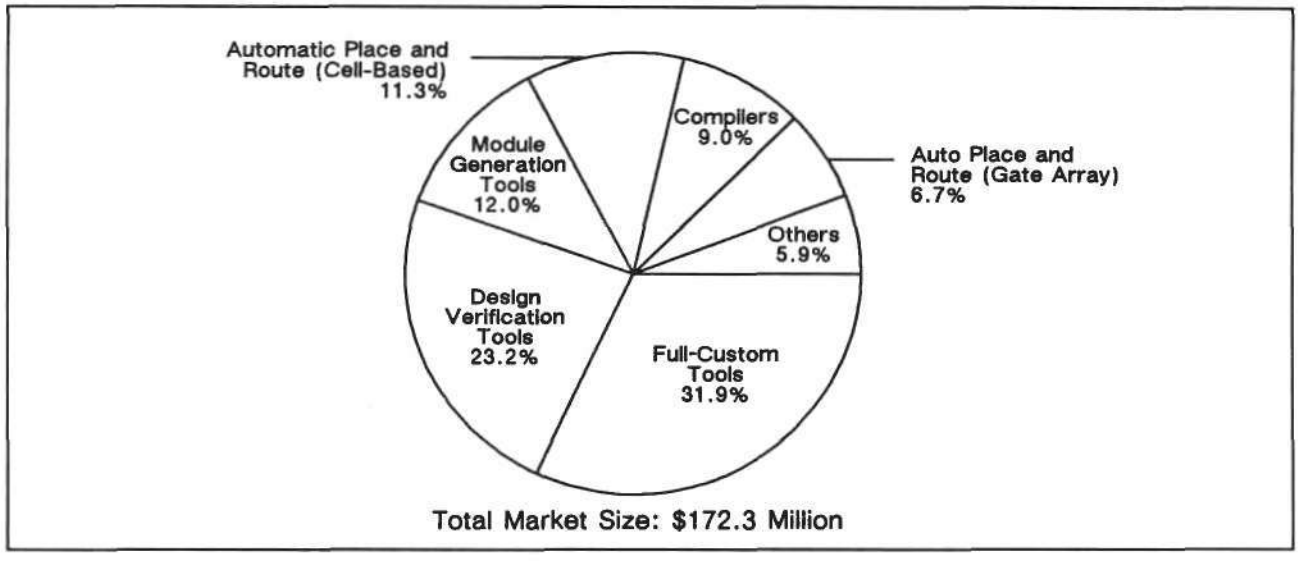
Figure 1 shows the breakdown of the various submarkets comprising the ICDA software market. Discussions of the submarkets follow.

Full-Custom IC Design Tools

With total sales of $55 million, full-custom IC design tools represented the largest segment of the 1989 ICDA software market. Products in this segment include polygon editors, symbolic editors, compaction tools, and floor planning systems. Although this market is highly penetrated with polygon editors, several thousand of these installed polygon editing systems are based on older technology such as Calma GDS II. Dataquest expects many of these seats to be replaced over the next few years by newer, more advanced polygon editors, as well as by symbolic editors and compaction tools.

Although cell-based and gate array design continue to replace the handcrafted full-custom approach, we believe that nearly all chip makers will still need polygon editors. These tools will be used to develop macrocell libraries, as well as to

FIGURE 1
1989 ICDA Software Market Breakdown



Source: Dataquest (September 1990)

make adjustments to the layout performed by the automatic placement and routing systems. And although we anticipate that polygon editing will be done less and less over the next five years, we expect symbolic editing and compaction to both replace and complement polygon editing as the technology improves.

Dataquest believes that floor planning also will find more widespread use over the next few years, as systems manufacturers designing ASICs will want to develop the chip's floor plan to ensure that timing performance is optimized. Systems designers developing ASICs represent a new market for ICDA vendors, as these engineers traditionally have not been directly involved in ASIC layout. This task has been the responsibility of the ASIC manufacturer. We believe that the shift in floor planning responsibility will be a significant trend in ASIC design over the next few years. In fact, we expect the majority of ASIC designers to perform floor planning by 1995. Dataquest forecasts that the full-custom ICDA tool market will experience a CAGR of 20 percent from 1989 through 1994.

In addition to the traditional market for full-custom ICDA tools (i.e., merchant and captive semiconductor manufacturers, including fabless semiconductor manufacturers), leading-edge systems manufacturers also will begin purchasing full-custom ICDA tools. This trend (discussed more thoroughly in the next section) also will help fuel growth in this market segment.

Automatic Placement and Routing

Dataquest expects the market for automatic placement and routing to experience very robust expansion over the next five years, growing at a compounded annual rate of 36 percent. Figure 1 shows that this segment (gate array and cell-based) represented 18 percent of the overall ICDA software market in 1989. Fueling this sector's growth is the fact that both ASIC and standard IC manufacturers will be forced to adopt advanced layout technologies to meet the challenges of laying out a rising number of increasingly complex semicustom chips. For instance, Dataquest forecasts that by 1993 over 70 percent of gate array design starts will be over 10,000 gates. Examples of new ICDA technologies include three- and four-layer metal placement and routing systems, layout synthesis systems, and advanced compaction tools.

As with the floor planning trend, we expect an increasing number of leading-edge systems manufacturers to become more involved in the layout of their ASICs. In the past, very few ASIC customers performed layout. Indeed, this layout has been the almost exclusive territory of the ASIC foundry. We believe that this trend will be driven by the following forces:

- Systems houses building high-speed systems will wish to get actual, albeit preliminary, interconnect delay information as early as possible in the design cycle, as well as on a continuous basis throughout the design cycle. Performing the layout in-house enables and facilitates this feedback of delay data to the ASIC design team.
- As the profit margins on electronic hardware narrow, electronic systems manufacturers will want to perform the layout as a means to reduce nonrecurring engineering (NRE) costs levied by the ASIC manufacturers and, thus, combat profit margin erosion. Similarly, costs can be lowered by reducing die size; gaining control of the layout process allows the ASIC design team to exercise greater control over the final die size.
- Systems houses will want to ensure that their products get to market on time, and taking control over the *complete* design cycle (assuming the systems house has brought in competent layout expertise) will help the cause.
- Systems houses want to maximize chip performance, and performing the layout internally allows them to spend as much time as they wish on improving timing performance.

As the systems design market opens up for ICDA tool suppliers, a question arises as to which camp will supply the layout tools to the electronic systems manufacturers: ASIC manufacturers or traditional electronic design automation (EDA) vendors. Dataquest believes that the answer is both. The following are possible scenarios as to how this emerging market will be served:

- ASIC vendors will become OEM purchasers of the ICDA tools developed by merchant ICDA vendors. (Cadence, for example, has established this model via its Silicon Alliance Access program, which allows ASIC suppliers to customize and resell Cadence's tools.)
- ASIC vendors will become more aggressive in marketing their in-house developed ICDA tools directly to the ASIC design market.
- ASIC vendors will certify and become reference sellers of the ICDA tools developed and sold directly by merchant ICDA suppliers.

- Merchant ICDA vendors will become OEM purchasers of the in-house ICDA tools developed by ASIC manufacturers.
- Merchant ICDA vendors will become reference sellers of the in-house ICDA tools developed by ASIC manufacturers.

In order for EDA vendors to be successful selling their own ICDA tools, they will be required to get ASIC vendors (that they support) to endorse, or at least certify, that the EDA vendor's tools are fully "compatible" with the ASIC foundry's fabrication process. Similarly, in order for ASIC vendors to be successful selling their proprietary, in-house developed products, they must integrate their internal tools into the frameworks of EDA vendors.

Providing layout tools to the ASIC design market is mutually beneficial for ASIC and ICDA vendors seeking to gain a greater degree of account control and lock out their respective competitors. However, Dataquest believes that ICDA and ASIC suppliers must work together very closely to successfully penetrate this emerging market and establish such account control.

Although Dataquest believes that the systems design market will gradually perform more ASIC layout responsibilities, there is a signficiant barrier that both ASIC vendors and EDA vendors must overcome: the market is loath to get "locked" into buying ASICs from a single supplier. (In fact, one reason the market is very enthusiastic about logic synthesis is because it offers a greater degree of foundry independence than has previously been possible.) Yet, making such a large investment in layout tools that support only a single foundry essentially locks the customer to the ASIC supplier. However, we believe that an increasing number of customers will be inclined to tie themselves to a single ASIC supplier, provided the supplier gives the customer preferential treatment (e.g., guaranteed supply, turnaround time, price). ASIC manufacturers, of course, will do this for strategically important customers.

An alternative for the customer would be to purchase foundry/process-independent layout tools (i.e., those that enable smooth process migration from one foundry to another). However, a *complete* turnkey environment that supports process migration and foundry independence is not yet available for the systems design market. Moreover, although ICDA vendors may be anxious to provide this capability to the market, most leading ASIC vendors will not be quick to disclose their fabrication process data in the form of a simple technology file, because foundry independence essentially vitiates account control by the ASIC vendor. Thus, it is not likely that this scenario will unfold to any great extent in the near term. However, over the next three to five years, we believe that market pressure will force ASIC manufacturers to support foundry independence.

Design Verification

With $40 million in sales, the design verification market was the second largest segment of the ICDA market in 1989. Dataquest expects the design verification market to experience continued growth as more systems manufacturers begin performing ASIC layout and new chip companies emerge (e.g., those developing application-specific standard ICs). Our forecast indicates that this market will exhibit a CAGR of 18 percent from 1989 through 1994.

Cadence's Dracula product line has enjoyed a near monopoly in the design verification market over the past five years. Mentor Graphics hopes to change this situation with its recently acquired Checkmate design verification system. Checkmate was acquired via Mentor's acquisition of Silicon Compiler Systems. Developed by Texas Instruments, Checkmate source code was purchased by Silicon Compiler Systems in November 1989. Mentor Graphics has stated publicly that it plans to employ an aggressive pricing strategy to attack Cadence's stronghold. Despite the prospect of dramatically lower pricing, we anticipate that displacing Dracula will be a formidable challenge for Mentor Graphics. Design verification is among the most critical steps in the chip design process, and injecting a change in tool technology is a risky proposition, as it could cause a severe perturbation in the design cycle.

Module Generation Tools and Compilers

With $36 million in sales, this market occupied approximately 21 percent of the overall ICDA market in 1989. We expect module generation tools to enjoy continued market success, with growth being fueled from several sources. For example, ASIC suppliers will attempt to strengthen their libraries to differentiate themselves from competitors. Offering the ASIC design market cell

libraries filled with module generators, or compilers, is one way to do this. Similarly, standard IC manufacturers (including fabless suppliers) will continue to feel market pressure to produce a greater variety of chips at a faster rate, and equipping internal chip design teams with module generators potentially yields significant design productivity improvement. Moreover, the distribution muscle of Mentor Graphics now behind the GDT module generation tool suite from Silicon Compiler Systems should help expand the market. Dataquest forecasts that the module generation tool market will grow at a CAGR of 17 percent over the next five years.

On the other hand, the cell compiler market (e.g., those from ASIC suppliers), which was $15 million in 1989, is not likely to experience any significant growth over the next five years (5 percent to 10 percent CAGR). Most ASIC manufacturers that offer compilers charge little, if anything at all, for their compilers. Instead, most bundle them with the library, which is often heavily discounted or given away at no charge. In addition, we believe that third parties selling compilers will continue to meet with only limited, if any, success because of stiff competition from ASIC suppliers.

DATAQUEST CONCLUSIONS

Dataquest believes that the ICDA market's relatively flat growth over the past two years is not an indicator of the future. The combination of strong pent-up demand, industry stability, workstation performance, and the trend toward open systems will act together to fuel healthy expansion over the next five years.

Ron Collett

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Research Newsletter

DAC 1990: EUROPE MOUNTS ITS EDA CHALLENGE

INTRODUCTION

A glance at the exhibitor list at this year's Design Automation Conference (DAC) in Orlando, Florida reveals nine European, or strongly European-related EDA vendors. Dataquest believes that the rise of European vendors could indicate a swing toward a greater European presence in worldwide EDA software production. The companies ranged from established multinationals to small start-ups; approximately half appeared for the first time. Application areas ranged from full-line EDA vendors to niche players. Moreover, the acquisition of Calay Systems by Siemens announced on July 31, 1990 further demonstrates the present level of activity in Europe. The "Europeans" at DAC are shown in Table 1.

DATAQUEST ANALYSIS

In 1989, Europe accounted for 28 percent of worldwide EDA market revenue. Dataquest forecasts that Europe's share will grow to 30 percent by 1994, exhibiting a revenue compound annual growth rate of 19 percent. Europe will maintain its position as number two to North America but will grow at a significantly faster rate (see Figure 1). Table 2 shows the 1989 EDA vendor market share for Europe.

A key question in connection with European vendors is whether European end users will favor them in preference to non-European vendors. Possible reasons for favoring European vendors include:

- Better support from locally-based companies
- Lower-cost products due to lack of import duty payable from non-EEC countries
- Nationalism
- Easy access to marketing and software development personnel

Let us consider these points in turn:

- The only occasions where small companies tend to provide better support is in the vicinity of the vendor's home city; this is not therefore a major consideration in most cases, especially when

TABLE 1
Europeans at DAC 1990

Company	Country	Product Area
Calay Systems	West Germany	Full-line EDA
Dassault Electronique	France	Synthesis
DOSIS GmbH	West Germany	Silicon cross compiler
formula GmbH	West Germany	Mac EDA applications
Plessey Semiconductors	United Kingdom	ASIC design tools
Racal-Redac	United Kingdom	Full-line EDA
Schlumberger CAD/CAM	US/France	CAE/CAD/packaging
Swiftlogic	United Kingdom	Post-layout simulation
Win Technology	France	Data/process manager

Source: Dataquest (August 1990)

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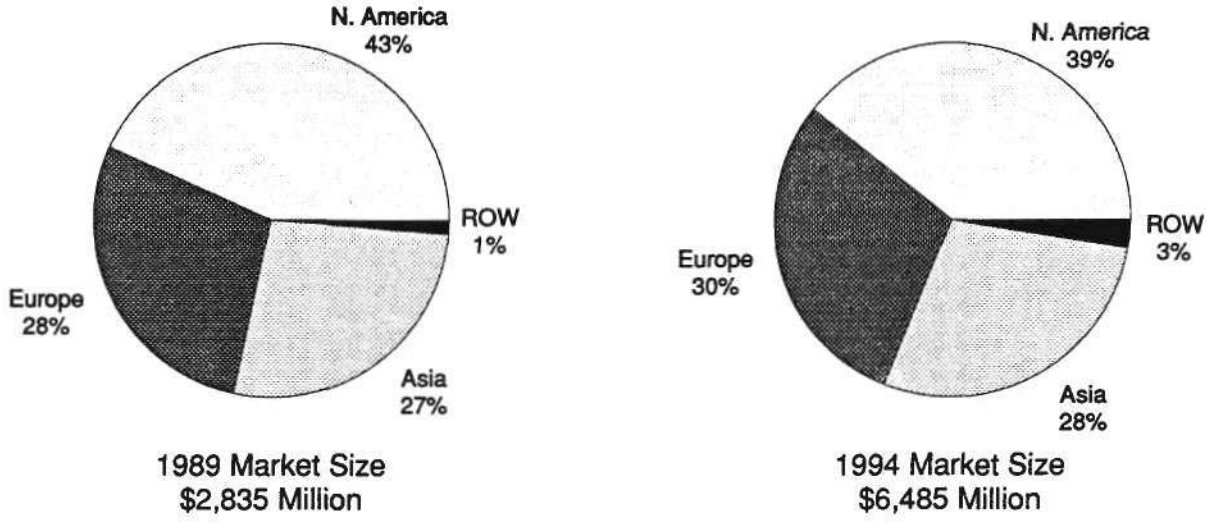
FIGURE 1
EDA Market by Region, 1989 and 1994



Source: Dataquest (August 1990)

compared with non-European full-line EDA vendors, with their comprehensive support networks.

- The effect of import duties is also relatively insignificant and can usually be absorbed by the larger vendors. In any event, price is often not a critical factor in the EDA buying decision.
- Nationalism can be a factor, but is often overstressed.
- Of much greater significance (and often mistaken for nationalism) is the perceived—and real—ability to influence the shape of the product through access to development personnel. This is a key factor. In view of this, we believe that European vendors can become successful, especially in the European marketplace, provided that they offer the right products with appropriate levels of customization available.

The financial resources, market presence and relative stability of the larger vendors reduces some of the risks for the customer. This is crucially important in EDA sales, indicating that smaller players need to form strategic partnerships with larger companies. Furthermore, the emergence of framework standards will remove many of the barriers to market entry.

VENDOR ANALYSIS

Calay Systems

Calay was aquired by AGIV Frankfurt in 1988, which integrated the company's US and European operations under a new Calay corporate headquarters near Frankfurt, Germany. However, on July 31 of this year, an agreement was reached with Siemens AG of Germany (revenue last year around $38 billion), whereby Siemens would acquire Calay at a price still to be determined. Siemens intends to develop and market Calay's products on a worldwide basis and will not use the tools purely for in-house design purposes. We believe Calay's PCB CAM tools to be attractive to Siemens, which is a highly manufacturing-oriented company. With Siemens' backing, Calay could be well-positioned to attack other full-line vendors (initially in Europe, where the company presently holds the number eight market share position in EDA software revenue).

At the show, Calay demonstrated the extended Prisma system comprising a suite of EDA tools in a recently integrated form. The tools include schematics capture, simulation (Saber and System HILO), the Framemaker documentation package, PCB layout, together with FOCUS post-processing and CAM applications (FOCUS was previously an entirely separate CAM-station product marketed as Calay ECAM). A key feature of Prisma is its common design database which permits real-time

TABLE 2
European 1989 EDA Market Shares

Company	Total Revenue ($M)	HW Revenue ($M)	SW Revenue ($M)	Work-stations Shipped	Total Revenue	HW Revenue	SW Revenue	Work-stations Shipped
Mentor Graphics	103.7	30.1	51.0	1,372	12.9%	8.0%	18.8%	5.5%
Digital	90.1	67.0	0.0	768	11.2%	17.7%	0.0%	3.1%
Hewlett-Packard	83.0	58.5	4.9	5,703	10.3%	15.5%	1.8%	23.0%
Dazix	55.3	21.0	22.2	551	6.9%	5.6%	8.2%	2.2%
Racal-Redac	46.0	0.2	37.8	163	5.7%	0.1%	13.9%	0.7%
Valid	43.5	10.9	23.5	475	5.4%	2.9%	8.7%	1.9%
Computervision	32.1	14.3	7.6	270	4.0%	3.8%	2.8%	1.1%
Intergraph	30.6	14.4	5.4	321	3.8%	3.8%	2.0%	1.3%
Sun	27.8	25.1	0.0	1,869	3.5%	6.6%	0.0%	7.5%
Compaq	26.4	26.4	0.0	4,402	3.3%	7.0%	0.0%	17.7%
IBM	18.4	12.8	2.8	752	2.3%	3.4%	1.0%	3.0%
Calay	13.5	4.2	6.8	134	1.7%	1.1%	2.5%	0.5%
Silicon Compiler Systems	13.0	0.0	8.7	0	1.6%	0.0%	3.2%	0.0%
Secmai	12.4	7.4	2.6	101	1.5%	2.0%	1.0%	0.4%
Cadence	10.1	0.0	8.5	0	1.3%	0.0%	3.1%	0.0%
Scientific Calculations	9.1	2.0	4.6	42	1.1%	0.5%	1.7%	0.2%
Zycad	7.9	5.5	0.2	38	1.0%	1.5%	0.1%	0.2%
LPKF	7.5	4.5	2.3	750	0.9%	1.2%	0.8%	3.0%
European Silicon Structures	7.3	1.8	5.5	40	0.9%	0.5%	2.0%	0.2%
VLSI Technology	7.2	0.4	5.7	24	0.9%	0.1%	2.1%	0.1%
Other Companies	159.8	71.3	71.2	7,045	19.9%	18.9%	26.2%	28.4%
All Companies	804.7	377.8	271.3	24,820	100.0%	100.0%	100.0%	100.0%
All US-Based Companies	677.1	349.0	190.8	22,347	84.1%	92.4%	70.3%	90.0%
All Asian-Based Companies	0.0	0.0	0.0	0	0.0%	0.0%	0.0%	0.0%
All European-Based Companies	127.6	28.8	80.5	2,473	15.9%	7.6%	29.7%	10.0%
All Hardware Companies	264.7	222.3	0.0	18,411	32.9%	58.8%	0.0%	74.2%
All Turnkey and Software Companies	540.0	155.4	271.3	6,408	67.1%	41.1%	100.0%	25.8%

Source: Dataquest (August 1990)

design changes between the CAE and CAD environments.

Calay will gain added stability following its acquisition by Siemens. The realignment of its product line and its capability for further development in view of Siemens' massive resources places the company in a position to compete aggressively with its major European competitor, Racal-Redac, especially for large customers involved in in-house manufacturing.

Dassault Electronique

A subsidiary of Dassault, the French aircraft manufacturer, Dassault Electronique is a FF 4 billion, 4,000-person company which traditionally produced turnkey electronics systems for military applications. Making its first appearance at DAC, Dassault Electronique demonstrated Frenchip, a logic synthesis tool for ASICs, originally produced for in-house use and said to be responsible for the design of over 40 complex ASICs internally. The product was originally launched in April 1990.

As a product not aligned to a specific full-line EDA vendor, Frenchip now competes directly with Synopsys following the acquisition of the other independent ASIC synthesis companies: Trimeter and Silicon Compiler Systems by Mentor Graphics; and Silc Technologies by Racal-Redac. Dassault Electronique will therefore face tough competition from the established products of Synopsys and the market presence of Mentor and Racal-Redac.

In the broader CAD/CAM industry, its sister company Dassault Systeme is better known as the developer of CATIA, the mechanical package marketed by IBM. Dassault Electronique has a stable, cash-rich parent which has proven its ability to encourage the development of advanced CAD/CAM products. Dataquest believes the key issues for Dassault Electronique are distribution, marketing and support. We believe the company may have to establish partnerships with large EDA vendors to distribute the product and to provide local support.

DOSIS GmbH

DOSIS demonstrated a silicon cross compiler, called DESIRE, which generates a new layout according to the design rules of a different process technology while ensuring compactness of the design. It can be used for updating cell libraries to a new technology, second-source conversion and minimization of redundant space in layouts. It is specifically aimed at hand-crafted silicon layout. The company sells other EDA products in Europe, including a graphic layout editor and simulation tools.

Founded in 1985, the company's corporate strategy is to transform the raw technology of university and institute research into commercial products and bring them to market. It has 35 employees and its first DAC attendance was in 1989. Target customers include captive and merchant semiconductor manufacturers. The major geographical market for DOSIS is North America at present.

University research in electronic CAD/CAM has typically been underexploited in Europe when compared with North America. However, recent collaborative ventures sponsored by the European Community, such as JESSI and ESPRIT, are attempting to change this situation.

formula GmbH

Based in Nürnburg, Germany, formula was formed in 1984 to develop PCB layout software which was supplied to other companies on an OEM basis. Its current product, RUN, is based on the Apple Macintosh platform and offers CAE and CAD applications for PCB and ASIC design. The product was introduced in October 1989. Approximately 100 copies have been sold since that time. The use of the Apple Macintosh is a significant differentiator for the company, which attended DAC for the first time. Although formula has an opportunity to capitalize on the market for Macintosh-based EDA systems, the Macintosh has yet to make any significant penetration into the EDA market.

Plessey Semiconductors

Plessey is headquartered in Swindon, England and produces CMOS, bipolar and emitter-coupled logic (ECL) arrays for analog, digital and mixed signal applications. The company demonstrated the PDS system for schematics, logic synthesis, automatic test-point generation (ATPG) and layout. Also shown, was the company's Analog ASIC Toolkit and the ERA design system for field-programmable gate arrays. All three systems were released within the past six months. Plessey's design systems are not general-purpose and are marketed specifically in connection with the company's semiconductor products. Plessey holds the number 16 position in the overall European IC market, although it has significantly higher shares in specific segments.

The ongoing development and support of EDA tools is expensive, and in this connection it is interesting to compare Plessey with another European ASIC vendor, European Silicon Structures (ES2). ES2 recently formed European CAD Developments (EuCAD) in conjunction with Cadence Design Systems with the partial intention to reduce its design system development costs. Although around ten times bigger than ES2 in revenue terms, Plessey Semiconductors will still find the ongoing development and support of its tools a significant drain on resources, and will find an increasing reluctance on the part of systems houses to invest in foundry-specific tools.

Racal-Redac

A division of Racal Electronics, the $3.5 billion UK electronics group, Racal-Redac has previously attended many DAC exhibitions. Redac's image in the US market has been enhanced through its acquisition of HHB Systems and Silc Technologies, and the company is aggressively attempting to complete its image transformation from a PCB layout company to an EDA full-line supplier, placing it in a favorable position to compete with its main full-line rivals—Mentor Graphics, Valid Logic and Cadence Design Systems. The company demonstrated its various tools from recent acquisitions, including simulation from HHB and synthesis from Silc Technologies.

Redac demonstrated INTELLIGEN Plus, an automatic testability and test-generation system for ASICs, and SilcSyn 2.0, an architectural design and test synthesis tool. In addition, the company announced and demonstrated Visula HPE, a high-speed PCB layout application integrated with Quantic Laboratories' Greenfield transmission line post-layout simulator. Also announced was Redac's intention to port the Visula EDA suite to IBM's RISC System/6000 platform and an agreement with Digital Equipment Corporation to join the POWERFRAME Synergy Program.

Schlumberger CAD/CAM

This US company was formed from the merger of Applicon and MDSI in 1984, but clearly has major links with Europe through the Schlumberger connection. The company showed a range of EDA tools including schematic capture, simulation, PCB layout and electronics packaging. Both VAX and Macintosh platforms are supported. Schlumberger's focus is still very heavily on mechanical CAD/CAM, where it holds the number four position in Europe (1989 mechanical software revenue).

Schlumberger has not held a strong position in EDA over the past several years. However, the company's experience in both EDA and mechanical applications place it in a favorable position to offer mixed technology applications such as electromechanical and electronic packaging (packaging was, in fact, demonstrated at the show). Schlumberger could then use its strengths and presence in the mechanical marketplace as leverage for additional EDA seats in electronic design departments of large organizations.

Swiftlogic

Swiftlogic demonstrated applications of growing significance at the show—high-speed PCB layout simulation, and transmission line and crosstalk analysis tools. EDA tools for high-speed design were a major theme at this year's DAC show. A mixed signal (analog/digital) simulator for ASICs designed as an extension to Mentor Graphics' Quicksim simulator was also shown.

Swiftlogic, a Unisys spin-off, is privately owned and is backed by venture capital and UK government regional assistance. The company has traditionally developed Mentor Graphics-compatible products and targeted these products exclusively at the Mentor user base. However, the high-speed logic products are now unbundled and can be sold into different vendors' environments. The company faces growing competition from other simulation companies, including Quad Design Technology, Quantic Laboratories and Pacific Numerix. In view of the recent agreement between Racal-Redac and Quantic Laboratories, Swiftlogic can expect to see this competition start to intensify in its European backyard.

Win Technology

Win Technology, a two-year-old, 20-person French company demonstrated Cad_Geode (pronounced "cad jee-ode"), an intelligent framework based upon an expert system. Cad_Geode is a framework that includes design data management capabilities. It controls both data and processes, allowing a company's design methodology to be described to the environment as a series of rules.

According to the company, the use of an expert system allows a more accurate and comprehensive description of these rules. This permits the user to create a tightly controlled custom-design environment across multiple disciplines (electrical, mechanical, software, etc.), forming the core of a concurrent engineering environment. As a framework, the product will encounter competition from Mentor Graphics' Falcon, Digital's Powerframe, Cadence's Design Framework and Interact Corporation's InterAct Integrator. The product presently has no distribution outside of France and although no copies have yet been sold, it has been used in a production environment in the design of the European Airbus aircraft.

Ron Collett
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Research Newsletter

CADENCE AND EUROPEAN SILICON STRUCTURES (ES2) JOIN FORCES

INTRODUCTION

Cadence Design Systems and European Silicon Structures (ES2) have announced the formation of a European joint-venture company known as European CAD Developments Limited (EuCAD). The company will be headquartered in the United Kingdom, with additional facilities in other European countries, initially in Paris. At this time, EuCAD is staffed by 35 people from ES2 and 10 people from Cadence.

The precise remit of the company is not being divulged, except in very general terms as to undertake research and development on the next generation of ASIC design solutions for both ES2 and Cadence. It is also known that the company will continue to develop and support ES2's Solo 1400 ASIC design system. The company will, in effect, become a technology division, concentrating its efforts on product development and marketing. Sales will be handled by Cadence and ES2. Cadence owns 51 percent of EuCAD and ES2 owns 49 percent.

Dataquest believes this venture has attractions for both parties, and in this bulletin we offer the following observations on the announcement.

THE CADENCE PERSPECTIVE

The venture offers Cadence benefits as follows:

- Cadence taps into European R&D expertise in an application area in which it has a major strategic interest.
- Partnership with a European silicon supplier leverages sales of ASIC design tools in Europe.

This is the first time Cadence has partnered a silicon supplier in this way. Dataquest believes it is a sound move for Cadence which, to date, has been relatively unsuccessful in Europe. ES2 is a European silicon foundry which supplied 380 design starts in 1989, representing some 47 percent of all cell-based European ASIC design starts in that year. It holds the number four position for European digital cell-based ASIC manufacturing revenue. Clearly, Cadence will be in a position to supply a fully validated ASIC design system, which will presumably be tightly integrated within the Cadence environment.

From Cadence's viewpoint, the company will perform the role of technology R&D center. Furthermore, EuCAD will undertake R&D with various ASIC vendors and will not be limited to ES2. Cadence already spends 27 percent of its revenue on R&D. Clearly, the company has its sights on the number one EDA software market position following its dramatic rise to number two in 1989. However, Mentor Graphics and Valid Logic remain formidable competitors in the systems marketplace.

THE ES2 PERSPECTIVE

For ES2, the advantages include:

- Access to additional international markets for both tools and silicon
- Greater returns on ES2's investment in the development of design tools
- Reduced expenditure on tools, allowing a greater focus on silicon production

ES2 specializes in small-batch, fast-turnaround, cell-based ASICs using e-beam processing. In Europe, MOS gate arrays represented the majority of design starts in 1989. Cell-based technology is not as mature but is growing faster, exhibiting 36.8 percent compound annual growth

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rate in the 1988 to 1989 period, compared with 28.3 percent for gate arrays. Dataquest believes that this places ES2 in a potentially strong position in spite of the company's relatively weak financial performance at this time.

The company already has a strong relationship with Cadence, as ES2 was an OEM purchaser of Cadence's tools under the banner of Solo 2000. Historically, IC layout was the realm of the silicon manufacturer. Recent indications show an increasing number of systems houses wanting to undertake layout in-house. It is also apparent that, like it or not, silicon suppliers are recognizing that their core business is silicon—not design systems.

CONCLUSIONS

ES2 has made the strategic decision to unbundle its design and manufacturing operations. In effect, it has transferred the bulk of its software development capabilities to EuCAD and picked up a 49 percent share in return. The company can now focus on silicon, backed in part by a major EDA vendor. This will help the company's efforts to achieve profitability. Cadence has inherited a ready-made team of developers to bolster its R&D capabilities. We believe that Cadence will achieve an enhanced presence in the European EDA market as a result of EuCAD's formation, in addition to the delivery of a wider range of tools over the coming years. This is a useful strategic move for both companies.

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Research Newsletter

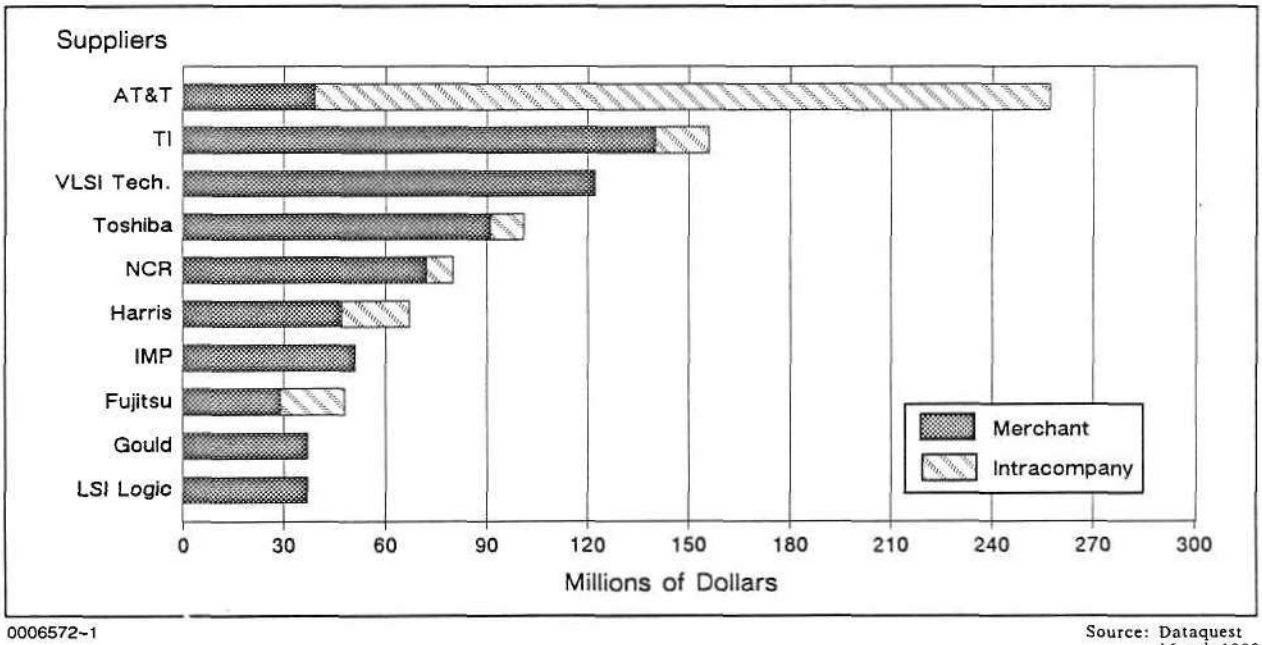
NORTH AMERICAN SUPPLIERS DOMINATE 1989 CBIC MARKET

During 1989, the worldwide cell-based IC (CBIC) market reached an all-time high of $1.5 billion, growing 17 percent over 1988. North American suppliers owned 67 percent of the market. Of the top 10 1989 worldwide CBIC suppliers, 8 were based in North America and just 2 were based in Japan. This situation is exceptional when compared with the gate array market, where 6 of the top 10 1989 worldwide suppliers were from Japan and only 3 were from North America.

AT&T topped the chart as the number one 1989 worldwide CBIC supplier; however, close to 85 percent of its revenue was generated from sales to internal divisions (intracompany revenue). As Figure 1 illustrates, Texas Instruments clearly was the number one 1989 CBIC supplier to the merchant market, followed by VLSI Technology, Toshiba, and NCR. LSI Logic rocketed into the top 10 1989 ranking after being ranked just 18th in 1988; the company had a healthy 117 percent annual merchant growth.

Figure 2 illustrates the worldwide CBIC market growth during the past seven years. Although the 1989 CBIC growth rate of 17 percent exceeds that of the worldwide semiconductor market at 10 percent, it is quite low in comparison with the growth of the previous five years.

FIGURE 1
Top 10 Suppliers
Preliminary 1989 Worldwide CBIC Shipments



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Source: Dataquest
March 1990

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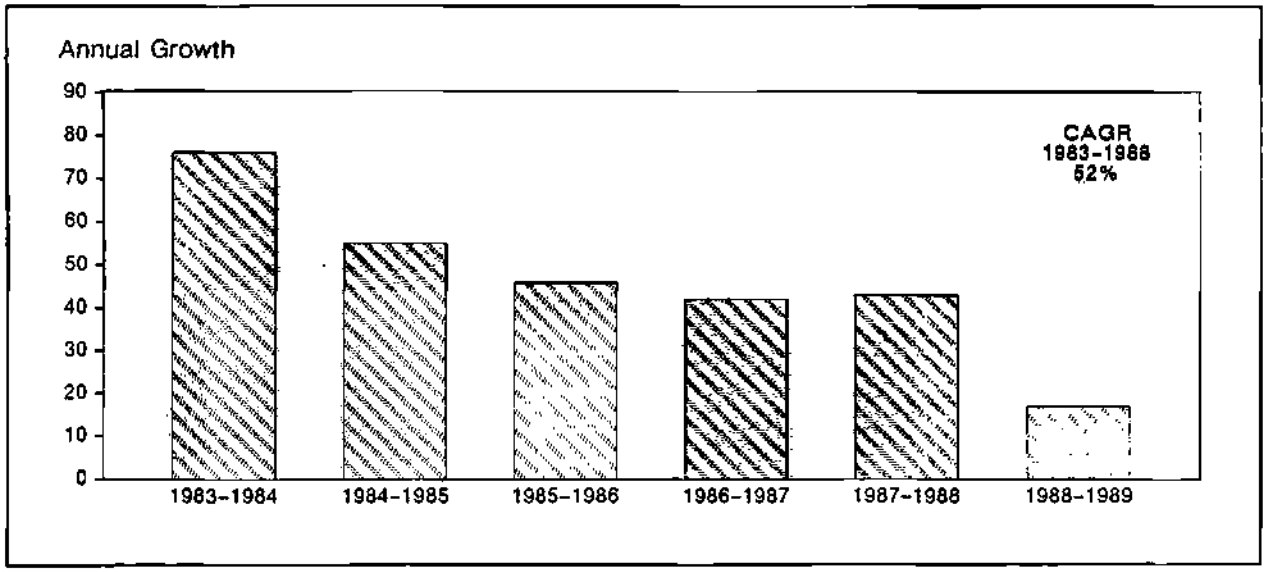
FIGURE 2
Estimated Worldwide CBIC Growth



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Source: Dataquest
March 1990

DATAQUEST ANALYSIS

Dataquest believes that there are four primary reasons for the slow growth in 1989: system shipments (primarily computer) were slow; disk drive shipments fell flat in the second and third quarters, hurting mixed analog/digital CBIC suppliers; gate arrays continued to gain ASIC market share (during 1989, gate arrays grew $480 million while CBICs grew $215 million); and chip sets or standard products replaced CBICs in many high-volume applications.

CBIC applications continue to evolve. During the early 1980s, system designers used CBICs over gate arrays when unit volumes were greater than 25,000 to 50,000 a year; by the mid-1980s, gate array pricing plummeted far below CBIC pricing so that the unit crossover point became almost nonexistent. System designers then adopted CBICs over gate arrays when they needed functionality that was not efficient in gate arrays such as memory or analog. Embedded gate arrays (megacells such as memory embedded in the base wafer) now are emerging, and we believe that they will capture a healthy portion of designs that require unique functions.

As we enter the 1990s, Dataquest believes that CBICs will find their place in the ASIC world. We believe that they will continue to dominate gate arrays in automotive, telecommunication, and mixed analog/digital applications. CBICs also are penetrating high-performance applications, primarily computers. Furthermore, Dataquest believes that a new CBIC market is emerging—altered standard products. CBIC libraries and tools are infiltrating many standard product groups in large broad-based IC suppliers. We believe that by the end of the 1990s, most of all standard logic products will be developed using some form of ASIC tools. Many of these standard products will be customized to fit the users' needs through the use of CBICs.

While applications for CBICs continue to evolve, the rewards remain great for those companies that can evolve with the technology.

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Research Newsletter

ELECTRONIC DESIGN AUTOMATION END USER SURVEY: UNITED STATES AND JAPAN

SUMMARY

Dataquest recently surveyed approximately 750 users of electronic design automation (EDA) equipment in the United States and Japan. The goal of this project was to profile the installed base of the EDA market. This newsletter presents the results of our findings, which include the following:

- The primary reasons for not buying another EDA system are: The EDA system's inability to meet the user's expectations and poor customer service and support.
- Users want better integration and higher performance from EDA systems.
- Users want to spend more time designing at the architectural level and less time designing at the gate level.
- Average investment in EDA in 1988 was $613,000.
- More than 50 percent of today's board designs in the United States include a programmable logic device; approximately 20 percent of the designs worldwide have a hybrid IC.

PART I: SURVEY DEMOGRAPHICS

Of the 750 survey responses, approximately 550 were from U.S. companies and 200 were from Japanese firms. Table 1 lists the EDA vendors in the United States and Japan that supplied the survey sample. Dataquest expresses its gratitude to all vendors that participated in the project.

The profile of the EDA end-user installed base was created by categorizing responses based on industry classification. The distribution of responses across industries in the United States are the following:

- Aerospace/military electronics—21%
- Communications—13%
- Computers—22%
- Consumer electronics—2%
- Government—3%
- Semiconductor—24%
- Test instrumentation—8%
- Other—7%

For Japan, the distribution of responses across industries is as follows:

- Communications—14%
- Computers—20%
- Consumer electronics—7%
- Semiconductor—30%
- Other—29%

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TABLE 1
Survey Respondents

United States		Japan	
Vendor	Percent of Sample	Vendor	Percent of Sample
Cadence	6.5	C. Itoh	2.6%
Calay	4.1	Daisy (Seiko)	14.0
Calma	9.1	Data I/O	6.2
Daisy/Cadnetix	14.9	Fujitsu	6.2
Data I/O	13.9	Marubeni Hytech	9.3
Gateway Design Automation	1.8	Mentor Graphics	10.8
PCAD	11.4	LSI Logic	8.7
Silicon Computer Systems	3.2	NEC	2.1
Silvar Lisco	3.2	Racal-Redac	5.2
Tektronix	2.3	Seiko (non-OEM)	5.5
Teradyne EDA	4.5	Sony/Tektronix	13.0
Valid Logic Systems	19.3	Tokyo Electric	5.7
Viewlogic	3.1	Valid Logic Systems	4.6
VLSI Technology	2.7	Yokogawa	6.1
Total	100%	Total	100%

Source: Dataquest
December 1989

Tables 2 and 3 identify the number of employees at each respondent's site.

The distribution of U.S. respondents by title of position is as follows:

- President—5%
- VP/VP engineering—3%
- CAD/CAM manager—23%
- Manager—14%
- Project manager—16%
- Staff engineer—24%
- Technical staff—4%
- Layout designer—4%
- Other—7%

The distribution of Japanese respondents by title of position is as follows:

- President—1%
- VP/VP engineering—1%
- CAD/CAM manager—21%
- Manager—31%
- Project manager—10%
- Staff engineer—16%
- Other—20%

TABLE 2
Number of Employees per United States Site

Employees	Frequency	Percent
Less than 100	253	46%
100 to 999	200	37
1,000 or more	95	17
Total	548	100%

Source: Dataquest
December 1989

TABLE 3
Number of Employees per Japanese Site

Employees	Frequency	Percent
Less than 100	124	68%
100 to 999	39	21
1,000 or more	20	11
Total	183	100%

Source: Dataquest
December 1989

TABLE 4
Average EDA Investment by U.S. Industry (Thousands of Dollars)

	Investment To Date	1987 Purchases	1988 Purchases
Aerospace/Military Electronics	$2,525	$394	$ 667
Communications	$1,899	$377	$ 332
Computers	$1,823	$517	$ 596
Consumer Electronics	$ 548	$204	$ 192
Government	$1,643	$719	$1,989
Semiconductor	$2,939	$589	$ 788
Service Bureau	$1,629	$609	$ 531
Test Instrumentation	$ 763	$172	$ 472
Other	$1,022	$217	$ 238
All Industries	$1,892	$435	$ 613

Source: Dataquest
December 1989

TABLE 5
Average EDA Investment by Japanese Industry (Thousands of Dollars)

	Investment To Date	1987 Purchases	1988 Purchases
Communications	$5,130	$ 697	$ 740
Computers	$2,368	$ 637	$ 740
Consumer Electronics	$2,831	$ 281	$ 332
Semiconductor	$5,518	$1,334	$1,093
Other	$1,717	$ 321	$ 303
All Industries	$3,462	$ 726	$ 702

Source: Dataquest
December 1989

TABLE 6
Computing Platforms by U.S. Industries (Average Number per Site)

	Technical Workstations	Host-Dependent Terminals	PCs
Aerospace/Military Electronics	23.33	25.69	24.08
Communications	14.79	2.73	4.23
Computers	45.35	27.55	10.66
Consumer Electronics	9.31	1.83	2.42
Government	49.53	28.93	94.47
Semiconductor	20.81	15.32	14.36
Test Instrumentation	9.70	7.37	25.24
Other	8.79	5.50	6.13
All Industries	22.74	16.1	15.93

Source: Dataquest
December 1989

TABLE 7
Computing Platforms Used by Japanese Industries (Average Number per Site)

	Technical Workstations	Host-Dependent Terminals	PCs
Communications	3.67	12.08	6.71
Computers	12.22	10.56	15.16
Consumer Electronics	3.08	4.17	0.42
Semiconductor	8.88	10.54	3.29
Other	4.25	2.67	1.88
All Industries	6.49	7.97	5.37

Source: Dataquest
December 1989

PART II: END-USER INVESTMENT

Tables 4 and 5 provide the average EDA investment per company across a range of industries.

PART III: END-USER COMPUTING ENVIRONMENTS

Tables 6 and 7 indicate penetration of computing platforms across the range of industries in Japan and the United States.

Dataquest Analysis

Sales of PCs into the EDA market peaked in 1986 and have remained flat since that time. Sales of host-based machines into the EDA market also have remained flat or declined since the mid-1980s. Dataquest believes that technical workstations and servers will be the dominant computing platforms in the EDA market as the industry moves into the 1990s.

The average number of hardware accelerators in use per industry in the United States is shown in the following:

- Aerospace/military electronics—1.03
- Communications—0.77
- Computers—1.05
- Consumer electronics—0.54
- Government—2.73
- Semiconductor—0.76
- Test instrumentation—1.17
- Other—0.88
- All industries—0.98

The average number of hardware accelerators used by various industries in Japan are as follows:

- Communications—0.42
- Computers—0.88
- Consumer electronics—0.25
- Semiconductor—0.29
- Other—0.10
- All industries—0.35

Dataquest believes that the hardware accelerator market is in a state of transition. With software simulators running on workstations currently working at 5 to 15 mips and forecast to work at 20 to 40 mips over the next two years, the need for hardware accelerators is questionable. The decision facing CAD managers is whether the cost of a dedicated piece of simulation hardware can be justified in the face of high-speed general-purpose machines. Hardware accelerators will compete not only with workstations, but also with high-performance general-performance computer servers.

Moreover, Dataquest believes that an increasing number of designers will be following top-down design methodologies, i.e., using mixed-level simulation to concurrently verify different portions of the design that are represented at different levels of abstraction, such as behavioral, functional, gate, or switch level. This contrasts sharply with current practice, in which designers predominantly simulate only at the gate level. To address the market's needs, hardware acceleration environments will be required to concurrently simulate at all modeling levels. At the present time, however, the integration is poor between gate-level accelerators and behavioral- and functional-level simulation vehicles. In the future, designers also will be concentrating more on architectural-level design and less on gate-level implementations. As a result, gate-level simulation will be used to verify that architectural specifications have been properly implemented.

PART IV: TIME ALLOCATION WITHIN THE PRODUCT DESIGN CYCLE

Tables 8 and 9 indicate the time spent on different parts of the product design cycle.

Dataquest Analysis

Electronics manufacturers in both the United States and Japan would like to devote more design-cycle time to architectural-level design. As a result, we believe that electronics manufacturers will be more aggressively adopting top-down design methodologies that include mixed-level simulation, as well as logic synthesis. In addition, given the market's desire to spend a greater percentage of time at the architectural level, we believe that high-level system modeling simulation tools will be needed in the near future.

PART V: PROFILE OF THE ICS CURRENTLY USED

Tables 10 and 11 show the primary types of IC devices used by various industries in the United States and Japan.

Dataquest Analysis

We expect the percentage of boards that use surface-mounted devices (SMDs) to continue to rise. We believe that EDA manufacturers should offer design environments that tightly integrate programmable logic device (PLD) design tools, because more than half the boards in production today use PLDs. We expect the PLD market to continue experiencing strong growth, with programmable gate arrays showing even stronger growth. Indeed, field programmable gate arrays continue to replace low-end mask programmable gate arrays.

The significant percentage of boards using hybrid circuits signals an opportunity for EDA vendors to complement PCB layout tools with hybrid IC design systems.

TABLE 8
Time Spent on Design Cycle—by U.S. Industry (Average Percentage of Time)

Current Use of Time

	Architectural Design	Logic Design	Transistor-Level Design	Physical Design	Test Development
Aerospace/Military Electronics	15%	32%	9%	24%	20%
Communications	16%	31%	6%	27%	20%
Computers	18%	33%	6%	21%	22%
Consumer Electronics	10%	23%	10%	34%	23%
Government	15%	29%	6%	31%	19%
Semiconductor	14%	24%	15%	32%	15%
Test Instrumentation	12%	25%	7%	31%	25%
Other	13%	28%	9%	31%	19%
All Industries	15%	29%	9%	28%	19%

Ideal Use of Time

	Architectural Design	Logic Design	Transistor-Level Design	Physical Design	Test Development
Aerospace/Military Electronics	27%	29%	7%	15%	22%
Communications	32%	31%	6%	14%	17%
Computers	28%	32%	5%	15%	20%
Consumer Electronics	16%	26%	12%	21%	25%
Government	16%	31%	9%	24%	20%
Semiconductor	32%	24%	11%	17%	16%
Test Instrumentation	20%	32%	8%	17%	23%
Other	21%	32%	7%	22%	18%
All Industries	27%	29%	8%	17%	19%

Source: Dataquest
December 1989

TABLE 9
Time Spent on Design Cycle—by Japanese Industry (Average Percentage of Time)

Current Use of Time

	Architectural Design	Logic Design	Transistor-Level Design	Physical Design	Test Development
Communications	25%	38%	7%	13%	17%
Computers	24%	30%	5%	12%	29%
Consumer Electronics	17%	26%	7%	32%	18%
Semiconductor	15%	23%	15%	29%	18%
Other	19%	30%	7%	20%	24%
All Industries	20%	29%	9%	20%	22%

Ideal Use Of Time

	Architectural Design	Logic Design	Transistor-Level Design	Physical Design	Test Development
Communications	40%	31%	7%	9%	13%
Computers	38%	27%	5%	8%	22%
Consumer Electronics	29%	30%	8%	18%	15%
Semiconductor	36%	25%	13%	14%	12%
Other	34%	25%	8%	14%	19%
All Industries	34%	25%	8%	14%	19%

Source: Dataquest December 1989

TABLE 10
Devices Used in U.S. Industry (Average Percent of Boards)

	Surface-Mount	Hybrid Circuits	Gate Array	Cell-Based/ Full-Custom	PLD
Aerospace/Military Electronics	39%	18%	28%	25%	43%
Communications	33%	18%	31%	31%	44%
Computers	35%	24%	48%	56%	75%
Consumer Electronics	27%	28%	29%	6%	27%
Government	24%	34%	29%	40%	61%
Semiconductor	N/A	N/A	N/A	N/A	N/A
Test Instrumentation	33%	19%	36%	22%	43%
Other	25%	25%	30%	35%	56%
All Industries	31%	18%	33%	31%	51%

Source: Dataquest December 1989

TABLE 11
Devices Used in Japanese Industry (Average Percent of Boards)

	Surface-Mount	Hybrid Circuits	Gate Array	Cell-Based/ Full-Custom	PLD
Communications	37%	18%	23%	28%	14%
Computers	37%	15%	45%	33%	35%
Consumer Electronics	47%	22%	23%	38%	13%
Semiconductor	N/A	N/A	N/A	N/A	N/A
Other	35%	30%	24%	51%	21%
All Industries	37%	20%	30%	37%	28%

Source: Dataquest December 1989

PART VI: EDA MARKET REQUIREMENTS AND EXPECTATIONS

U.S. respondents said they would not buy from the EDA vendor again for the following reasons (percentage citing reason):

- Does not meet expectations—55%
- Poor support—30%
- Too expensive—27%
- Falling behind technology—25%
- Poor integration/closed system—23%
- Difficult to use—14%
- Unreliable—12%
- Corporate standard precludes—9%
- Other—15%

Among the Japanese respondents, the reasons were as follows (percentage citing reason):

- Does not meet expectations—54%
- Poor integration/closed system—21%
- Falling behind technology—21%
- Poor support—15%
- Too expensive—15%
- Difficult to use—6%
- Other—15%

The above question regarding EDA vendors was answered by 194 U.S. respondents and 33 Japanese respondents.

Dataquest Analysis

In both the United States and Japan, the most prevalent reason for not buying again was that the system does not meet expectations. And the primary reasons that a system did not meet expectations were poor performance and software bugs. The data make it clear that vendors must focus R&D resources on improving execution speed and ensuring that products are not shipped before undergoing exceptional quality assurance procedures.

In the United States, poor support continues to be a primary reason for refusing to buy again. It is likely that respondents in Japan did not rank poor support highly because vendors are expected to provide good support. We believe that as the EDA market matures, customer service and support will play an increasingly important role in the buying decision.

When asked what changes they desired in the system, 417 U.S. respondents listed the following:

- Better integration—48%
- Higher performance—33%
- More functionality—13%
- Lower cost—12%
- Better user interface—12%
- Support of standards—11%
- Add system-level design tools—10%

- Better support by vendor—8%
- More reliable—8%
- Add design management—6%
- Add test automation tools—3%
- Handle larger designs—3%
- Better ASIC design tools—2%

The Japanese respondents (101 people) mentioned the following changes that they would like:

- Better integration—55%
- Higher performance—38%
- More functionality—22%
- Add system-level design tools—16%
- Better user interface—10%
- Add kanji characters—10%
- Add test automation tools—9%
- Support standards—8%
- Reduce cost—7%
- More reliable—4%
- Add design management—4%
- Better ASIC design tools—4%
- Handle larger designs—2%

Better integration and higher performance are the most commonly desired changes by both the U.S. and Japanese markets. The integration problems of today's EDA systems will be addressed by the emergence of frameworks and standard framework specifications. Several vendors are scheduled to introduce frameworks in 1990, and standards are being developed by the CAD Framework Initiative (CFI). Indeed, CFI will be demonstrating a common procedural interface at the 1990 Design Automation Conference.

Higher-performance workstations will no doubt fill some of the performance demands of the market, but the complexity of code currently under development will usurp large quantities of the compute performance in the upcoming generation of workstations. In other words, the performance problem will not be solved simply by making the hardware faster. Software efficiency, advanced databases, and enhanced database management are likely to be the most effective solutions to the problem.

PART VII: DATAQUEST CONCLUSIONS

Dataquest believes that the EDA market of the 1990s will be dramatically different from that of the 1980s. In the 1980s, the market evaluated vendors primarily on the quality of their individual point tools. Benchmarks and functionality assessments were the order of the day. While these assessments will still be used to compare vendors, a range of other parameters also will be compared. For example, vendors will be evaluated on the robustness of their framework, as well as the openness of their system. Conformance to industry standards will be taken into account also. And customer service and support, as well as the vendor's ability to keep pace with EDA technology advancements, will be another consideration, and the ease of porting EDA software to additional platforms will be an issue. Finally, the vendor's stability and corporate strategy will be analyzed to determine the vendor's long-term viability.

Ron Collett

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Research Newsletter

EUROPEAN MOS GATE ARRAY AND CBIC DESIGN STARTS ANALYSIS

INTRODUCTION

For the past two and a half years, Dataquest's European Semiconductor research staff have been compiling data on ASIC design starts. This newsletter presents the results of two major in-depth ASIC surveys and numerous face-to-face interviews conducted during that time period.

According to Dataquest, a design start occurs when a nonrecurring engineering (NRE) fee for an ASIC design is billed to the customer. Some of the tables in this newsletter refer to gate count per design. This refers to gross gates per chip, not gates used.

SUMMARY

Table 1 shows estimated European design starts broken down by MOS gate arrays and MOS cell-based ICs (CBICs). Historic estimates for 1987 and 1988 are given, along with a projection for 1989.

MOS gate arrays represent the majority of design starts. The technology is more mature than CBIC, and design tools have made gate arrays more accessible to designers. Nevertheless, as Table 1 shows, CBIC design starts are increasing rapidly. All of the MOS gate array design starts are pure digital designs. However, of the 570 CBIC design starts in 1988, one-third (190) were mixed analog/digital designs.

Our research highlights the high proportion of mixed-signal ASIC design that is taking place in Europe in CBICs. This amount is due to the strength of the telecommunication, industrial, and consumer segments in Europe. (A more detailed discussion of this can be found in ESIS Research Newsletter number 1989-22, entitled "Mixed Analog/Digital ASIC—An Embryonic Market.")

This newsletter analyzes MOS gate array and CBIC design starts by European region, by application, and by gate count for 1988 and 1989 and, where available, 1987.

TABLE 1
European MOS Gate Array and MOS CBIC Design Starts, 1987 to 1989

	1987	1988	CAGR % 1987-1988	1989	CAGR % 1988-1989
MOS Gate Array	830	1,116	34.5%	1,432	28.3%
MOS Cell-Based	385	570	48.1%	780	36.8%
Total	1,215	1,686	38.8%	2,212	31.2%

Source: Dataquest December 1989

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TABLE 2
European MOS CBIC Design Starts by Region

	1988 Starts	%	1989 Starts	%	% Growth 1988-1989
Benelux	6	1%	16	2%	174%
France	160	28	250	32	56%
Italy	103	18	133	17	29%
Scandinavia	11	2	23	3	105%
U.K. and Ireland	51	9	109	14	113%
West Germany	205	36	218	28	6%
Rest of Europe	34	6	31	4	(9%)
Total	570	100%	780	100%	37%

Source: Dataquest
December 1989

Table 2 lists European MOS CBIC design starts by region. The following points should be noted:

- France and West Germany represent more than 50 percent of European CBIC design starts, with a strong element of mixed-signal designs in each of these countries.
- The fastest-growing region is Benelux, due to the presence of Alcatel/Bell Telephone, Philips, and Siemens/GTE. However, Philips' major activity here is in the consumer arena, and because of the large quantities of products involved, full-custom designs still are preferred to CBICs in most designs.
- Northern Europe, including U.K./Ireland and Scandinavia, shows the next fastest percentage of growth but altogether represented only 17 percent of total European CBIC design starts in 1989.
- Design of CBICs into PCs is a major activity in U.K./Ireland. The two main applications here are as follows:
  - Replacement of existing gate array designs, absorbing 2 or 3 gate arrays and extra discrete logic
  - Mixed-mode CBIC design for disk storage and display

TABLE 3
European MOS CBIC Design Starts Percentage by End Use

	1987 Starts	%	1988 Starts	%	% Growth 1987-1988	1989 Starts	%	% Growth 1988-1989
Data Processing	69	18%	80	14%	15%	148	19%	86%
Communications	162	42	211	37	30%	243	31	15%
Industrial	73	19	108	19	48%	148	19	37%
Military	50	13	74	13	48%	101	13	37%
Transportation	12	3	40	7	245%	62	8	56%
Consumer	19	5	57	10	196%	78	10	37%
Total	385	100%	570	100%	48%	780	100%	37%

Source: Dataquest
December 1989

Table 3 lists European MOS CBIC design starts by end use. The following points should be noted:

- Communications clearly represents the largest applications segment for CBICs, although its overall share of design starts is decreasing. The key applications are modems, signal-processing applications, and mobile communications.
- Data processing and industrial applications represent the second-largest group of CBIC users. Key applications are in PCs, printers, and memory storage including tape, floppy, and hard disk.
- The biggest growth from 1987 to 1989 was in the transportation segment. Although it represents only 8 percent of total design starts in 1989, its rapid growth indicates that CBICs are adapting quickly to the requirements of this segment. Mixed analog/digital technology is important here.
- Military applications represent a considerable proportion of CBIC designs. Several companies, such as MEDL, specialize in servicing this segment. Military applications include avionic control systems, missile guidance, and communications systems. Most of the leading players, including AT&T, ES2, Texas Instruments, and VLSI Technology, draw significant revenue from military applications.

TABLE 4
European MOS CBIC Design Starts Percentage by Gate Count

	1987 Starts	%	1988 Starts	%	% Growth 1987-1988	1989 Starts	%	% Growth 1988-1989
0-1K	65	17%	80	14%	22%	70	9%	(12%)
1K-2K	54	14	34	6	(37%)	39	5	14%
2K-3K	31	8	29	5	(7%)	62	8	119%
3K-5K	130	34	202	36	55%	155	20	(23%)
5K-7K	12	3	17	3	48%	86	11	402%
7K-10K	23	6	57	10	147%	78	10	37%
10K-15K	12	3	29	5	147%	55	7	92%
15K-20K	12	3	34	6	196%	47	6	37%
20K-30K	27	7	57	10	112%	109	14	92%
30K-50K	19	5	29	5	48%	70	9	146%
50K-100K	0	0	2	0	N/A	9	1	368%
100K+	0	0	0	0	N/A	0	0	N/A
Total	385	100%	570	100%	48%	780	100%	37%

N/A = Not Available

Source: Dataquest
December 1989

Table 4 lists European MOS CBIC design starts by gate count, and Figure 1 shows these data graphically. The following points should be noted:

- In 1989, 60 percent of design starts had gate counts of less than 10K gates, compared with 81 percent in 1987.
- Although the percentage of total designs with 2K gates or less has decreased considerably since 1987, the largest number of designs during the 1987 through 1989 time frame have been between 3K and 5K gates.
- As expected, gate counts per design is spreading to higher gate densities. In 1989, the second most popular gate range was 5K to 7K gates. However, in 1989, only 11 designs will be completed with greater than 50K gates.
- Designs in the 0 to 1K gate count area primarily are for mixed-mode devices. Design activity will continue steadily in this area.
- The 20K to 30K gate peak that emerged this year reflects the increase in designs that contain memory.

TABLE 5
European MOS Gate Array Design Starts by Region

	1988 Starts	%	1989 Starts	%	% Growth 1988-1989
Benelux	33	3%	72	5%	114%
France	179	16	272	19	52%
Italy	257	23	258	18	0
Scandinavia	67	6	100	7	50%
U.K. and Ireland	235	21	301	21	28%
West Germany	312	28	372	26	19%
Rest of Europe	33	3	57	4	71%
Total	1,116	100%	1,432	100%	28%

Source: Dataquest
December 1989

Table 5 lists the European MOS gate array starts by region. The following points should be noted:

- West Germany has the most gate array design starts of any European region with 372 designs in 1989. However, the number of designs in 1989 grew by only 19 percent compared with 1988.
- France's design activity in gate arrays, unlike in CBICs, was less than in both U.K./Ireland and Italy in 1988.
- Design activity in Benelux, Spain, and Portugal is increasing rapidly. Philips' decision to promote its gate array capability stimulated Benelux activity.
- France tends to have higher gate count per design than U.K./Ireland. U.K./Ireland focuses on second revision equipment design using gate arrays to mop up standard logic. In France, Alcatel and Bull focus on a high gate count "system on a chip" approach.
- In Italy, Olivetti's data processing business drove very high design start activity in 1988. Although we expect design starts to decrease in 1989, Italy still will represent a considerable 18 percent of European designs.

TABLE 6
European MOS Gate Array Design Starts Percentage by Application

	1988 Starts	%	1989 Starts	%	% Growth 1988-1989
Data Processing	413	37%	486	34%	18%
Communications	290	26	444	31	53%
Industrial	279	25	301	21	8%
Military	56	5	72	5	28%
Transportation	11	1	29	2	157%
Consumer	67	6	100	7	50%
Total	1,116	100%	1,432	100%	28%

Source: Dataquest
December 1989

Table 6 lists European MOS gate array design starts by region. The following points should be noted:

- The largest amount of design activity occurs in the data processing application segment. Gate arrays that are used to condense standard logic in PCs and other fast-changing systems are driving this activity.
- Strong design activity still exists in communications and industrial applications. Together, they represent 50 percent of all designs.
- Although the number of designs in transportation is small, design activity should increase by 157 percent in 1989 compared with 1988. This increased design activity is also seen in CBICs. Gate array design activity here is largely prototyping. Once production ramps up, automotive companies seek to reduce costs by moving to CBICs or full-custom ICs, thus reducing component costs.
- In consumer applications, average gate counts are low, around 2K to 3K at most. These arrays perform simple logic functions.
- In data processing, there is evidence of second-iteration gate array design taking place. Here, first-generation lower gate count designs are being replaced by one bigger gate array. Thus, the number of gate arrays in the system is decreasing.

TABLE 7
European MOS Gate Array Design Starts Percentage by Gate Count

	1987 Starts	%	1988 Starts	%	% Growth 1987-1988	1989 Starts	%	% Growth 1988-1989
0-1K	75	9%	123	11%	64%	143	10%	17%
1K-2K	158	19	201	18	27%	215	15	7%
2K-3K	222	27	276	25	24%	172	12	(38%)
3K-5K	125	15	212	19	70%	484	34	128%
5K-7K	83	10	78	7	(6%)	115	8	47%
7K-10K	83	10	78	7	(6%)	86	6	10%
10K-15K	42	5	67	6	61%	72	5	7%
15K-20K	25	3	45	4	79%	29	2	(36%)
20K-30K	17	2	33	3	102	100	7	199%
30K-50K	0	0	3	0	N/A	14	1	377%
50K-100K	0	0	0	0	N/A	2	0	N/A
100K+	0	0	0	0	N/A	0	0	N/A
Total	830	100%	1,116	100%	34%	1,432	100%	28%

N/A = Not Available

Source: Dataquest
December 1989

Table 7 lists European MOS gate array design starts by gate count, and Figure 2 shows these data graphically. The following points should be noted:

- In both 1987 and 1988, 70 percent of gate array design starts were 5K gates or less. This percentage shows that there is still considerable concentration on commodity low-gate-count arrays.
- The data show that the peak design activity transferred from the 2K to 3K gate area in 1987 to the 3K to 5K gate area in 1988 and 1989. A further peak is emerging around the 20K to 30K gate area, caused by second-generation gate array design.
- A comparison between gate array and CBIC gate counts shows that arrays are very much concentrated on the lower gate count area. Only 10 percent of array designs had gate counts of 20K or more gates in 1989 compared with 27 percent of CBICs.

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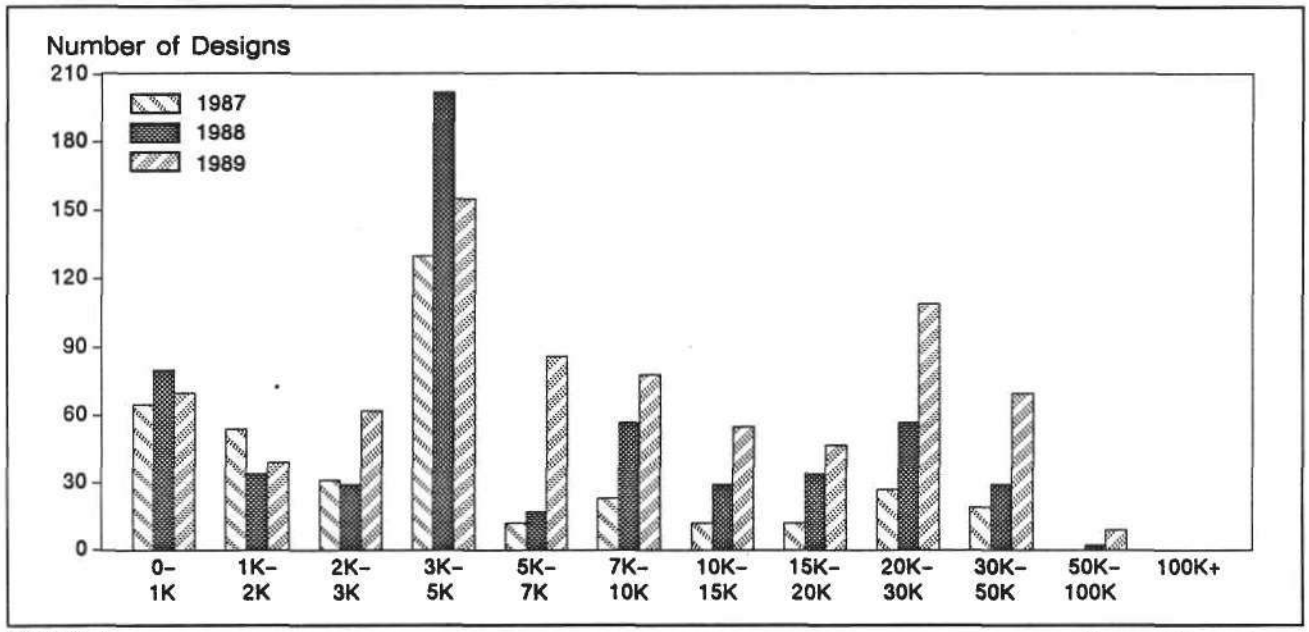
Ron Collett
Jim Eastlake

FIGURE 1
European MOS CBIC Design Starts
Percentage by Gate Count



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Source: Dataquest
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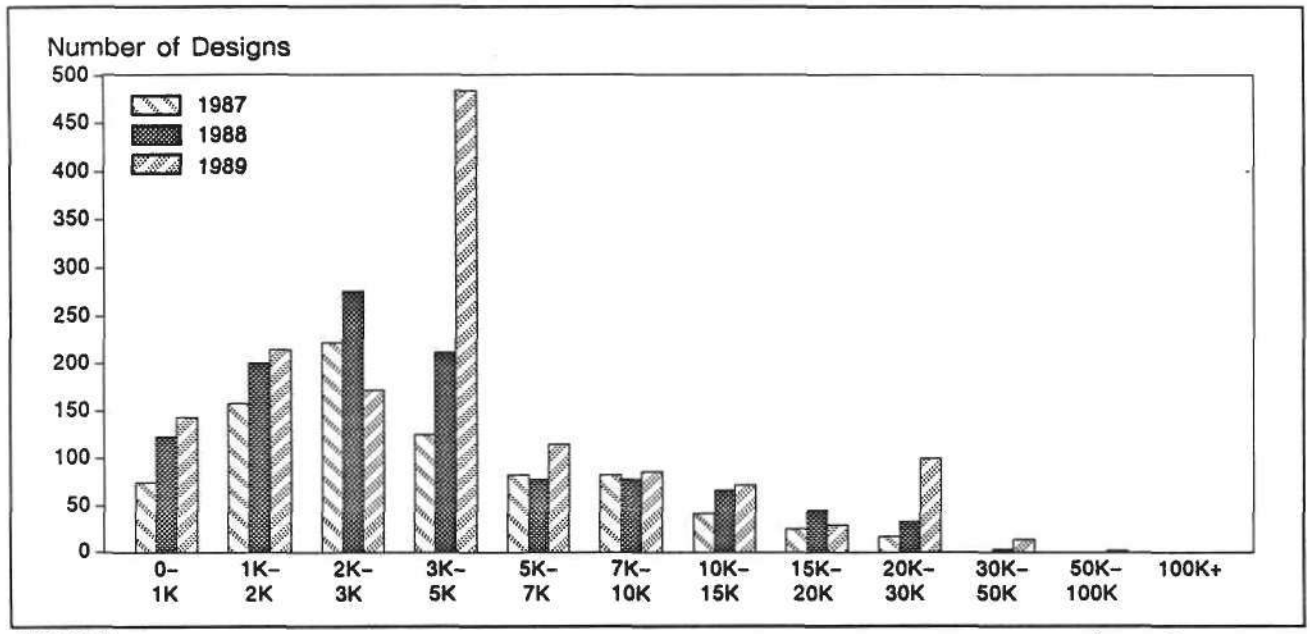
FIGURE 2
European MOS Gate Array Design Starts
Percentage by Gate Count



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Research Newsletter

ANALOG ICs IN THE 1990s: THE FUTURE IS MIXED

INTRODUCTION

The analog IC market has remained at a fairly consistent 20 percent of the total IC market for nearly two decades, yet analog products have been going through significant changes during this period. The pure analog signal processing ICs such as amplifiers, regulators, timers, and other mature product types are losing ground to more advanced products that feature mixtures of analog and digital circuits. Although much has been made of mixed-mode ASIC as a growth area for the next decade, this area represents only a small part of the substantial growth that will be experienced by mixed analog/digital ICs in the coming years. Irrespective of design methodology—ASIC, full-custom, or standard—the market is looking for more complex ICs that simplify design, reduce board space, increase reliability, and lower costs. Mixed signal or mixed-mode ICs provide this solution for the analog/digital interface.

Dataquest estimates that the mixed analog/digital portion of the market is growing 34 percent faster than the analog IC market in general. We expect the mixed-mode products to grow by more than 16 percent compounded over the next five-year period, a period that is expected to see a significant IC sales slowdown in 1989 and 1990. This growth is paced by the 21.4 percent compounded growth anticipated for the mixed ASIC market during the next five years.

MIXED-MODE PRODUCTS AND MARKETS

A mixed-mode or mixed-signal IC combines both analog and digital signal processing functions on the same chip. As Figure 1 shows, the $2.29 billion market for mixed-signal ICs is made up of products from many traditional segments. For this evaluation, we have excluded any mixed-signal portion of the consumer-specific IC market because of the difficulty in quantifying these product types at this time.

Forecast Growth Rates

A comparison of the anticipated compound annual growth rates (CAGRs) for the various analog product categories is given in Figure 2. It is significant that most of the fastest-growing product categories are the categories of mixed products, which are identified by an asterisk (*) on the chart. In addition to the identified mixed-mode categories, the fastest-growing subsegments of largely nonmixed products (such as the switching regulator portion of voltage regulators) also are included in the consolidated mixed-mode products.

The combination of the identified mixed-mode segments and subsegments and their individual forecasts yields the mixed IC forecast listed in Table 1 and depicted graphically in Figure 3.

Figure 3 shows the individual contributing categories to this aggregate five-year growth forecast for mixed-mode ICs.

Analog Market Segments

Partitioning the analog IC market into mixed-mode (or mixed-signal) ICs, pure analog ICs, consumer-specific ICs, and hybrid ICs shows that the mixed-mode ICs will be growing faster than the pure analog products, gaining an additional 5 percent share of the analog market in just five years. Market share will be lost by both hybrid ICs and the traditional analog signal processing ICs to the mixed monolithic ICs. Figure 4 shows the proportional growth of the mixed-mode ICs versus the three other categories. It should be noted that the consumer-specific ICs also will show a rapid

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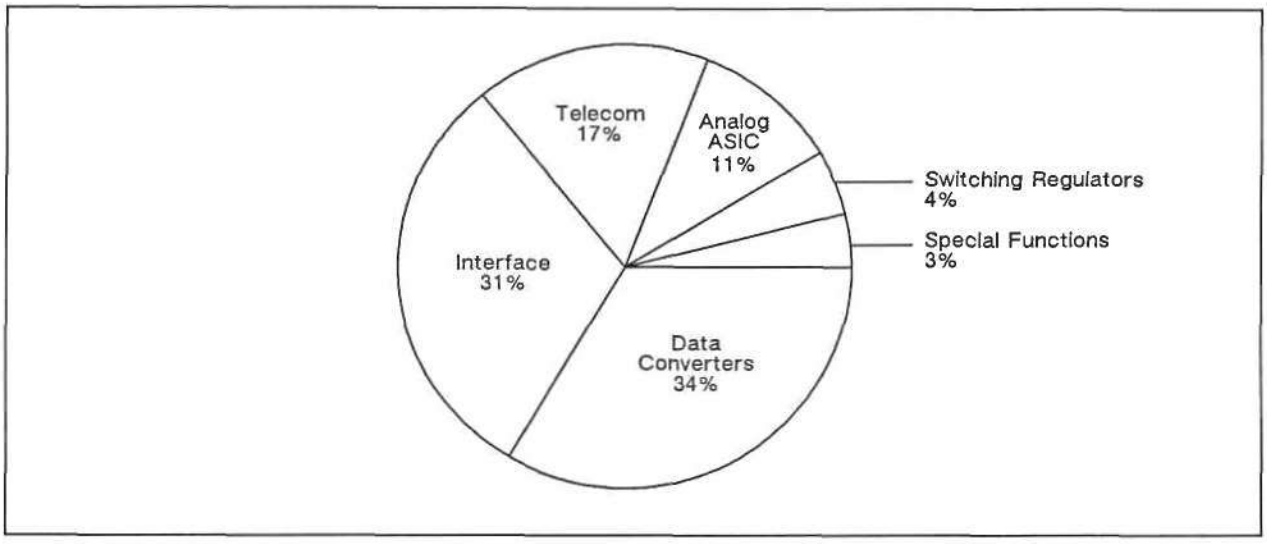
FIGURE 1
Mixed-Mode ICs by Product Category



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Source: Dataquest
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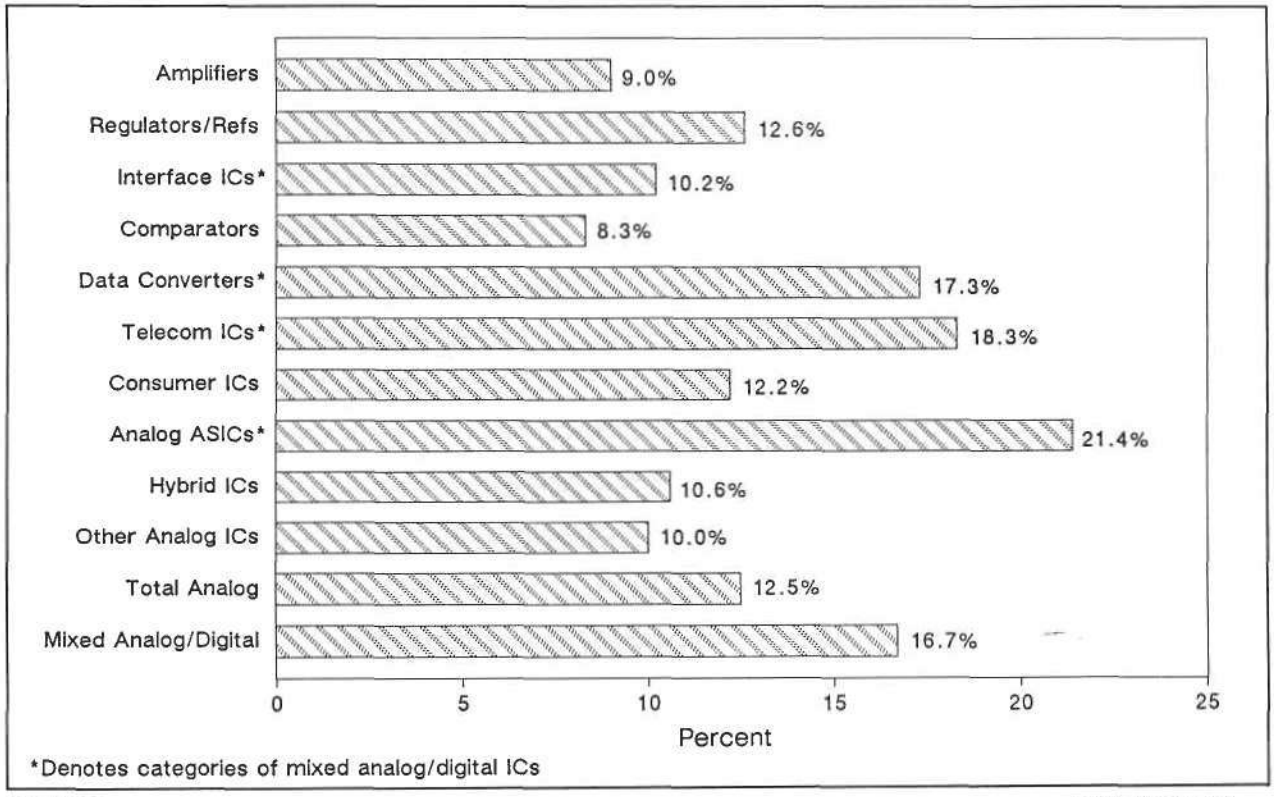
FIGURE 2
Forecast CAGRs by Product Category



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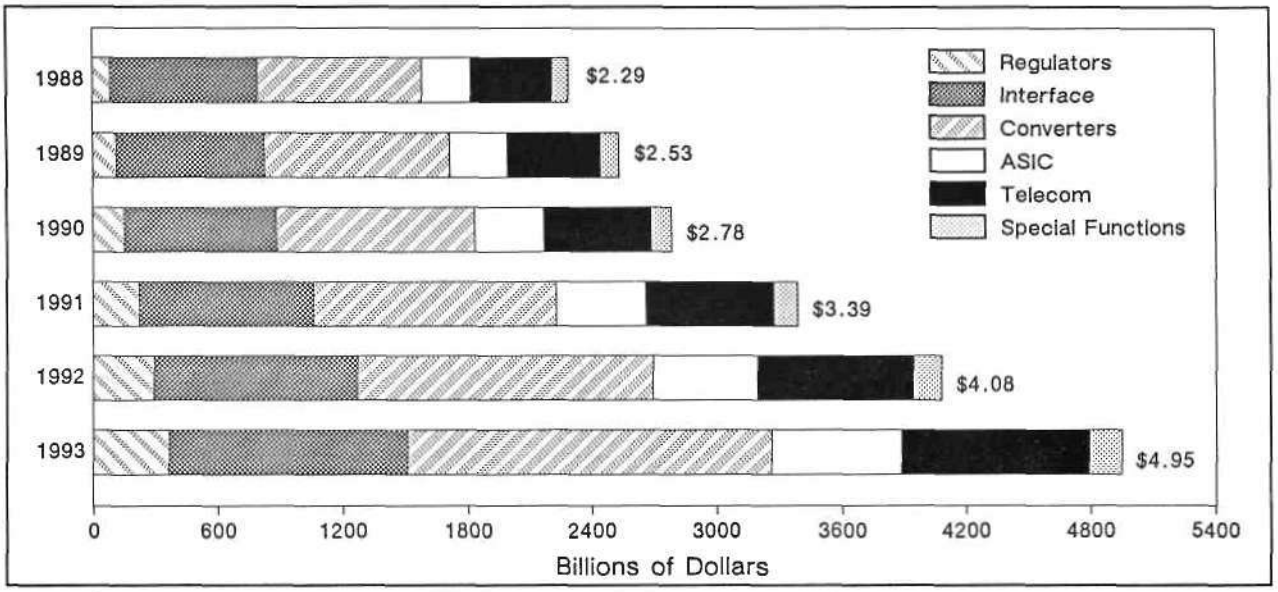
Source: Dataquest
October 1989

TABLE 1
Estimated Mixed Analog/Digital Market (1988-1993)

Segment (Billion $)	1988	1989	1990	1991	1992	1993	CAGR 1988-1993
Total Analog Sales	9.00	9.35	9.80	11.50	13.80	16.30	12.5%
Total Mixed IC Sales	2.29	2.53	2.78	3.39	4.08	4.95	16.7%
Mixed ASIC Sales	0.24	0.29	0.35	0.42	0.50	0.62	21.4%

Source: Dataquest
October 1989

FIGURE 3
Mixed-Mode IC Forecast



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Source: Dataquest
October 1989

change to mixed-mode ICs as demand increases from the entertainment (HDTV, digital audio) and automotive markets.

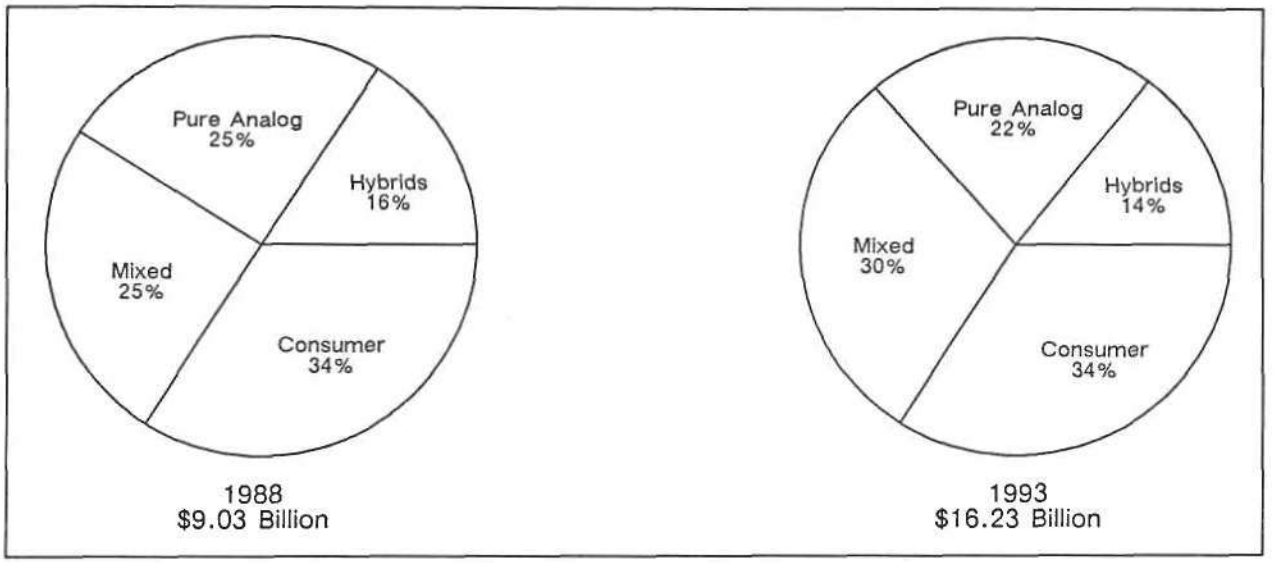
Mixed ASIC and Smart Power

The mixed-mode IC grouping contains ASIC and smart power ICs as well as standard, nonpower ICs. As Figure 5 shows, both ASIC and smart power are relatively minor portions of the mixed-signal grouping. These product types are growing faster than the standard product segments, however, and they present specialized opportunities for growth within the broad mixed-mode product grouping. Mixed ASICs have the potential to replace many of the data converter, interface, and telecom devices now offered as standard mixed-mode products.

Mixed-Mode IC Application Markets

Because the mixed-mode category is a collection of the fastest-growing segments of the analog market, it should not be surprising that these mixed-signal ICs serve the fastest-growing end-application markets. Figure 6 illustrates 1988 mixed-mode IC consumption by application markets. Note that the combination of computer, consumer, and telecom markets consumed 72 percent of the mixed-mode products in 1988.

FIGURE 4
Analog IC Forecast by Special Category



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Source: Dataquest
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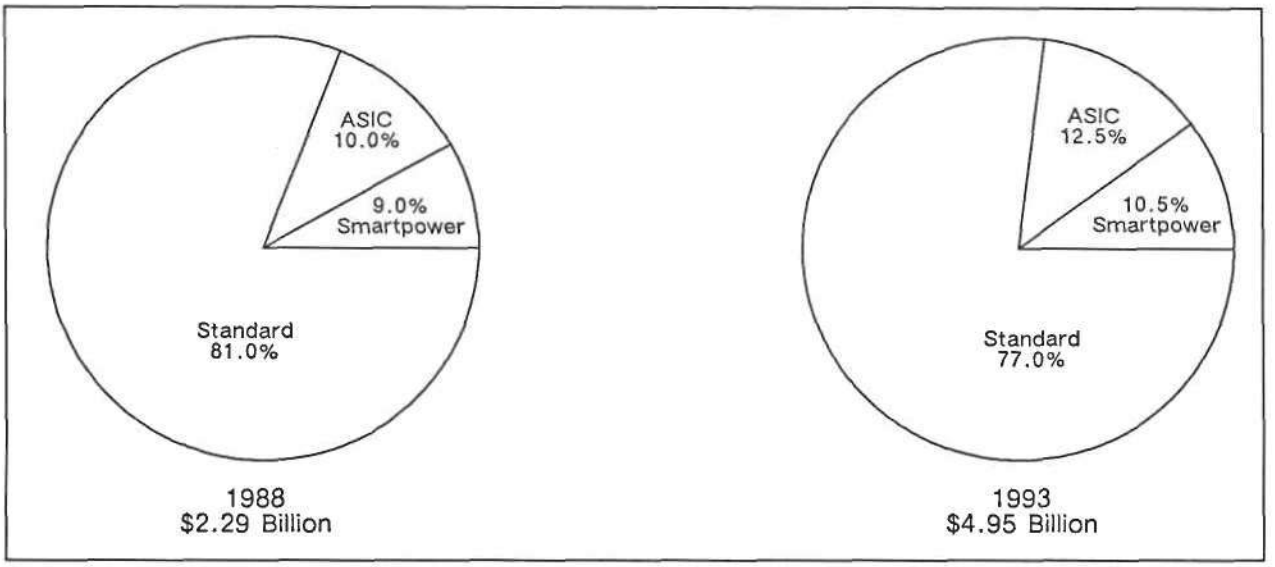
FIGURE 5
Mixed-Mode IC Forecast by Specialty Products



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Source: Dataquest
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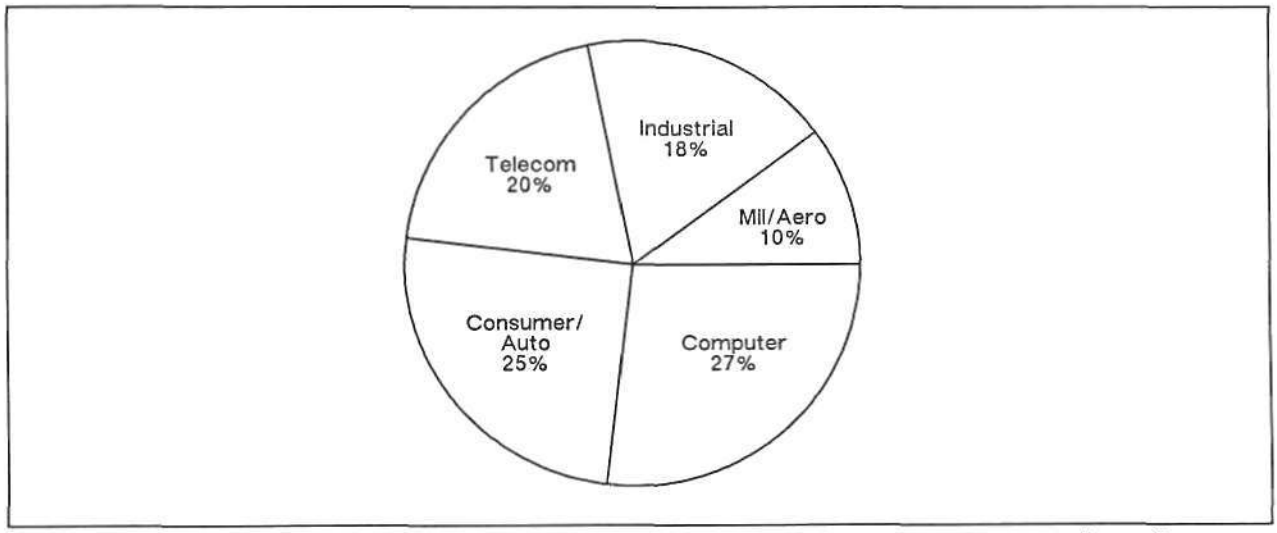
Process Technology

Mixed-mode ICs are processed with a wide variety of technologies. Bipolar still dominated in 1988, but we expect it to continue losing ground to CMOS and the various combinations of bipolar, CMOS, and DMOS that we refer to under the BiCMOS designation. BiCMOS is the preferred technology to optimize mixed analog/digital ICs. (See the Dataquest Analog Newsletter entitled, "BiCMOS: A High-Performance Complement to CMOS.") Fewer than 2 percent of analog ICs were processed with this technology in 1988. Dataquest estimates that 7 percent of all IC revenue will come from products utilizing BiCMOS by 1993. The mixed IC forecast by technology is shown in Figure 7.

FIGURE 6
Mixed-Mode IC Consumption by Application Markets



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Source: Dataquest
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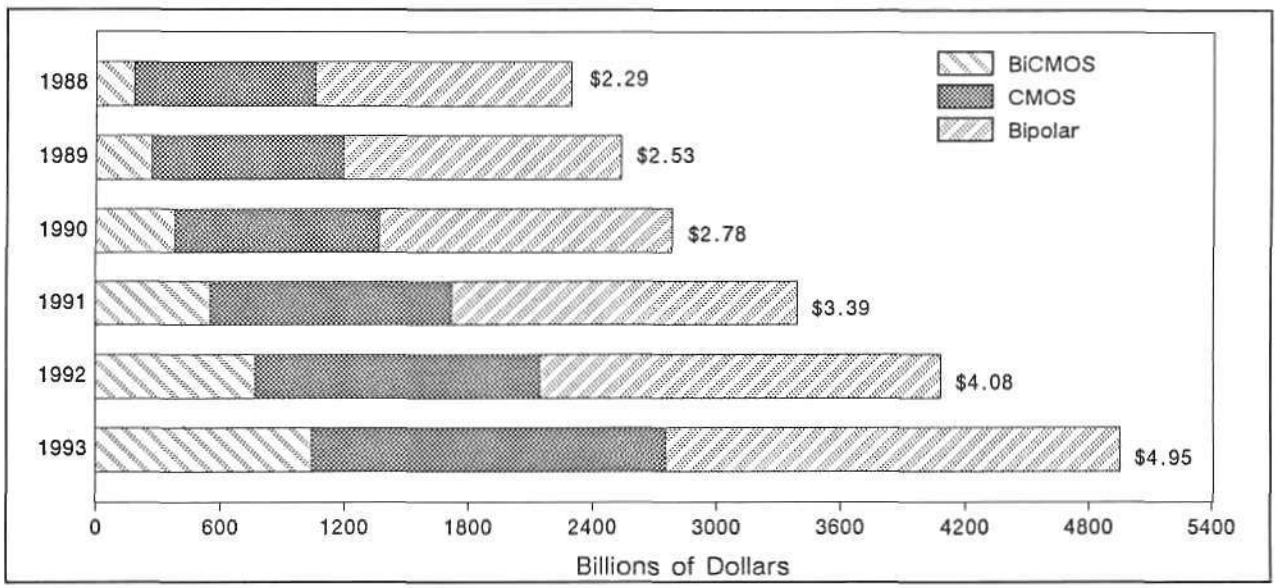
FIGURE 7
Mixed-Mode IC Forecast by Process Technology



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Source: Dataquest
October 1989

Suppliers

Because mixed-mode analog has long been part of the broad analog IC definition, the majority of analog IC suppliers do offer mixed-mode products. Table 2 lists these suppliers in order of market share. The consumer-specific product segment was not included in this review of mixed-mode products; therefore, the top five suppliers are U.S. manufacturers. A review of this chart shows that the mixed-mode IC market is quite fragmented, with a 3 percent market share sufficient for "top 10" status.

TABLE 2
1988 Market Share for Mixed-Signal ICs

Rank	Company	Market Share	Millions of Dollars
1	Analog Devices	8.5%	$ 193.0
2	National Semiconductor	8.1	184.0
3	Texas Instruments	6.9	158.0
4	Motorola	5.8	133.0
5	AMD	4.0	92.0
6	SGS-Thomson	3.8	86.0
7	Ericsson	3.5	80.0
8	Philips	3.4	78.0
9	Sprague	3.3	76.0
10	Matsushita	2.7	61.6
11	Silicon Systems	2.7	61.0
12	Burr-Brown	2.3	53.4
13	Inmos	2.1	47.6
14	Brooktree	2.0	45.0
15	Fujitsu	1.9	44.0
16	GE Solid State	1.9	43.0
17	Toshiba	1.8	42.0
18	Siemens	1.8	40.3
19	NEC	1.8	40.0
20	Harris	1.7	38.2
21	Exar	1.7	37.7
22	Hitachi	1.6	36.1
23	Oki Semiconductor	1.4	31.5
24	Rohm	1.1	24.0
25	Precision Monolithics	1.0	23.8
26	Sierra	1.0	23.0
27	Plessey-Interdesign	1.0	23.0
28	NCR Microelectronics	1.0	23.0
29	Mitel	1.0	22.5
30	Sharp	1.0	22.5
31	Sony	0.9	20.0
32	Telefunken Electronics	0.9	20.0
33	Unitrode	0.9	19.7
34	Silicon General	0.9	19.5
35	International Micro Products	0.8	18.9
36	TRW	0.8	18.0
37	Mitsubishi	0.7	17.0
38	Teledyne Semiconductor	0.7	17.0
39	Maxim	0.7	17.0
40	Linear Technology	0.6	12.7
	Other	10.4	247.0
	Total	100.0%	$2,290.0

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
October 1989

DATAQUEST CONCLUSIONS

Mixed analog/digital ICs are not a new phenomenon; analog suppliers have a long history of supplying mixed-signal ICs to the market. Now, however, the trend toward mixed-signal ICs is accelerating, pressed by the continued incursion of both analog and digital ICs into previously "pure" analog or digital applications and by the success of digital ASICs to integrate digital functions. Mixed-mode is not synonymous with ASIC, but mixed-mode ASIC does represent an explosive growth area for mixed-mode ICs if the standard cells, design tools, and design capability can be brought together. Whether in custom, semicustom, or standard ICs, the future of analog ICs is certainly mixed.

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Ron Collett
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CADENCE DESIGN SYSTEMS MARCHES INTO ELECTRONIC CAE; BUYS GATEWAY DESIGN AUTOMATION

INTRODUCTION

In a deal valued at approximately $74 million, IC layout market leader Cadence Design Systems Incorporated purchased Gateway Design Automation. Gateway's primary product line is the Verilog digital simulator, but the company also has been addressing the test-automation market. Prior to the acquisition, Cadence had been marketing Verilog jointly with Gateway. This acquisition demonstrates Cadence's continuing determination to expand beyond the IC layout market and into the system's electronic design automation (EDA) market. Table 1 shows Cadence's overall position in the EDA market.

Table 1

1988 EDA Market (Millions of Dollars)

Company	Total EDA Revenue[1]
Mentor Graphics	$295.9
Daisy Systems	$191.2[2]
Valid Logic	$141.0[3]
Racal-Redac	$ 87.0[4]
Cadence	$ 77.7[5]

[1]Does not include OEM revenue
[2]Includes Daisy Systems, Cadnetix, and Simucad
[3]Includes Valid Logic, IMS, ADT, and Calma IC division
[4]Includes Racal-Redac and HHB Systems
[5]Includes Cadence, Gateway Design Automation, and Tangent

Source: Dataquest
October 1989

DETAILS OF THE DEAL

Under the terms of the agreement, Gateway will merge with Cadence in a transaction that is considered a pooling of interests. Cadence will issue approximately 4 million shares of its common stock in exchange for all Gateway stock, at an exchange ratio of 0.97 shares of Cadence common stock for each share of Gateway. Cadence stock closed at $18.50 on the day of the agreement.

The agreement between Cadence and Gateway positions the deal as a merger, with Gateway becoming a Cadence division. Gateway's 150-person work force increases Cadence's personnel to a total of 900 employees. Gateway's founder and president, Prabhu Goel, reports directly to Joseph Costello, Cadence's president.

DATAQUEST ANALYSIS

Although the acquisition clearly strengthens Cadence's CAE market position, the company's ability to attack the electronic-systems market remains relatively weak. This weakness is particularly apparent when we compare Cadence with competing companies such as Daisy/Cadnetix, Mentor Graphics, Racal-Redac, and Valid Logic.

For example, Cadence offers only a handful of ASIC design kits, whereas its major competitors offer in the range of 100 to 200 such kits. From the Gateway merger, Cadence gains several standard components libraries (TTL, ECL, and CMOS) but only 12 ASIC design kits. Also, Cadence currently does not offer a printed circuit board layout product, which is an essential tool for system manufacturers. Moreover, Cadence's distribution and customer support channels have been tailored primarily to address the IC CAD marketplace, not the systems design marketplace.

The installed base of the Verilog simulator exists primarily within the IC design market, specifically semiconductor manufacturers, with only a handful of systems manufacturers currently using the products.

At the same time, the Verilog hardware description language (HDL) has been moving toward de facto standard status within the industry. Its inability to become the undisputed de facto standard is due to the limited marketing and distribution resources of Gateway Design Automation together with the growing presence of the VHSIC hardware description language (VHDL). VHDL currently is the IEEE standard, and it enjoys the backing of the U.S. Department of Defense. With Cadence applying its marketing muscle to the Verilog HDL, we believe that it may become an industry standard alongside VHDL, which Cadence also plans to support.

Whether or not Verilog HDL can coexist with VHDL depends on the commercial market's willingness to accept two hardware description languages. We believe that the market will accept a second standard provided Verilog demonstrates industry-wide staying power—and that will depend largely on Cadence's marketing savvy. If such coexistence between VHDL and Verilog HDL becomes a reality, Cadence will gain a powerful advantage over its competitors by delivering to its customers access to two powerful HDLs.

DATAQUEST CONCLUSIONS

Dataquest believes that the merger brings strength not only to Cadence, but to Gateway as well. Cadence's strength also stems from the fact that the company already has managed a successful merger: the early-1988 merger between ECAD and SDA Systems that resulted in Cadence Design Systems. In 1988, the combined company increased revenue 62.9 percent over the 1987 sales of the individual entities—an unusual after-merger result. This current merger clearly fills a gap in Cadence's product line, and Gateway's products are fully complemented by the Cadence EDA environment. Gateway, too, will surely benefit from the powerful combination of Cadence distribution channels and marketing know-how.

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Research Newsletter

THE EDA INDUSTRY'S IMPENDING OPEN SYSTEMS REVOLUTION

SUMMARY

Dataquest believes that this year's Design Automation Conference (DAC) marked the beginning of a new era in the electronic design automation (EDA) industry. The open systems revolution occurring in the workstation industry over the past five years is spilling over into the EDA software industry. We anticipate that this will spark open system, or framework, wars between the major EDA vendors. We also believe that the shift toward open systems will redefine the industry's competitive forces, requiring EDA vendors to compete along new dimensions. This newsletter addresses and analyzes the following issues:

- The impending open systems revolution
- Mentor Graphics' OpenDoor announcement
- The changing competitive forces in the EDA industry
- The positioning strategies for the 1990s

KEY ANNOUNCEMENTS AT DAC 1989

No technology breakthroughs were introduced at this year's Design Automation Conference (DAC), although common elements among industry suppliers included support for the VHSIC Hardware Description Language (VHDL) and the unveiling of several open EDA systems (i.e., open frameworks). Enormous implications stem from these and other recent open systems announcements.

The most significant open systems announcement came from Mentor Graphics, which unveiled its OpenDoor program. Briefly, OpenDoor, which will not be fully available until mid-1990, allows non-Mentor tools to be tightly integrated into the Mentor EDA environment. However, the level of integration—tight or loose coupling—varies according to what the third party desires. What is most surprising is the level of openness Mentor plans to offer. For instance, non-Mentor tools can be integrated at both the user interface and data base levels. A common data base allows a foreign application real-time access to Mentor's data structures and obviates the need for data base translators. This will dramatically improve the performance of heterogeneous EDA systems. Moreover, foreign tools will be permitted to coexist simultaneously on the screen with Mentor's tools.

Tight integration at the user interface and data base levels is a sharp departure from past practice. Until now, Mentor, like other EDA suppliers, permitted only loose coupling to its environment.

THE BEGINNING OF THE OPEN SYSTEMS REVOLUTION

For an EDA system to be truly open, its framework must offer at least the following capabilities:

- An easy, seamless integration of all kinds of third-party and proprietary electronic system design tools
- A user interface that can be customized and that allows all tools to have a common look and feel

Mentor is not the first company to disclose an open systems strategy. Cadence has been following this course for more than two years with its Design Framework product. Valid Logic also has been aggressively promoting itself as a champion of open systems. And recently, other EDA vendors such as Daisy/Cadnetix, Scientific Calculations, Silicon Compiler Systems, Teradyne, and Viewlogic embarked upon similar paths. Likewise, ASIC suppliers, including Fujitsu, Motorola,

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National Semiconductor, and NEC, that rely on EDA software to leverage their chip sales recently introduced open EDA environments for ASIC design.

It is clear that the EDA industry is on the verge of a metamorphosis. The predominantly closed systems of the 1980s will be replaced in the 1990s by open systems based on both industry-endorsed and de facto standards. In support of this conclusion, we point to the following indicators:

- An increasing number of EDA and ASIC vendors, in addition to industry leader Mentor Graphics, are either positioning themselves as advocates of open systems and/or supplying all or part of what we define as an open system. We believe that the aggregate has reached the critical mass necessary to force all vendors to supply open systems.
- It has become apparent that no single vendor can provide all of the different kinds of tools the market wants.
- Market demand for tightly integrated heterogeneous environments is very high.

We anticipate that, in the early 1990s, the EDA market will be evaluating vendors not only on particular application packages but also on the framework that binds these applications together. And just as workstation vendors compete on the number of independent software vendors (ISVs) supporting their machines, EDA vendors will compete on the number of third-party EDA tools tightly integrated into their framework. Similarly, EDA vendors will compete on how easy or difficult it is to tightly integrate the customer's proprietary tools into the framework.

However, we also believe that winning in the market will require more than just a robust framework, because the framework is merely the glue that holds the tools together. A broad set of production-proven design tools must be integrated into the framework and be readily available with the framework. The result of the EDA industry's open systems revolution will be the emergence of an array of proprietary frameworks. This emergence has begun. We believe that over the next three years, the combination of these frameworks will collectively define the industry standard. In the interim, vendors will battle to influence the final direction for the standard. Between 1991 and 1993, we anticipate a battle among framework titans, similar to that now occurring in the operating systems world between Open Software Foundation (OSF) and UNIX International.

MENTOR: ATTEMPTING TO DEFINE THE INDUSTRY'S FRAMEWORK STANDARD?

Open systems in general are not unique to the EDA industry. In other computer-related industries, the evolution of open systems has been characterized by one or more vendors with market power attempting to mold the standard to their advantage, either implicitly or explicitly. For example, in the workstation industry, Sun Microsystems aggressively made its Network File System a de facto standard. Likewise, in the board industry, Intel and Motorola defined open systems standards for bus interfaces (Multibus and VME bus) to leverage their own board and chip businesses. And in the mechanical CAD industry, Autodesk pioneered an open systems strategy that was instrumental in achieving a 64 percent compound annual growth rate (CAGR) over the past five years.

We believe that Mentor Graphics, with its OpenDoor program, will attempt to make its framework (or a close derivative) an EDA industry standard. In support of this, we point to the fact that Mentor announced the OpenDoor program one year before it will be available. Announcing far in advance is often aimed at preempting competitive offerings. We believe that Mentor's goal was targeted, at a minimum, at either preempting or influencing the direction of other emerging framework standards, such as those being generated by the CAD Framework Initiative (CFI). (The CFI is a consortium chartered to define a set of standard framework guidelines.)

Preemption is not a new strategy to Mentor Graphics. Most recently, the company announced a VHDL-based system 9 to 12 months before its delivery date. The goal, it appears, was to slow the penetration rate of other hardware description languages, such as Gateway Design Automation's Verilog HDL.

We believe that announcing a year early was also an attempt by Mentor to muffle the closed system guns continuously fired by its competitors. In our view, if Mentor had not disclosed its open systems strategy, it would have begun to suffer some erosion of its market position.

From a technological perspective, Mentor claims that its framework is not EDA specific. Instead, it was designed to accommodate design tools from all Mentor's design automation

divisions: CAE, IC, PCB, CASE, electronic system packaging (MCAD), and CAP (documentation). Thus, Mentor has the luxury of receiving continuous internal feedback on a highly diverse, yet related, set of EDA framework requirements. In our view, this may give Mentor's framework a technological edge over frameworks from competitors, because it has the potential to be more accommodating and robust than any which have been, or could be, developed by a single EDA competitor, or perhaps even the CAD Framework Initiative.

On the downside, however, Mentor's first release of its new software will not run under a truly standard UNIX operating system or a standard windowing system. Instead, the UNIX version will be Mentor's own subset of UNIX from AT&T and Berkeley, and the windowing system will remain proprietary. Third parties, however, can use X Window graphics calls, which Mentor's system will translate to the proprietary graphics calls. The user interface will be MOTIF compliant. Later releases of the upcoming software will be based on OSF's AIX and X Window standards. Despite apparent migration toward standards and its open systems announcement, the company still supports only the Apollo platform, which keeps its environment closed to EDA software that does not run on that machine. This restriction has prompted many Mentor competitors to continue labeling Mentor's system as closed. We believe that Mentor will be able to deflect this criticism only when it fully supports OSF AIX and X Window standards. We believe that running on a single platform is Mentor's most formidable nemesis. In fact, much of the business that Mentor is unable to capture is because it does not run on the Sun platform.

THE KEY TO DEFINING THE FRAMEWORK STANDARD: MARKET POWER

Using an open framework as the hook to capture business is not a new concept in the EDA industry. EDA Systems used the same blueprint during its start-up phase several years ago. The company tried to make a business of selling frameworks, hoping that its framework specifications would garner enough support to become an industry standard. This never happened. We believe that there were several reasons for this, the common denominator being that EDA lacked market power. EDA attempted to generate market power by gathering third parties to adopt its framework, but this proved unsuccessful. The risk associated with espousing the start-up company's framework was high, because it was believed that EDA did not have the critical mass necessary to successfully deploy such a strategy. Similarly, EDA did not have any design tools to leverage its framework. Furthermore, framework technology, as well as the concept of a framework, was still in its embryonic stage. The collective result was EDA Systems' inability to provide the requisite incentive for enough EDA tool suppliers to fully endorse its framework to become an industry standard.

In contrast, Mentor Graphics wields market power. Arguably, it has the most market power among all participants in the EDA industry. We believe that Mentor Graphics' present market power can be measured by the following parameters:

- Market Share—Mentor has the largest revenue market share (12.6 percent), which is 4 points higher than its closest competitor (Daisy/Cadnetix Inc.). We expect Mentor's market share to be higher by the end of 1989.
- Installed Base—Mentor's installed base of EDA systems is the largest in the industry (14,000 to 15,000 at the end of 1988). This is 30 percent more than its closest competitor, Daisy/Cadnetix.
- Stability—Virtually all of Mentor's growth has been sustained through internal development, as opposed to mergers and acquisitions, permitting the company to focus on product development. The company's cash and marketable security reserves of $130 million as of the end of the second quarter of 1989 provide even greater stability.
- Broad Product Line—Mentor has a solid market position across all three EDA domains (CAE, PCB, and IC). In addition, Mentor has separate divisions devoted to electronic system packaging and mechanical CAD (MCAD), computer-aided software engineering (CASE), and computer-aided publishing (CAP) for documentation. No other EDA vendor has addressed this much of the design automation problem.

In Dataquest's view, unlike EDA Systems, Mentor Graphics may have both the requisite technology and the market power to attract third parties to develop code around the Mentor framework. This, of course, is a linchpin of the whole strategy. However, if enough third-party support migrates to another framework, that framework will become the industry standard and Mentor will be forced to conform.

Thus, the number of ISVs that tightly integrate their tools into the Mentor environment will be a test of Mentor's market power. It is important to note that third parties may not be in a position to fully support multiple frameworks. Another test will be the amount of influence Mentor can exert over the framework standards being developed by the CAD Framework Initiative.

STRATEGIC POSITIONING FOR THE NEW EDA INDUSTRY

Because the market will begin to shift its focus toward the framework, we anticipate that many EDA companies will be forced to adopt new positioning strategies. In our view, an example of a good strategic positioning model in an impending open systems climate is the strategy used by Sun Microsystems several years ago. Sun defined and aggressively promoted industry standards, simultaneously using those standards as leverage to sell its workstations. A closer look at the execution of Sun's strategy proves helpful in deriving the EDA positioning model.

Between 1985 and 1986, Sun began aggressively challenging Apollo, Digital Equipment, Hewlett-Packard, and IBM. Its workstations consistently offered 1.2 to 2.0 times better price/performance ratios than the competitors, but this alone was not enough to catapult Sun to the top.

The added punch came from Sun's positioning itself as the pioneer in heterogeneous computing, as well as a champion of standards. Here the strategy was to offer a workstation based on a standard backplane, a "standard" UNIX operating system, and a local area network—SunNet—that could tightly link computers from different manufacturers running dissimilar operating systems.

The core of SunNet consisted of Ethernet and TCP/IP, both of which were publicly available, and the Network File System (NFS), which was the upper layer protocol developed by Sun to link dissimilar computers and operating systems. NFS, in essence, was the enabling technology that engendered heterogeneous computing. It was also the critical value-added by Sun. NFS was even more powerful from a marketing standpoint, as Sun used it to position itself as the workstation manufacturer spearheading the march toward heterogeneous computing environments. The market clearly wanted this kind of topology, for, by the end of 1986, Sun licensed NFS to more than 80 computer vendors and universities.

Sun's success can be traced to the company's aggressive positioning along three dimensions: as a champion of standards, as a pioneer in heterogeneous computing, and as the aggressor constantly pushing the price/performance curve. The importance of convincing ISVs to configure their software to its workstations was also critical and cannot be overlooked. These ingredients, combined with a well-orchestrated marketing plan, provided the leverage necessary to wrest market share leadership from Apollo and keep Digital Equipment, Hewlett-Packard, and IBM at bay.

APPLYING THE SUN MODEL TO THE EDA INDUSTRY

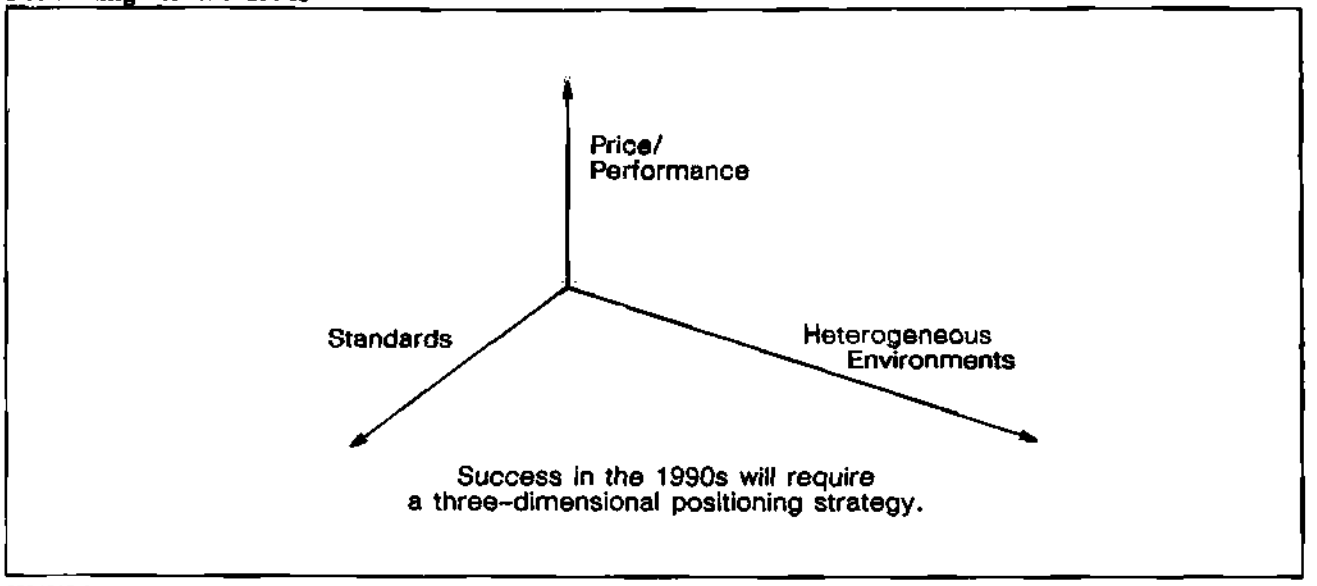
Albeit Sun used its positioning formula in the workstation industry, we believe that a derivative can be applied with equal success by EDA vendors over the next five years. In fact, this appears to be Mentor's underlying strategy—to use the openness of its framework as leverage to sell its own design automation tools, simultaneously making large portions, if not all, of its framework an industry standard and using these standards as further leverage to sell its own products. We believe that the three elements of Sun's model that can be applied in the context of the EDA industry are heterogeneity, standards, and the price/performance ratio (see Figure 1).

Heterogeneity

Offering a framework that supports tightly integrated third-party and proprietary tools will allow an EDA vendor to position itself aggressively along the heterogeneous vector. Sun, of course, used NFS in a similar manner. Mentor and Cadence, for example, are positioning themselves as the EDA vendors with the requisite enabling technology to support such environments.

Cadence, of course, has been doing this for longer and has a significant lead on Mentor in terms of market perception. However, because Cadence's customers are predominantly IC design groups, this perception barely exists in systems design groups. On the other hand, the fact that Cadence supports seven different workstations will be a significant boost to its open systems marketing strategy.

FIGURE 1
Positioning for the 1990s



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Source: Dataquest
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Standards

As a first step toward making its framework an industry standard, an EDA vendor will require support from other EDA tool suppliers. The more vendors that adopt its framework, the closer the framework moves to becoming a de facto standard. As an incentive to get third parties to adopt their framework, EDA vendors will offer their distribution channels to the third parties (e.g., OEM and joint marketing agreements).

Mentor, however, appears to be taking an additional step toward making its framework a standard. Just as Sun did with NFS, Mentor plans to license its framework to third parties, including competitors. Toward this end, Mentor already has begun soliciting third parties to espouse its framework. Fifteen software vendors, including VLSI Technology and Gateway Design Automation, announced initial support for the Mentor OpenDoor program at the Design Automation Conference. And, Mentor plans to publish a catalog, similar to Sun's Catalyst catalog, comprising the third-party EDA vendors that support its framework. Widespread adoption of its framework will also give Mentor greater influence over the direction of the CAD Framework Initiative (CFI).

However, a core issue is the price Mentor will charge third parties to integrate into its environment. Mentor plans to announce the pricing plan by the end of 1989. Pricing the OpenDoor program so that it does not alienate third parties, while at the same time charging enough to offset its integration support services, will be a significant challenge for Mentor.

Price/Performance Ratio

Providing an open framework that can be or is stacked with tightly integrated proprietary and third-party tools should enable higher design throughput. We believe that the market will equate this to price/performance leadership.

WHY OPEN UP?

Providing the core framework will give an EDA vendor a great deal of control over the customer account. Account control always has been a key part of EDA vendors' business strategy. In the past, Mentor, like other vendors, gained account control by selling closed turnkey systems. A closed turnkey system forces customers to rely predominantly on a single supplier for hardware, software, and support. However, an increasing portion of the market is now demanding unbundled software. We anticipate that this trend will force traditional turnkey suppliers such as Mentor to sell more unbundled software, which would normally result in the loss of a certain amount of account control. Providing the core framework for EDA will act to preserve control over the account.

Moreover, by allowing third parties to develop applications around its framework, an EDA vendor can offer tightly integrated heterogeneous design automation environments—exactly what the market is demanding.

However, by opening its framework, an EDA vendor makes a new assumption: The company believes that even though it may lose a certain level of business to its third-party partners, this loss will be offset by the additional business captured through its open framework.

OPENDOOR OR TRAP DOOR?

For ISVs, the thought of tightly integrating into the Mentor environment is intriguing. The allure is the opportunity to latch onto Mentor's coattails—that is, leverage Mentor's sales, marketing, and distribution channels to promote and sell its own product. Even more significant, third parties will have access to Mentor's huge installed base of EDA systems. However, there is a potential downside for ISVs. First, there is a serious question as to whether the ISVs' tools will suffer any performance degradation by adopting the Mentor framework. Mentor must demonstrate that this will not occur if it hopes to get third parties to adopt its framework.

Second, ISVs that have products competing directly with products from Mentor must be assured that they will not be put at a disadvantage by adopting the Mentor framework. We believe that this will also be an enormous challenge for Mentor. In essence, Mentor is attempting to be a framework supplier to other EDA companies, which requires assurance of a tight customer-supplier relationship.

Finally, Mentor must convince third parties that its framework will become the template for the industry standard. Initially, this will be a tremendous challenge. Mentor's framework, or portions of it, will become a standard only if endorsed by either a large number of small to medium-size EDA vendors, a few large EDA vendors, or, of course, the CFI. But Mentor is caught in a paradox: Its framework cannot become an industry standard until enough vendors support it, but those vendors will not *fully* support Mentor's framework until it becomes an industry standard.

DATAQUEST CONCLUSIONS

Dataquest believes that until Mentor is able to support operating system and windowing system standards, the company will not make its entire framework a standard. However, we anticipate that Mentor will have the muscle to define some portions of the final standard framework. We believe that, unless Mentor's framework is so technologically superior to the others, the combined market power of other large EDA vendors, such as Cadence, Daisy/Cadnetix, and Valid Logic, will outweigh Mentor's market power and allow the combination of these vendors to define the majority of the standard.

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HIGH–TECH BUSINESS OPPORTUNITIES IN INDIA

INTRODUCTION

Key opportunities exist for high–technology business in India. This newsletter discusses important recommendations by the Joint Scientific Committee, which was appointed by India's Prime Minister Rajiv Gandhi to outline a microelectronics blueprint for the next 10 years. The committee recommends free–market–driven, private–sector development of the electronics components and systems business in India, collaborating with leading foreign companies as needed. The Indian government would play a guiding role in defining technology road maps and coordinating industrial strategies.

The committee has identified several areas for short–term business development. These include design centers for ASICs, microprocessors, and gallium arsenide microwave ICs; semiconductor foundry facilities; and advanced printed circuit board and packaging technology. The markets for these technologies will include low–cost personal computers, office automation products, consumer appliances, telecommunications, and industrial automation. We at Dataquest believe that this information is of particular interest to our clients in the semiconductor design, manufacturing, equipment, and materials industries.

BACKGROUND

The world has seen the meteoric rise of countries such as Japan, Korea, and Taiwan, based on carefully orchestrated industrial strategies for penetrating all segments of the electronics food chain, from discrete devices to complete systems. Top government policy makers in India are increasingly aware of the importance of microelectronics and its value–added leverage in electronic systems. As shown in Table 1, the Department of Electronics has outlined ambitious production levels for India to become a world player in the electronics business.

Table 1

Semiconductor Components and Electronics Production
(Millions of Dollars)

Year	Annual Components Production	Annual Electronics Production
1988	$ 10	$ 4,500
1995	$ 800	$15,000
2001	$1,600	$30,000

Source: Department of Electronics
Government of India

India is the 10th-ranked industrial country in the world, with a population of 800 million and a gross national product of $225 billion. It has the third-largest engineering and scientific human resource base in the world. The English language is used widely for business communication. Recently, India has emerged as a powerhouse in software products and services. To round out its high-technology portfolio, India is currently embarking into VLSI design and manufacturing to meet the needs of advanced electronic systems.

BUSINESS OPPORTUNITIES IN INDIA

The following areas have been identified by the committee as short-term priorities for high-technology business development in India:

- VLSI design centers—The committee proposed that design centers be set in major industrial cities in India to encourage VLSI use in reducing system costs and improving system performance. Dataquest believes that significant opportunities exist for ASIC design, software, and CAD companies in India.

- VLSI fabs for ASICs—World-class semiconductor manufacturing capability is essential to India's electronic systems business success. Collaboration opportunities exist in setting up fabs for IC manufacturing. A high level of compatibility with ASIC design and software tools will be required. Foreign ASIC companies with a full range of CAD, software, and manufacturing capabilities will have an advantage in penetrating the Indian market.

- Microprocessor and digital signal processor design—The Indian government considers the development of microprocessors and digital signal processors essential for advanced system architectures. Companies with expertise in these areas have an opportunity for licensing their technology and developing a low-cost manufacturing source for their products.

- Microwave IC design—Domestic design capability development for GaAs microwave ICs for satellite communications is a priority. Opportunities exist for design and CAD collaboration. The devices will be manufactured by relevant partners at foundries in either Japan or the United States.

- Advanced printed circuit boards and VLSI packaging—The Indian government has emphasized the need for multilayer board technology and high-pin-count VLSI packaging using surface-mount and TAB techniques. Opportunities exist for semiconductor and board-assembly companies to expand in India.

DATAQUEST CONCLUSIONS

Dataquest believes that India offers exciting opportunities for high-technology companies to expand their markets. With its newly liberalized industrial policies, its tremendous technical resources, and its huge domestic markets, India could well be the next Asian economic miracle.

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RACAL-REDAC SCORES MAJOR WIN, ACQUIRES HHB SYSTEMS

SUMMARY

Daisy/Cadnetix, headquartered in Mountain View, California, last month sold its Mahwah, New Jersey-based wholly owned subsidiary, HHB Systems, to Racal-Redac of Great Britain, for $19 million in cash. The deal closed on May 31, 1989. This newsletter addresses the following issues:

- Motivation behind the purchase and sale
- Strategic significance of the acquisition
- Structure of the deal
- Impact on the HHB Systems' OEMs

BACKGROUND

In the second quarter of 1988, Cadnetix, an independent, publicly traded manufacturer of printed circuit board (PCB) layout systems, acquired HHB Systems, a firm specializing in digital logic simulation and test automation, for 7.2 million shares of Cadnetix stock. When the deal closed November 8, 1988, Cadnetix's stock was trading at approximately $8 per share. This puts the acquisition price at $60 million.

In the fourth quarter of 1988, Daisy Systems acquired Cadnetix to obtain its PCB layout technology, products, distribution, and customer base. Cadnetix's ownership of HHB Systems was incidental to the deal. Daisy had little interest in HHB Systems, which is best known for its CADAT logic simulator. Total revenue for Cadnetix in 1988 was $66.9 million; Daisy recorded revenue of $121.4 million in 1988.

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Behind the Deal: Daisy/Cadnetix's Perspective

Daisy/Cadnetix Inc. has been actively looking to divest HHB Systems because there is duplication of products between the two companies (i.e., Daisy/Cadnetix and HHB Systems.) Since the time of Daisy's acquisition of Cadnetix, HHB Systems has been operating as an independent, wholly owned subsidiary of Daisy/Cadnetix Inc. The key overlapping areas are logic simulation, hardware acceleration, and hardware modeling. Daisy's core logic simulation products include the Daisy Logic Simulator (DLS), the GigaLogician/MegaLogician hardware accelerators, and the PMX Hardware Modeler. HHB's CADAT logic simulator, CATS hardware accelerator, and CATS Hardware Modeler compete directly with the three Daisy/Cadnetix products.

HHB Systems' revenue in 1988 was $17 million (not including the SimuCAD division), 40 percent of which was derived from OEM sales. OEMs include Racal-Redac, Zuken, ComputerVision, Data I/O, Calay, Silvar-Lisco, Harris Semiconductor, Schlumberger Technologies, Fujitsu (Japan), NCR Microelectronics, and Scientific Calculations.

Behind the Deal: Racal-Redac's Perspective

Dataquest believes that the following are prerequisites to continued growth in the electronic design automation (EDA) market:

- Providing customers with front-end design capabilities (i.e., design entry, simulation, test automation) and back-end design automation tools (e.g., PCB layout, tight links to manufacturing) for both chip- and PC board-level design.

- Tight coupling between the front-end and back-end design tools.

Racal-Redac, which recorded revenue of $75 million in 1988, had been addressing the first issue by signing on as an OEM of HHB Systems' simulation products. (Seventeen percent of HHB's revenue came from Racal-Redac in 1988.) But an OEM agreement in the electronic design automation industry is often a double-edged sword. On the one hand, it allows the OEM to immediately fill a product void. But, on the other hand, it typically does not permit the tightest possible integration between products, because such integration requires extensive modifications to each of the products. Thus, Racal-Redac was unable to seamlessly integrate its PCB layout tools with HHB Systems' simulation products, although a certain level of integration was obtained as a result of both companies' products running on the same computer platforms.

Cadnetix's acquisition of HHB Systems dramatically affected Racal-Redac's position with respect to its front-end strategy. Cadnetix, a direct competitor, gained control of Racal-Redac's simulation offerings. This left Racal-Redac with an uncertain position in the simulation market, an area of strategic importance to the company.

Daisy's subsequent acquisition of Cadnetix flipped the situation 180 degrees, because duplication of products between Daisy and HHB Systems forced Daisy to find a buyer for HHB Systems. Thus, Racal-Redac was presented with an opportunity to permanently solve its simulation dilemma.

RACAL-REDAC SCORES A MAJOR WIN

Dataquest believes that Racal-Redac has scored a major victory in the chain of events leading to its acquisition of HHB Systems. Positives for Racal-Redac include the following:

- Racal-Redac paid $19 million for HHB Systems, which is three to four times less than Cadnetix paid for HHB Systems just one year earlier.
- Its tenuous position in the CAE market has been strengthened considerably now that it owns a solid simulation and test automation company.
- The company is now in a position to compete more effectively against such heavyweights as Mentor Graphics, Daisy/Cadnetix, and Valid Logic Systems.
- It can now begin to tightly integrate its PCB layout products with the HHB simulation tools.
- The newly acquired simulation and test products will provide significant market leverage for Racal-Redac's PCB layout products, allowing the company to more aggressively expand its position in the electronic design automation field.

STRUCTURE OF THE DEAL

Details on the structure of the deal between Daisy/Cadnetix Inc. and Racal-Redac are as follows:

- Daisy/Cadnetix Inc. received $19 million in cash from Racal-Redac.
- All assets and business of SimuCAD, a division of HHB Systems, will remain with Daisy/Cadnetix.
- Daisy/Cadnetix retains OEM rights to all of HHB Systems' products.
- HHB Systems will operate as a wholly owned subsidiary of Racal-Redac (e.g., the two companies will maintain independent sales forces).

IMPACT ON HHB'S OEMS

The sale of HHB Systems to Racal-Redac will have minimal impact on HHB Systems' OEMs because most of them began rethinking their simulation strategies after Cadnetix acquired HHB Systems.

However, logic simulators are becoming increasingly important to electronic engineers, and supplying proven simulation capabilities to customers is a must for EDA vendors. But logic simulators are complex and difficult to design. HHB Systems is one of the few EDA suppliers to offer a proven logic simulator for OEM resale, which is why so many third-party EDA companies are OEMs of HHB's product.

According to Racal-Redac, it plans to maintain all of HHB Systems' OEM relationships. However, Dataquest believes that OEMs such as ComputerVision, Scientific Calculations, and Zuken, which compete directly against Racal-Redac in the PCB layout market, eventually may phase out their OEM agreements with HHB Systems. We expect that a major challenge for Racal-Redac will be to keep its competitive OEMs from migrating away from the HHB Systems products.

Dataquest also believes that competitive OEMs must restructure their relationship with HHB Systems to ensure that they will not suffer any major disadvantages (e.g., price). Nonetheless, because of the inherent disadvantage of having a direct competitor supplying a critical piece of a company's product line, we anticipate that several of HHB's OEMs may attempt to offer alternate simulation products. Examples include the Verilog simulator from Gateway Design Automation, the Vantage Spreadsheet from Vantage Analysis Systems, and the HILO simulator from GenRad.

DATAQUEST CONCLUSIONS

Dataquest views the acquisition of HHB Systems by Racal-Redac as a significant boost for both companies. HHB Systems has been operating in a state of uncertainty since late 1988, when it became clear that it did not fit into the Daisy/Cadnetix Inc. picture. HHB Systems is now in a position to focus more effectively its efforts on product development.

Also, with the strong financial backing of the Racal Electronics Group, HHB Systems will be able to focus more extensively on the development of new products.

HHB Systems also will benefit significantly from Racal-Redac's solid presence in the European (55 percent of Racal-Redac's revenue) and Asian (34 percent of Racal-Redac's revenue) markets, regions that Dataquest believes will grow at compound annual growth rates (CAGRs) during the next five years of 15.2 percent and 17 percent, respectively.

We believe that Racal-Redac has several challenges ahead. The company must tightly integrate HHB Systems' products into its electronic design automation environment. Racal-Redac also must piece together an infrastructure that allows for effective management of HHB Systems, establish a strong presence in the ASIC design market, and, finally, Racal-Redac must position itself as a full-line EDA tool supplier and convince the market that its solutions are superior to market leaders such as Daisy/Cadnetix, Mentor Graphics, and Valid Logic Systems.

Ron Collett

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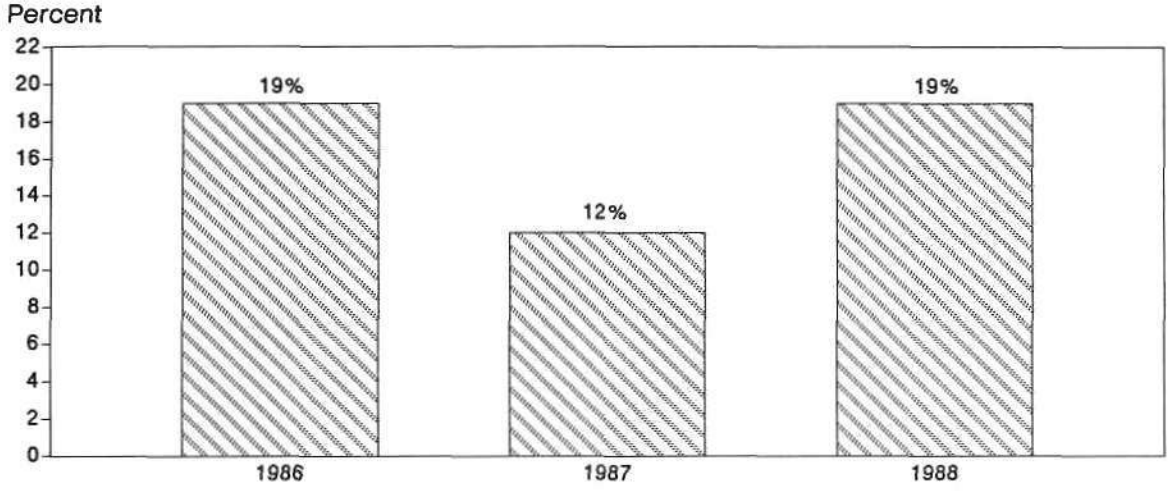
ELECTRONIC DESIGN AUTOMATION MARKET REBOUNDS

SUMMARY

Rebounding from its modest 12.1 percent growth in 1987, the electronic design automation (EDA) market forged ahead at 18.6 percent growth in 1988. Spearheading this expansion was the computer-aided engineering (CAE) sector, which grew by 20.8 percent, with revenue reaching $1.12 billion. The PCB layout market exhibited equally strong growth, jumping 20.3 percent to $884.0 million. The IC layout market showed only a moderate increase of 8.7 percent, however, advancing to $333.6 million. Figure 1 illustrates the growth trend over the past four years.

Figure 1

Worldwide EDA Market Percentage Growth Rates



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This newsletter discusses our new worldwide EDA market review and forecast (see Tables 1 through 7 at the end of this document) and addresses the following issues:

- Signs of maturity in the EDA market
- The forces behind consolidation in the EDA arena
- What the mergers and acquisitions did for the players
- Analysis of 1988 market growth
- Regional analysis of the EDA market (North America, Asia, Europe)
- Changing EDA business models
- 1988 events impacting EDA's future
- Future opportunities in EDA

EDA INDUSTRY MOVES TOWARD MATURITY

What makes 1988's robust expansion most significant is that it occurred while the industry averaged more than one merger or acquisition per month. Clearly, consolidation and the volatility of the EDA industry failed to shake the market's confidence in either suppliers or technology. Yet market confidence will be short-lived for those merged vendors that fail to demonstrate positive short-term gains; customers will perceive lackluster growth as a sign of vendor instability and will turn quickly to suppliers demonstrating strength and longevity. It is important to note that many of the mergers and acquisitions occurred late in the year and had little impact on the 1988 growth. Market reaction to those mergers will become apparent in 1989 and 1990.

Dataquest believes that this level of consolidation demonstrates that the industry has begun moving into its adolescence. Yet consolidation has had a negligible effect on concentration: the top ten vendors captured 53.2 percent of revenue in 1988, compared with 50.9 percent in 1987. Similarly, the top 20 held 71.8 percent of revenue in 1988, up slightly from 68.7 percent in 1987. Insignificant changes in concentration indicate that more consolidation can be expected.

Moreover, the leading EDA vendor, Mentor Graphics, commands only a 12.6 percent market share, which is a far cry from market dominance. Daisy, with its acquisition of Cadnetix, now holds an 8.8 percent market share, pulling to within striking distance of Mentor. And Valid's string of acquisitions has brought the company 6.0 percent of the EDA pie. In sum, 1988 was the year that market leaders were forced to become stronger, either by acquisitions, mergers, or internal expansion; despite the consolidation, the industry remains highly fragmented.

THE FORCE BEHIND CONSOLIDATION

Several reasons for the high rate of consolidation stand out. Discussion of the more important reasons follow.

Critical Mass

In some instances, vendors recognized that competing with Mentor Graphics would first require reaching "critical mass." Other vendors concluded that simply keeping pace with Mentor's EDA growth (35.6 percent in 1988), or narrowing its market share lead, could be accomplished only through mergers or acquisitions.

Filling Product Voids

Competitors also acknowledged that unsuccessful and undeveloped product voids had to be filled immediately, thus precluding in-house product development. Ostensibly, the urgency was in response to the market's demand for integrated, end-to-end EDA solutions. But merging products from different companies does not necessarily result in a tightly integrated EDA product line. In fact, it usually does not. Dissimilar data bases and user interfaces, for example, present a roadblock to seamless integration. Over the long term, there is little doubt that vendors that acquire products through acquisitions will tightly integrate these tools into their environments, but this is by no means an overnight process.

Product Line Differentiation

With compute environments becoming more standardized across the EDA industry (e.g., platform, operating system, networking, graphics), vendors can no longer differentiate themselves along the "compute dimension." In essence, the workstation is becoming somewhat of a commodity. So the more application software an EDA vendor acquires or develops, the more the vendor distinguishes itself from its competitors.

End-to-End Solution

Expanding product line breadth instantaneously via acquisitions is advantageous from a market positioning standpoint. It provides a tactical edge for competing against focused niche players that are selling tools accredited with either functionality or performance superiority. Here, the goal is to offset that superiority by providing the market with an "integrated" product line together with one-stop shopping. One-stop shopping simplifies service and support, which is extremely important to schedule-conscious EDA managers, many of whom do not relish the idea of dealing with a myriad of suppliers.

Although a full-line, integrated product suite is beneficial, Dataquest believes that the EDA market will not adopt tools from a full-line supplier if these products exhibit any substantial disparities in either performance or functionality when compared with competitive offerings. Gateway Design Automation, with its Verilog simulator, is a prime example of a niche player that continued to haunt the full-line suppliers in 1988. Companies are buying EDA tools primarily to increase productivity and slash time to market. EDA packages unable to deliver a noticeable edge in these areas will be unsuccessful in the market, even if they come from a vendor offering a plethora of "integrated" EDA products. As a result, "integration" frequently will take a back seat to performance and functionality. However, this will not always be the case. Dataquest believes that use of a truly integrated EDA intertool system (i.e., common data base, common user interface, intertool communication) will slash more time off the design cycle than a set of loosely coupled, high-performance tools. As a result, individual tool capabilities will become secondary to integration, as vendors begin delivering truly integrated systems. Of course, the optimal situation is to provide the market with tightly integrated, full-featured, high-performance tools—a goal that EDA vendors continue to strive toward.

WHAT THE MERGERS AND ACQUISITIONS DID FOR THE PLAYERS

The slew of mergers and acquisitions in 1988 changed the competitive forces within the EDA industry significantly. In almost every case, the combination yielded a more competitive company in one area or another. These mergers and their effects include the following:

- Daisy's acquisition of Cadnetix thrusted Daisy into the top slot in the PCB layout arena, a significant accomplishment given that Daisy was at the bottom in 1987.

- Cadnetix's purchase of HHB Systems gave the company a solid base of simulation and automatic test generation technology in which to complement the firm's increasing strength in PCB layout. However, Cadnetix did not anticipate the initially hostile takeover orchestrated by Daisy Systems. (The Daisy/Cadnetix/HHB Systems merger resulted in duplication of products in several key areas, including simulation, leaving Daisy with little choice but to either sell part or all of HHB Systems.)

- SDA's merger with ECAD, which resulted in a renaming of the combination to Cadence Design Systems, provided the firms with the critical mass and product-line depth needed to accelerate them into a leadership position in IC design tools.

- Cadence's acquisition of Tangent Systems from Intergraph further strengthened Cadence's product line (with Tangent's auto place-and-route software for sea-of-gates gate arrays) and customer base.

- Silicon Compiler Systems' acquisition of Caeco helped reposition it from a silicon compiler company to a full-line supplier of IC design tools, which was necessary in order to compete with Cadence, Mentor, Valid, Silvar-Lisco and Seiko.

- Valid Logic's purchase of Analog Design Tools catapulted the firm into leadership position in the analog design automation market.

- Valid's acquisition of Calma (IC division) gave Valid an installed base of 3,000 seats and the opportunity to significantly grow its fledgling IC layout business.

- Valid's purchase of Integrated Measurement Systems yielded a presence in the prototype ASIC verification market, which sets the stage for the company's foray into the automatic test equipment (ATE) market.

- Mentor Graphics' purchase of Trimeter Technologies in 1989 was initiated to bring logic synthesis technology into the Mentor product fold.

- Mentor's acquisition of Tektronix's CAE Systems Division increased the Mentor installed base and gave Mentor computer-aided software engineering (CASE) technology.

- Mentor's purchase of Contour Design Systems bolstered Mentor's analog design automation technology.

- Cadam's purchase of PCAD gave the former a low-end PCB layout product to complement its high-end Prance offering.

- Prime Computer's merger with ComputerVision moved Prime into the EDA field, while ComputerVision received an infusion of marketing and sales support from Prime.

Can The Niche Player Survive?

Dataquest expects 1988's market forces to remain in place throughout 1989 and into 1990, resulting in further consolidation. Can the niche player remain viable? Surviving as a niche player will require three elements, as follows:

- Significant product differentiation

- Integration of the tool into an existing design environment must be a straightforward task.

- Diversified distribution channels and strategic alliances must be established (e.g., direct sales, a few strategic OEMs, reference selling, joint marketing).

ANALYSIS OF 1988'S MARKET GROWTH

Standards

Further proliferation of standards (e.g., platform, operating system, networking, graphics, EDIF) was a significant factor driving 1988's expansion. The market has been far more receptive toward EDA solutions configured around nonproprietary compute environments. Dataquest believes that the continuing push toward standards will play a major role in fueling continued growth (e.g., VHDL, UNIX, X-Windows, FDDI, CAD Framework Initiative).

Renewed Confidence

Also contributing to the growth was renewed confidence in the technology and suppliers. For example, the number of $1 million-dollar orders jumped significantly in 1988. However, the market remains very sensitive to delivery delays. Addressing this issue will be critical for recently merged or acquired vendors.

Similarly, because nearly all EDA systems are unavoidably shipped with software bugs, among the most important deliverables to today's EDA market is customer service and support (e.g., helping customers to work around inherent system deficiencies). This fact was confirmed in Dataquest's 1988 end-user survey, in which the single most common reason cited for not repurchasing from a vendor was poor support and service. Moreover, consolidation and instability of the EDA industry makes rapid, uninterrupted, quality service even more important—especially in the Far East, where mergers and acquisitions are an unfamiliar phenomenon.

Workstation Performance

The dramatic increases in workstation performance was also a major factor behind 1988's growth. EDA managers saw productivity gains reaped from workstations churning away at 4 to 10 mips. Time to market is the primary litmus test used by EDA managers in evaluating the tools—whether the tools will help shrink product development cycles—and today's systems are yielding noticeable return on investment (ROI) in this domain. The competitive pressure on workstation manufacturers to double performance every two years will undoubtedly provide further leverage for EDA market expansion.

Tumbling ASPs

In an effort to grab market share (installed base), both workstation vendors and EDA suppliers continued slashing prices in 1988. EDA suppliers and workstation vendors recognize that increasing market share now, while their respective markets are riding high-growth curves, is imperative. Capturing market share when the industry reaches its maturing, slower growth stage will be far more difficult.

More Expensive Systems

Much of the industry's revenue growth resulted from vendors shipping systems that have high software value (e.g., PCB layout). Vendors have a greater incentive to ship these kinds of systems because margins are so much higher in comparison with front-end products (e.g., design entry).

EDA MARKET REGIONAL ANALYSIS

North America

In 1988, the North American market for EDA tools grew 12.2 percent over 1987. Much of this growth stems from sales related to spending by the military and aerospace industries, which were preparing for possible cuts in defense projects due to the uncertainties of a new administration.

Similarly, EDA companies received an increased number of $1-million-to-$2-million orders from U.S. customers, especially in the military and aerospace industries. The U.S. semiconductor and computer industries also consumed large quantities of EDA tools.

Market Leadership

Mentor continued to dominate North America, outpacing its nearest competitor, Daisy, by nearly a 2:1 margin. Mentor's $143.6 million revenue translated to a 14.8 percent market share, up from $112.6 million and a 12.9 percent market share in 1987.

However, both Daisy and Valid gave Mentor reason to start looking over its shoulder, as each firm's North American EDA revenue doubled from the previous year. Daisy recorded revenue of $87.3 million, equivalent to a 9.0 percent market share, and Valid weighed in at $74.8 million, giving the company a 7.7 percent slice of the pie.

Daisy's North American growth was due primarily to its acquisition of Cadnetix, and much of Valid's increase came from its acquisition of Analog Design Tools and Integrated Measurement Systems. It is highly doubtful that the firms can repeat 1988's growth without additional acquisitions or mergers.

Although Mentor enjoyed considerable success in 1988, Apollo's eroding position in the marketplace made it difficult or impossible for Mentor to penetrate some accounts. This fueled speculation that Mentor would complement its Apollo-based offering with a second platform. Dataquest believes that the platform issue may have been solved with Hewlett-Packard's acquisition of Apollo, which resulted in workstation market-share leadership for HP/Apollo, as of the end of 1988 (30.4 percent).

But the acquisition also creates a conflict between HP/Apollo and Mentor, because HP sells not only workstations, but EDA software that competes with Mentor's product line. With the acquisition, HP controls the workstations that Mentor purchases from Apollo. Dataquest believes that HP may address the problem by selling its EDA business

to Mentor in exchange for Mentor's commitment to port to the HP platforms, since HP has not been a major player in EDA software. In fact, of HP's $70.4 million in 1988 EDA sales, only $14.0 million was in software. The revenue HP would derive from Mentor selling HP workstations would substantially outweigh its loss of EDA software business.

Asia

The Asian EDA market grew by 27.3 percent in 1988, from $524.0 million in 1987 to $667.0 in 1988. Dataquest believes that several factors explain the Asian market's growth in 1988, as follows:

- Rebound from market sluggishness in 1987 resulted from the yen's appreciation.
- After factoring the yen's appreciation into 1988's market growth, actual growth was approximately 16.0 percent.
- Profitability for Japanese semiconductor manufacturers over the past two years was very high, allowing for increased investment in EDA tools.

Market Leadership

What is most significant about the Asian market is the marginal penetration by U.S. vendors: Four of the top five market-share slots are held by Japanese suppliers, although Mentor Graphics remains the leader with revenue of $74.0 million and an 11.1 percent market share. Mentor's strength was primarily due to its CAE business, which accounted for more than 70 percent of its Asian revenue.

Following Mentor are Zuken ($57.9 million), Fujitsu ($53.8 million), NEC ($53.4 million), and Seiko ($42.2 million). Despite the lack of U.S. penetration, Dataquest anticipates that U.S. EDA vendors will begin making significant inroads into the Asian market in 1989, as U.S. firms turn their sights from North America to the Far East. Vendors making successful penetration in 1989 will derive 20 percent to 35 percent of their worldwide revenue from Asian campaigns.

Unlike the CAE sector, the PCB layout market, which expanded by 26 percent to $293.9 million in 1988, was completely dominated by Japanese suppliers: Zuken (15.1 percent), Fujitsu (11.5 percent), NEC (9.7 percent), and Sharp (5.1 percent). Zuken's success is tied to its stable position in the marketplace—it is one of the oldest PCB layout companies in the industry and has been the revenue leader for many years. However, in 1988, with an increasing number of vendors competing for the Asian PCB market, the firm expanded into CAE, unveiling schematic capture and simulation tools for both analog and digital design. This was a positive move for Zuken, as its CAE offerings accounted for more than 15 percent of the firm's 1988 revenue.

A big surprise in Japan came from Seiko, which continued to hold onto its leadership position in IC layout, despite the increasing competition from Cadence and Mentor. Seiko captured a 29.7 percent market share in Asia in 1988, down slightly from its 30.1 percent share in 1987; Cadence is the next closest competitor, with 12.0 percent.

And worldwide, Seiko ranks second (11.5 percent) behind Cadence (15.4 percent). Seiko's recent success stems from its SX-8000 IC layout system, which the company has been actively marketing since Daisy's commitment in the IC layout market became questionable. (Seiko is a distributor for Daisy.) Daisy is still selling its ChipMaster IC design system, but no further development of the product is planned.

Europe

The European market grew 20.9 percent in 1988, from $561.0 million to $678.1 million. CAE experienced the largest growth, with revenue climbing 23.7 percent, from $270 million in 1987 to $333.9 million in 1988. Also exhibiting robust expansion was the PCB arena, where revenue grew to $272.5 million, up from $229.0 million in 1987. (After factoring in appreciation of European currencies, 1988 EDA growth was approximately 17.7 percent.)

Presently, Europe is in a transition period and is attempting to enhance its competitive position against Japan and the United States. Examples of the European commitment include the following:

- Europe's goal of tearing down internal trade barriers by 1992 is well underway.
- Many of Europe's large system manufacturers are striking alliances with foreign companies (e.g., VLSI Technology and Philips) to gain access to strategic areas of technology.
- European electronics manufacturers also have been upgrading their EDA capabilities significantly, as witnessed by the steady growth over the past two years.

Dataquest anticipates that many U.S. and Asian electronics firms will establish manufacturing and design sites in Europe during the next two to three years to avoid the tariff that will be imposed in 1992. And large European systems manufacturers will continue upgrading EDA capabilities during the next few years as they strive to reduce development costs and increase product offerings. This upgrading, together with the increased effort EDA vendors are putting on European sales and marketing, will provide healthy expansion of the European EDA market during the next few years.

Market Leadership

In 1988, Mentor and Daisy were locked in a heated race for EDA market-share leadership, finishing up the year with 11.6 percent and 11.4 percent, respectively. Daisy held a slight edge over Mentor in PCB layout (9.7 percent to 7.2 percent), whereas Mentor was just ahead of Daisy in CAE sales (15.7 percent to 14.5 percent). This is in sharp contrast to the North American CAE sector, where Mentor outpaced Daisy by a 2:1 margin.

Racal-Redac was third in the European market, with revenue of $53.9 million. Racal-Redac, whose primary business is PCB layout, maintained its leadership position in this area with a 16.1 percent market share. However, the firm also had a presence in CAE, deriving more than 13 percent of its revenue from front-end design tools (e.g., Racal is an OEM of HHB Systems' CADAT simulator).

In 1988, Racal-Redac, like Zuken in Asia, began feeling the competitive pressures from U.S. PCB layout vendors (e.g., Mentor, Valid, Daisy,) and, as such, put more emphasis on its CAE business. But the company is an OEM of the CADAT simulator and, thus, is unable to enjoy high margins on the product. Dataquest believes that an acquisition of HHB Systems by Racal-Redac would provide Racal-Redac with the margin incentives to expand into the CAE arena aggressively into the CAE arena. The combination also would provide Racal-Redac with a much stronger position against Mentor, Daisy, and Valid.

CHANGING BUSINESS MODELS

The EDA industry is undergoing a major change, moving from a predominantly turnkey business (Daisy Systems, Mentor Graphics, Valid Logic) to one that now includes a healthy mix of software-only vendors (e.g., Cadence, Silicon Compiler Systems) and workstation suppliers (Sun, Digital Equipment, IBM, HP/Apollo, Intergraph, Solbourne, Sony) selling directly to EDA end-users.

Dataquest believes that this trend toward unbundling is driven by the following factors:

- A better deal. Large-volume workstation customers often believe they can extract higher discounts for the hardware if they buy it separately through an alternate distribution channel (i.e., a non-EDA workstation OEM such as a workstation clone manufacturer).

- Network licenses. The market is beginning to demand network licenses for EDA software instead of site-and-node licenses. With network licensing, the customer purchases the software either separately or bundled on a file server. The license allows a fixed number of nodes to use the software concurrently, and the customer is free to load the software onto any node on the network. Thus, the customer is not purchasing a turnkey workstation for each license. Valid's Access system, for example, is among the first to meet this new market demand. Several other vendors, including Cadence, also have begun offering network licensing.

- Market expectancy. With an increasing number of vendors unbundling their software, the market is expecting other vendors to do the same.

- Porting gets easier. With standards such as the C language and the UNIX operating system becoming more pervasive, porting to additional platforms is becoming less burdensome. Yet, the costs and complexities (e.g., inventory, quality control, service) of selling multiple-platform turnkey systems can become prohibitive. Shipping only software simplifies and expedites porting to new platforms.

- Shrinking hardware margins. Vendors supporting even one turnkey platform are finding it increasingly difficult to sustain turnkey profit margins because hardware margins are slipping, a result of the tumbling workstation prices.

Dataquest believes that the combination of these factors will continue chipping away at the once healthy turnkey profit margins, thereby slowing the growth of turnkey systems. However, many EDA vendors remain committed to selling turnkey systems, and large segments of the EDA market still wish to buy both hardware and software from a single supplier.

Extending the Life of Turnkey Systems

Dataquest believes that vendors can forestall the market's demand for unbundling by leveraging the turnkey solution with attractive service contracts, which include both hardware and software maintenance. Because EDA managers are looking for complete design automation solutions, and not simply a list of separate technical requirements (e.g., the application software, workstations, operating systems, networking, graphics), large segments of the market will be inclined to buy turnkey systems if the unified service contract makes buying the hardware separately less palatable.

Solutions to Falling Margins

Dataquest believes that EDA suppliers will combat slipping hardware margins by attempting to ship more turnkey systems that have a higher software value content. This strategy preserves system margins due to the dramatically wider margins reaped from software.

Vendors also will attack the problem by improving inventory management. For Mentor Graphics, employing this strategy in 1988 yielded positive results: Sales volumes increased, yet inventory levels as of December 31, 1988, were $20.6 million, down from $23.3 million in 1987. However, this reduction in inventory could also be indicative of the close relationship between Apollo Computer and Mentor.

Similarly, some vendors have resorted to just-in-time (JIT) inventory management. This, of course, is risky business, but an increasing number of companies across a range of different industries have resorted to it.

The Achilles Heel: Software Pricing

Falling average selling prices (ASPs) of hardware will present another problem for EDA suppliers: Customers will expect a corresponding erosion of software prices. This puts EDA vendors in a difficult position, because software development costs are rising. The problem is less acute for vendors selling turnkey systems, because software pricing can be buried in the bundled system price. Nonetheless, the huge margins on software are in jeopardy, as more and more software is sold unbundled.

To solve the problem and reduce the cost of development, some vendors are turning to object-oriented programming languages such as C++, which appears to be an emerging standard in the EDA industry. Several EDA vendors, including Mentor, Valid, and Cadence, have been using C++ extensively. In fact, Mentor's Package Station is based exclusively on C++. The C++ language is an extension of C that adds the concept of class, a mechanism for creating user-defined data types. The language was developed at the Computer Science Research Center at AT&T Bell Laboratories (Murray Hill, New Jersey).

Object-oriented programming is a relatively new style of programming that seems to be yielding significant increases in programmer productivity. Much of the assets of today's EDA vendors is measured by the productivity of the firms' software engineers, so a boost in productivity will produce a more favorable asset turnover (sales/total assets). Even more important, object-oriented programming enables code reuse and better maintainability, which can dramatically increase the code's life span.

On the down side, because object-oriented software construction is a new style of programming, there are relatively few experts in the field. Recognizing the importance of using C++, however, both Mentor and Valid established in-house training projects to get developers up to speed.

Dataquest believes that EDA vendors that are able to significantly reduce the cost of software development and maintenance will be among the most competitive in the 1990s.

1988 EVENTS IMPACTING 1989 AND BEYOND

VHDL Comes of Age

The VHSIC Hardware Description Language (IEEE-1076) leaped to center stage in 1988. Most of the major EDA vendors have announced that they will support it. However, the vast majority of the market is unfamiliar with VHDL, and several issues have yet to be resolved (e.g., whether existing simulators will be afforded the luxury of accepting only a particular "standard" subset of VHDL constructs). As a result, VHDL will not immediately impact the market. In fact, the VHDL test validation suite, which will enable the Department of Defense (DOD) to verify the capabilities of each vendor's VHDL simulator, will not be available until early 1990. The suite of software test programs is being developed by Intermetrics and Vantage Analysis Systems, both of which provide VHDL simulators.

Presently, the market is curious about VHDL, as much has been written about it in the press over the last year. However, Dataquest believes that VHDL's rate of market penetration in the commercial sector will depend on how well it performs against competitive hardware description languages (HDLs).

Logic Synthesis

Logic synthesis made its debut in 1988, with three start-up companies capturing most of the attention: Synopsys, Silc Technologies, and Trimeter Technologies. Briefly, logic synthesis allows engineers to describe the behavior of a design in a hardware description language; from this description, a circuit is automatically synthesized by the logic synthesis system. The circuit is then optimized to minimize the number of gates necessary to implement the design.

Logic synthesis' primary advantage is twofold: First, the optimization ensures that the least amount of real estate will be consumed by the design; and second, working with a high-level language instead of gates simplifies and speeds the design process dramatically, since the designer is not bogged down with the intricacies of gates and primitive macrocells.

Logic synthesis is a step higher than silicon and cell compilation, both of which require the designer to work at the structural level of design (e.g., block- and register-level). Silicon and cell compilation can be thought of as a subset of logic synthesis, since the high-level descriptions used in logic synthesis are transformed into structural representations, which are then compiled into a physical representation and mapped onto a selected physical structure (e.g., a full-custom, gate array, cell-based, programmable logic device).

The total market for logic synthesis tools in 1988 is estimated at $8.0 million (including logic synthesis tools for PLD design—Boolean equations, state machines, etc.). Dataquest expects this figure to jump to $13.0 million in 1989. Most of the large EDA vendors, as well as the ASIC vendors, are currently formulating a strategy to meet the market's demand for logic synthesis tools. Mentor took the first step by announcing its intent to acquire Trimeter Technologies in early 1989. Others, such as Cadence and LSI Logic, have become OEMs of the Synopsys product.

The central issue surrounding logic synthesis is which hardware description language will become the de facto standard for describing circuit behavior. Silc Technologies provides its own language, Synopsys offers Gateway Design Automation's Verilog language, and Trimeter supports VHDL. However, because VHDL is becoming a broadly supported standard, both Silc and Synopsys have committed to developing VHDL-based logic synthesis tools. The problem with VHDL is its all-encompassing nature, which makes synthesis of the entire language impossible. So again, the issue will be which VHDL constructs the logic synthesis vendors will support.

New Muscle behind Analog Design Automation

Dataquest estimates that the analog design automation market in 1988 was between $50 million and $60 million. Until now, most EDA vendors have given little attention to the analog design automation market due to its limited size. However, because almost all of the analog design automation environments are a composite of very loosely integrated tools from universities, in-house development projects, and commercial vendors, a substantial need for sophisticated, high-performance tools existed. In 1988, EDA vendors took aim at this market. The results were as follows:

- Valid acquired Analog Design Tools, the leader in the analog design automation market with 1988 revenue of $15.4 million.

- Daisy acquired SimuCAD, a niche company focusing on analog simulation, as part of its Cadnetix/HHB Systems acquisition. Daisy's analog design automation groups have consolidated and now exist as separate divisions.

- Mentor Graphics increased the depth of its analog offering by purchasing Contour Design Systems, a supplier of analog component libraries and modeling technology.

- Cadence is establishing its place in the analog design automation field by adopting a series of technology partners. This is the same strategy used by the firm (formerly SDA) during its start-up period several years ago. Under the agreements, Cadence receives an infusion of capital and feedback for improvements on Cadence's products from each of its partners. In return, the partner receives access to the technology born from the development.

Dataquest believes the significant muscle now behind the development of analog design automation tools will translate to high growth. In addition, analog design automation technology will benefit from major research efforts currently underway at universities throughout the United States, where areas of focus include analog synthesis, simulation, modeling, and physical design.

Mixed-Signal Simulation Gains Momentum

Mixed-signal simulation (i.e., analog/digital) took a leap forward as HHB Systems, GenRad, and Gateway Design Automation each teamed independently with Analogy to link their logic simulators with Saber, Analogy's behavioral-level analog simulator. These Saber-based products join several other mixed-signal simulators already on the market, including those from ViewLogic/MicroSim, Silicon Compiler Systems, Silvar-Lisco, and Sierra Semiconductor.

Dataquest believes that development and proliferation of board-level, mixed-signal simulators will significantly boost the penetration of simulation technology into the mainstream systems design houses. However, for these products to be successful, they must possess robust component model libraries and exhibit high execution speeds.

A New Push Toward Standardization: CAD Framework Initiative

With 1988 came the birth of the CAD Framework Initiative (CFI). The CFI comprises a body of EDA vendors and users whose charter is to develop guidelines for standard EDA framework implementation. A framework is a software infrastructure providing a common operating environment for EDA tools. The CFI is currently addressing six elements: system environments (e.g., operating systems), design methodology management, design data management, design representation, user interfaces, and intertool communications.

The CFI group is attempting to solve the problems of heterogeneous design environments, since most current EDA environments consist of a mixture of software and hardware from an array of vendors. Heterogeneous environments are what the market is demanding—users want the freedom to buy design tools from different suppliers and to easily integrate them into a standard EDA environment.

Some vendors have responded by offering software utilities that allow users to more easily integrate tools into that vendor's proprietary framework. This is a good first step, but the market still remains fearful of relying on any particular vendor's framework, for even with such an "open" system, users must base their design environment on a nonstandard framework from a single vendor.

Dataquest views formation of the CFI as very positive. Most of the market is unaware of the group, but those that are—mostly EDA managers—are hopeful, although somewhat skeptical, that the CFI will bear fruit. Skepticism stems from the fact that a large amount of plurality and bias exists among the CFI vendor membership, which may slow development of a standard framework.

Despite the CFI's aggressive development schedule to generate a preliminary standard by late 1990, Dataquest believes that it may be well into 1991 or early 1992 before an industry-endorsed standard set of guidelines emerges from the group. However, development and acceptance will accelerate as more large EDA users pressure the group to come to a consensus. Currently, CFI has approximately 40 members, including Mentor Graphics, Valid Logic Systems, Cadence Design Systems, EDA Systems, Digital Equipment Corporation, Hewlett-Packard, Motorola, MCC, VLSI Technology, Sony, Philips, Siemens, and Nixdorf.

Silicon Vendors Aim at Software Market

Several chip manufacturers, most notably LSI Logic and VLSI Technology, launched major EDA software campaigns to leverage their silicon offerings in 1988. Both firms surpassed the $20 million barrier and will continue developing and marketing EDA software that facilitates silicon sales. As ASIC manufacturing becomes more of a commodity, ASIC vendors will attempt to differentiate themselves not only on fabrication capabilities, but design tools as well.

But the high cost of developing tools, as well as the difficulty of keeping pace with the technology advances from commercial EDA vendor offerings, is increasingly prohibiting in-house development. To solve the problem, several ASIC vendors are opting to serve as OEMs for commercial EDA suppliers. ASIC vendors are offering customers with "open" EDA systems that combine the ASIC vendor's proprietary tools with third-party packages. Among the first to espouse this strategy are Motorola, LSI Logic, and NEC.

EDA vendors also are doing their part to open the newly discovered ASIC-vendor distribution channel. For instance, Cadence recently established its Silicon Access Alliance (SAA) OEM program, whereby Cadence helps the ASIC vendor integrate proprietary, third-party, and Cadence software into a common design environment. All or part of the resulting design automation system is then remarketed to the ASIC supplier's customers, which are predominantly systems houses. Initial members of the SAA program include National Semiconductor, Harris Semiconductor, and European Silicon Structures.

Cadence's strategy thus provides the firm with a second distribution channel into the systems market that complements its direct channel. This channel will "prime the pump" for Cadence to more effectively penetrate electronic systems manufacturers.

Cadence: A New Member of the Daisy-Mentor-Valid Triumvirate?

Cadence, which traditionally has been attacking the back end of the IC design process, has clearly begun targeting the systems market with not only back-end IC design tools, but front-end system design products. Cadence is using the following strategies to penetrate this territory:

- Establishing a separate division whose charter is to thrust the company into the systems domain
- The SAA OEM program
- Signing of several technology partner agreements with systems houses
- Striking an agreement with Gateway Design Automation to integrate and reference sell the Verilog simulator, a tool used for front-end design
- Signing an agreement with Synopsys to be an OEM of the Design Compiler logic synthesis system, which is used by systems engineers for front-end ASIC design

Dataquest anticipates that Cadence will pose a significant threat to the market shares of Mentor, Daisy, and Valid. In fact, in 1988, Cadence surpassed Valid in software revenue.

FUTURE OPPORTUNITIES

Dataquest believes the EDA market will adopt tools that deliver verifiable productivity increases to engineers. The kinds of products that are needed, and that will be successful over the next few years are as follows:

- VHDL-based products
- Logic synthesis tools
- Automatic/interactive partitioning tools
- Analog design automation (e.g., modeling, simulation, layout, synthesis)
- Test synthesis tools (e.g., scan, ATPG)
- Advanced PC board layout systems (e.g., automatic timing-driven layout—crosstalk, impedance matching)
- Mixed-signal simulators
- Design management systems
- Hybrid IC layout tools
- System simulation packages
- IC layout tools geared toward the system designer (e.g., floor planning)

DATAQUEST CONCLUSIONS

Dataquest believes that the hardy growth witnessed in 1988 will continue over the next five years. Electronic design automation, previously viewed as a luxury by most companies, is now clearly recognized as a necessity for remaining competitive. We expect this to be the underlying force driving our forecast 15 percent compound annual growth rate (CAGR) through 1993.

Ron Collett

Table 1

1988 EDA Worldwide Market Share

	Revenue	Units	Revenue Share	Units Share
Mentor Graphics	295.9	4,083	12.6%	6.8%
Daisy Systems	205.2	2,005	8.8%	3.3%
Digital	156.0	1,967	6.7%	3.3%
Valid	141.0	1,277	6.0%	2.1%
Sun	124.9	5,942	5.3%	9.8%
Apollo	96.6	5,010	4.1%	8.3%
Racal-Redac	77.0	149	3.3%	.2%
Hewlett-Packard	70.4	4,040	3.0%	6.7%
Cadence	61.7	0	2.6%	.0%
Intergraph	60.4	662	2.6%	1.1%
Zuken	58.0	347	2.5%	.6%
Fujitsu	53.8	382	2.3%	.6%
NEC	53.4	2,815	2.3%	4.7%
Prime Computer	51.7	403	2.2%	.7%
Compaq	50.0	9,600	2.1%	15.9%
IBM	48.3	1,760	2.1%	2.9%
Seiko - No OEM	42.2	200	1.8%	.3%
Zycad	35.4	51	1.5%	.1%
Silicon Compiler Systems	30.4	0	1.3%	.0%
Scientific Calc.	29.0	101	1.2%	.2%
Other	603.1	19,531	25.7%	32.4%
All Companies	2,344.4	60,324	100.0%	100.0%
All U.S.-Based Companies	1,854.1	53,114	79.1%	88.0%
All Asian-Based Companies	317.0	5,410	13.5%	9.0%
All European-Based Companies	173.4	1,799	7.4%	3.0%
All Hardware Companies	566.9	44,204	24.2%	73.3%
All Turnkey & SW Companies	1,777.6	16,119	75.8%	26.7%

Source: Dataquest
May 1989

Table 2

EDA Worldwide Forecast by Application

	1988	1989	1990	1991	1992	1993	CAGR
All EDA Applicat.							
Revenue	2,344	2,732	3,174	3,662	4,126	4,645	14.7%
Systems	58,599	69,800	83,400	95,580	110,750	125,150	16.4%
Workstations	60,324	71,140	84,360	96,230	111,160	125,440	15.8%
Electronic CAE							
Revenue	1,127	1,307	1,525	1,760	1,959	2,169	14.0%
Systems	31,590	37,120	45,570	53,140	62,210	69,920	17.2%
Workstations	31,851	37,290	45,690	53,230	62,290	70,020	17.1%
IC Layout							
Revenue	334	420	505	581	652	740	17.3%
Systems	4,152	5,670	7,240	8,510	9,800	11,460	22.5%
Workstations	4,314	5,790	7,320	8,560	9,830	11,480	21.6%
PCB Layout							
Revenue	884	1,004	1,144	1,321	1,515	1,736	14.4%
Systems	22,856	27,010	30,580	33,940	38,740	43,770	13.9%
Workstations	24,158	28,060	31,350	34,440	39,040	43,950	12.7%

Source: Dataquest
May 1989

Table 3

EDA Worldwide Forecast by Region

	1988	1989	1990	1991	1992	1993	CAGR
Worldwide							
Revenue	2,344	2,732	3,174	3,662	4,126	4,645	14.7%
Systems	58,599	69,800	83,400	95,580	110,750	125,150	16.4%
Workstations	60,324	71,140	84,360	96,230	111,160	125,440	15.8%
North America							
Revenue	971	1,075	1,195	1,342	1,504	1,680	11.6%
Systems	29,952	34,420	38,420	41,370	45,970	49,510	10.6%
Workstations	30,491	34,760	38,590	41,440	45,990	49,520	10.2%
Europe							
Revenue	678	797	932	1,107	1,234	1,378	15.2%
Systems	15,796	18,270	22,800	27,210	32,630	38,210	19.3%
Workstations	16,264	18,700	23,150	27,460	32,760	38,270	18.7%
Far East							
Revenue	667	821	993	1,142	1,296	1,465	17.0%
Systems	12,114	16,100	20,690	24,860	29,060	33,070	22.2%
Workstations	12,790	16,610	21,070	25,110	29,220	33,190	21.0%
Rest of World							
Revenue	29	39	53	71	92	122	33.6%
Systems	737	1,010	1,480	2,140	3,090	4,350	42.6%
Workstations	779	1,060	1,550	2,220	3,190	4,470	41.8%

Source: Dataquest
May 1989

Table 4

EDA Worldwide Forecast by Platform

	1988	1989	1990	1991	1992	1993	CAGR
All Platforms							
Revenue	2,344	2,732	3,174	3,662	4,126	4,645	14.7%
Systems	58,599	69,800	83,400	95,580	110,750	125,150	16.4%
Workstations	60,324	71,140	84,360	96,230	111,160	125,440	15.8%
Technical Workstation							
Revenue	1,536	1,945	2,480	3,118	3,699	4,314	22.9%
Systems	24,582	33,610	47,220	65,550	85,910	106,800	34.1%
Workstations	24,583	33,610	47,220	65,550	85,910	106,800	34.1%
Host-Dependent/Server							
Revenue	459	426	354	271	214	175	-17.5%
Systems	2,179	2,370	2,200	1,860	1,600	1,390	-8.6%
Workstations	3,902	3,710	3,170	2,510	2,020	1,690	-15.4%
Personal Computer							
Revenue	349	361	340	274	213	155	-14.9%
Systems	31,838	33,820	33,980	28,170	23,240	16,960	-11.8%
Workstations	31,838	33,820	33,980	28,170	23,240	16,960	-11.8%

Source: Dataquest
May 1989

Table 5

EDA Worldwide Average Price per Seat Forecast by Platform

	1988	1989	1990	1991	1992	1993	CAGR
Turnkey & Hardware-Only							
Technical Workstation	39.6	35.3	30.8	26.7	22.9	20.5	-12.3%
Host-Dependent/Server	152.1	128.6	112.1	98.6	86.9	77.9	-12.5%
Personal Computer	5.4	5.4	5.1	4.8	4.5	4.3	-4.5%
All Platforms	25.2	23.9	22.5	21.6	19.9	19.0	-5.5%
Turnkey							
Technical Workstation	62.0	58.2	54.3	50.4	48.4	48.2	-4.9%
Host-Dependent/Server	376.8	361.4	341.6	315.9	317.4	321.0	-3.2%
Personal Computer	15.1	16.9	14.4	13.0	13.1	9.6	-8.7%
All Platforms	64.9	61.3	56.4	51.9	49.4	49.0	-5.5%
Hardware-Only							
Technical Workstation	18.1	16.4	14.9	13.5	12.4	11.9	-8.0%
Host-Dependent/Server	88.1	79.5	72.9	68.6	62.6	57.1	-8.3%
Personal Computer	4.6	4.7	4.7	4.6	4.3	4.3	-1.3%
All Platforms	11.7	11.6	11.3	11.4	11.1	11.2	-.9%

Source: Dataquest
May 1989

Table 6

EDA Worldwide Revenue Sources Forecast by Platform

	1988	1989	1990	1991	1992	1993	CAGR
All Platforms							
Hardware	1,154	1,236	1,385	1,524	1,639	1,779	9.0%
Software	866	1,114	1,338	1,606	1,879	2,175	20.2%
Service	325	382	451	532	607	690	16.3%
Total	2,344	2,732	3,174	3,662	4,126	4,645	14.7%
Technical Workstation							
Hardware	703	835	1,032	1,252	1,430	1,623	18.2%
Software	587	806	1,062	1,383	1,700	2,031	28.2%
Service	241	304	385	482	569	659	22.3%
Total	1,536	1,945	2,480	3,118	3,699	4,314	22.9%
Host-Dependent/Server							
Hardware	282	235	193	147	114	91	-20.3%
Software	110	131	111	87	71	61	-11.1%
Service	65	60	49	37	29	24	-18.3%
Total	459	426	354	271	214	175	-17.5%
Personal Computer							
Hardware	169	166	159	124	95	66	-17.2%
Software	169	177	165	137	108	82	-13.4%
Service	18	18	16	13	10	7	-17.1%
Total	349	361	340	274	213	155	-14.9%

Source: Dataquest
May 1989

Table 7

EDA Worldwide Forecast by Distribution Class

	1988	1989	1990	1991	1992	1993	CAGR
Total Hardware and Software Revenue							
Turnkey	960	1,106	1,222	1,327	1,345	1,371	7.4%
Unbundled	1,061	1,243	1,501	1,803	2,173	2,583	19.5%
Total	2,021	2,350	2,723	3,130	3,518	3,954	14.4%
Hardware Revenue							
Turnkey	637	671	731	783	777	774	4.0%
Unbundled	518	565	654	741	862	1,005	14.2%
Total	1,154	1,236	1,385	1,524	1,639	1,779	9.0%
Software Revenue							
Turnkey	323	436	491	544	568	597	13.1%
Unbundled	543	678	847	1,063	1,311	1,578	23.8%
Total	866	1,114	1,338	1,606	1,879	2,175	20.2%
Workstation Shipments							
Turnkey	16,119	18,360	21,420	24,720	25,830	26,130	10.1%
Unbundled	44,204	52,780	62,940	71,510	85,330	99,310	17.6%
Total	60,324	71,140	84,360	96,230	111,160	125,440	15.8%

Source: Dataquest
May 1989

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ASICs SURPASS $7.4 BILLION IN 1988

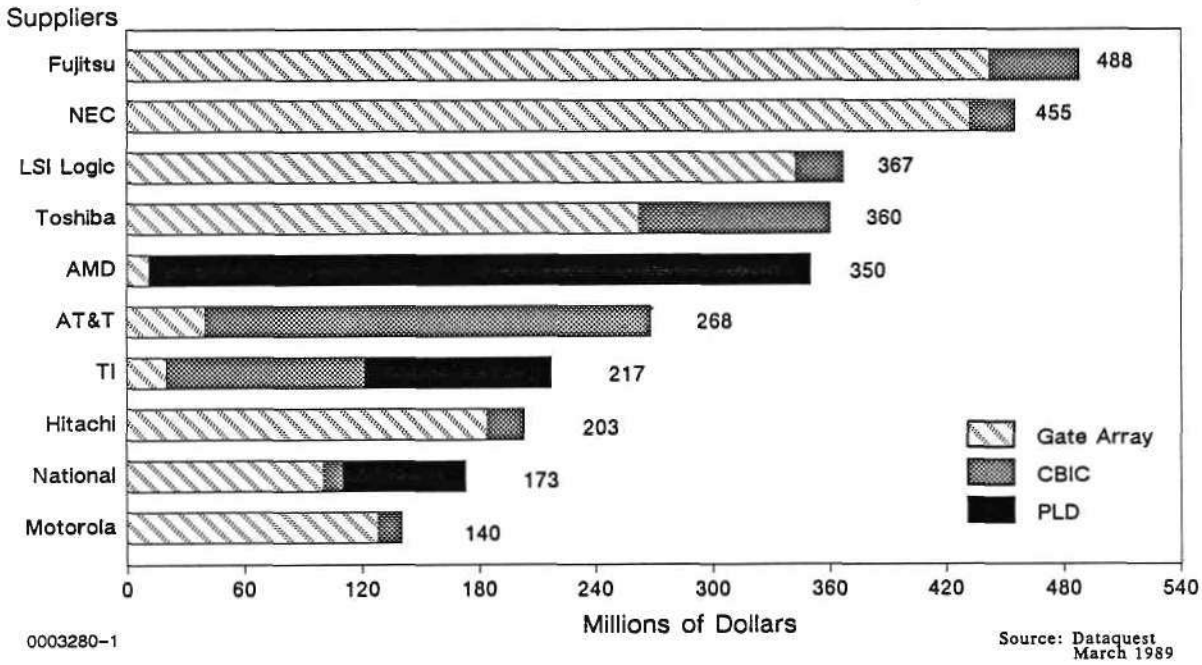
SUMMARY

Application-specific integrated circuits (ASICs) now account for more than 20 percent of worldwide IC consumption, and Dataquest believes that ASICs will be an astounding $17.4 billion market by 1994. Worldwide ASIC consumption grew from $2.3 billion in 1983 to $7.4 billion in 1988. ASICs can incorporate the microprocessor, memory, and logic on a single chip, thus reducing the size and cost of a system while improving the performance and reliability. ASICs are transforming the IC industry.

Gate arrays are the largest ASIC market, followed by full-custom ICs, cell-based ICs (CBICs), and programmable logic devices (PLDs). During 1988, gate array consumption rose 27.6 percent, CBIC consumption grew 33.4 percent, and PLD consumption grew 39.9 percent. Figure 1 illustrates the top ten 1988 worldwide ASIC suppliers and their respective product mixes.

Figure 1

Estimated 1988 Worldwide ASIC Ranking



Source: Dataquest March 1989

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THE 1988 ASIC MARKET

Table 1 lists the estimated 1988 worldwide ASIC shipments for the top ten suppliers shown in Figure 1.

Table 1

Estimated 1988 Worldwide ASIC Shipments
(Millions of Dollars)

1988 Ranking	Companies	Gate Array	CBIC	PLD	Total
1	Fujitsu	$ 442.0	$ 46.0	0	$ 488.0
2	NEC	432.0	23.0	0	455.0
3	LSI Logic	343.0	24.0	0	367.0
4	Toshiba	262.0	98.0	0	360.0
5	Advanced Micro Devices	11.0	0	$338.8	349.8
6	AT&T Technologies	40.0	228.0	0	268.0
7	Texas Instruments	20.0	101.0	96.3	217.3
8	Hitachi	184.0	19.0	0	203.0
9	National Semiconductor	100.0	10.0	63.0	173.0
10	Motorola	128.0	12.0	0	140.0
	Total	$1,962.0	$561.0	$498.1	$3,021.1

Source: Dataquest
March 1989

Fujitsu was the number one ASIC supplier for the fifth year in a row. Second-place NEC stated three years ago that it would become the number one ASIC supplier, and it seems to be right on schedule. NEC grew 35.4 percent from 1987 to 1988, while Fujitsu grew just 24.7 percent. NEC was only $33 million behind Fujitsu in total 1988 ASIC revenue, and we believe that 1989 may well be the year that NEC becomes the number one ASIC supplier. LSI Logic and Toshiba are formidable competitors also and experienced growth surpassing both Fujitsu and NEC with 40.7 percent and 54.4 percent, respectively.

Seven of the top ten ASIC suppliers generated the majority of their revenue from gate arrays. AMD is unique in that it was the only supplier to make the top ten ranking with the majority of its revenue in PLDs, having little or no revenue in gate arrays and CBICs. During 1988, there were no major Japanese suppliers in the PLD market; however, Fujitsu just announced a PLD product that it will begin shipping in 1989. Samsung also has entered the PLD market and currently is involved in a lawsuit with AMD on PLD patents. We expect to see fierce competition in the PLD market during 1989 and 1990.

AT&T Technologies and Texas Instruments (TI) both derived the majority of their ASIC revenue from CBICs. Both companies had healthy years in ASICs, growing 64.4 percent and 53.4 percent, respectively. Although Hitachi, National, and Motorola had 1987 to 1988 ASIC growth rates that were only in the high teens to mid-twenties, each has made a major commitment to the ASIC market.

Gate Arrays

As mentioned earlier, seven of the top ten ASIC suppliers generated the majority of their revenue from gate arrays. Furthermore, Table 2 shows that the top four ASIC suppliers are the same as the top four gate array suppliers.

Table 2

Top Five 1988 Worldwide Gate Array Suppliers
(Millions of Dollars)

1988 Ranking	Companies	1987	1988	1987-1988 Growth	Market Share
1	Fujitsu	$ 357.0	$ 442.0	23.8%	15.0%
2	NEC	318.0	432.0	35.8%	14.7%
3	LSI Logic	251.0	343.0	36.7%	11.7%
4	Toshiba	174.0	262.0	50.6%	8.9%
5	Hitachi	149.0	184.0	23.5%	6.3%
	Total	$1,249.0	$1,663.0	33.1%	56.5%

Source: Dataquest
March 1989

Four of the top five gate array suppliers are Japanese companies. Fujitsu is still the number one supplier, although NEC is narrowing the gap. LSI Logic is holding its own against the Japanese giants and maintained the number three position in total worldwide gate arrays and the number one position in worldwide MOS gate arrays. All four Japanese suppliers are not only leaders in the gate array market, but also leading computer suppliers. This gives them an advantage in two ways. First, they use their internal computer needs to help define future merchant gate array products. And second, they achieve increased economies of scale in manufacturing.

Fujitsu, NEC, and Hitachi all had significant revenue generated from bipolar (ECL) gate arrays, of which a large portion was consumed internally by their computer divisions. Fujitsu was the number one 1988 worldwide bipolar gate array supplier with $220 million; it was followed by NEC, Motorola, and Hitachi with $141 million, $103 million, and $85 million, respectively. Although Motorola was the number three total worldwide bipolar gate array supplier, it was the number one supplier to the merchant market.

LSI Logic captured the number one position in the 1988 worldwide MOS gate array market, with $343 million. NEC was the number two supplier, with $291 million. Toshiba, Fujitsu, and Hitachi followed with $262 million, $222 million, and $99 million, respectively. It is interesting to note that four of the top five MOS gate array suppliers are Japanese companies.

It comes as no great surprise that Japanese companies are leaders in the gate array market. Over the last 10 years, Japanese companies have made major investments in gate array manufacturing, technology, software, and marketing. Moreover, Fujitsu was a pioneer in the gate array market and marketed its first gate array product in the mid-1960s.

Cell-Based ICs

Table 3 shows the top five 1988 worldwide cell-based IC (CBIC) suppliers.

Table 3

Top Five 1988 Worldwide CBIC Suppliers
(Millions of Dollars)

1988 Ranking	Companies	1987	1988	1987-1988 Growth	Market Share
1	AT&T	$155.0	$228.0	47.1%	18.0%
2	Texas Instruments	63.0	101.0	60.3%	8.0%
3	Toshiba	59.1	98.0	65.8%	7.7%
4	NCR	71.4	89.0	24.6%	7.0%
5	VLSI Technology	71.4	85.0	19.0%	6.7%
	Total	$419.9	$601.0	43.1%	47.5%

Source: Dataquest
March 1989

AT&T is by far the largest worldwide CBIC supplier; however, a large portion of its revenue is generated from sales to internal divisions. The race is close among the next four suppliers. TI jumped from the number four position in 1987 to the number two position in 1988. Toshiba also moved up in the ranking from number five in 1987 to number three in 1988.

Dataquest believes that a large portion of Toshiba's 1988 sales were derived from what we call optimized gate arrays. Toshiba converted some of its gate arrays that were running in high volume by removing the unused gates and routing channels; the company retooled the device using a full set of masks. This device fits the CBIC definition because it is customized with a full set of masks but is not a traditional CBIC.

NCR broke the 1987 tie with VLSI Technology and captured the number four position. NCR experienced healthy growth in 1988 by focusing on mixed analog/digital CBICs. VLSI Technology is focusing on gate arrays now as well as CBICs, thus affecting its CBIC growth. Although the company's CBIC growth was only 19 percent, its gate array growth was a healthy 60 percent, growing from $25 million in 1987 to $40 million in 1988.

It is interesting to note that only one Japanese company made the top five CBIC suppliers in 1988. We believe that the Japanese suppliers will continue to focus on gate arrays as well as structured arrays (megacells embedded in gate array base wafers) and that CBICs will be of secondary importance to them.

Programmable Logic Devices

Table 4 shows the top five worldwide programmable logic device (PLD) suppliers in 1988.

Table 4

Top Five 1988 Worldwide PLD Suppliers
(Millions of Dollars)

1988 Ranking	Companies	1987	1988	1987-1988 Growth	Market Share
1	Advanced Micro Devices	$274.0	$338.8	23.6%	48.0%
2	Texas Instruments	61.0	96.3	57.9%	13.7%
3	National Semiconductor	45.0	63.0	40.0%	8.9%
4	Philips/Signetics	45.9	53.6	16.8%	7.6%
5	Altera	20.7	37.0	78.7%	5.2%
	Total	$446.6	$588.7	31.8%	83.5%

Source: Dataquest
March 1989

Advanced Micro Devices (AMD) tops the chart in 1988 PLD shipments with a clear lead over its competitors. AMD became the largest PLD supplier when it acquired Monolithic Memories in 1987. Texas Instruments experienced growth surpassing AMD and is expected to do well in 1989. The top four suppliers shown in Table 4 derived the vast majority of their revenue from bipolar PLDs. The bipolar PLD market is mature, and the MOS PLD market is in the early growth phase of its product life cycle. The compound annual growth rate (CAGR) from 1989 to 1994 for MOS PLDs is estimated to be 31.3 percent, compared with a negative 3.3 percent CAGR for bipolar PLDs.

In excess of 20 MOS PLD suppliers are active in the market, compared with only 4 bipolar PLD suppliers. Altera leads the pack of MOS PLD suppliers, capturing the number five position in total PLDs with an exclusive MOS product line. Cypress, Xilinx, Lattice, and Intel follow with 1988 MOS PLD revenue of $34 million, $27 million, $21 million, and $16 million, respectively.

Full–Custom ICs

Full–custom ICs are being phased out and replaced by other ASIC technologies; therefore, Dataquest research has been focused on the growing ASIC markets. The vast majority of full–custom ICs are watch and calculator chips, and most of the production is offshore. Leading full–custom IC suppliers include NEC, Matsushita, Sharp, Toshiba, and Oki.

1989 AND BEYOND

Dataquest believes that the ASIC market will start to slow during the second half of 1989 and that 1990 will be the lowest growth year. We expect the ASIC market to grow 15.7 percent in 1989 and 5.8 percent in 1990. We then foresee 1991 through 1993 to be prosperous years, with annual growth rates in the 20 to 25 percent range, followed by the next slowdown in 1994.

Table 5 shows estimated worldwide ASIC consumption by technology from 1987 through 1994. Dataquest forecasts include NRE revenue, CAD software revenue, intracompany revenue (internal sales), and device production revenue. Dataquest forecasts do not include captive manufacturing of companies that do not sell to the merchant market such as IBM, Digital Equipment, and Unisys.

Table 5

Estimated Worldwide ASIC Consumption by Technology
(Millions of Dollars)

	1987	1988	1989	1990	1991
Total ASIC	6,225.1	7,437.9	8,605.8	9,104.8	11,021.5
MOS	4,403.7	5,374.8	6,351.9	6,743.2	8,253.7
Bipolar	1,790.4	2,003.3	2,145.8	2,141.6	2,365.0
BICMOS	31.0	59.8	108.1	220.0	402.8
Gate Arrays	2,305.4	2,941.3	3,552.8	3,958.1	5,026.7
MOS	1,446.5	1,933.5	2,382.1	2,617.9	3,353.5
Bipolar	827.9	949.0	1,067.6	1,139.2	1,321.4
BICMOS	31.0	58.8	103.1	201.0	351.8
Programmable Logic	504.2	705.4	898.2	950.6	1,236.9
MOS	82.3	176.9	335.7	442.6	702.7
Bipolar	421.9	528.5	562.5	508.0	534.2
Cell-Based ICs	949.5	1,266.2	1,551.0	1,753.1	2,298.9
MOS	912.9	1,214.4	1,481.5	1,659.4	2,153.9
Bipolar	36.6	50.8	64.5	74.7	94.0
BICMOS	0	1.0	5.0	19.0	51.0
Full-Custom ICs	2,466.0	2,525.0	2,603.8	2,443.0	2,459.0

(Continued)

Table 5 (Continued)

Estimated Worldwide ASIC Consumption by Technology
(Millions of Dollars)

	1992	1993	1994	CAGR 1989-1994
Total ASIC	13,355.8	15,888.2	17,814.4	15.7%
MOS	10,065.3	11,857.5	12,962.5	15.3%
Bipolar	2,567.5	2,762.7	2,886.7	6.1%
BICMOS	723.0	1,268.0	1,965.2	78.6%
Gate Arrays	6,380.1	7,962.5	9,122.1	20.8%
MOS	4,269.0	5,250.9	5,828.5	19.6%
Bipolar	1,513.1	1,724.8	1,862.8	11.8%
BICMOS	598.0	986.8	1,430.8	69.2%
Programmable Logic	1,496.0	1,641.5	1,785.2	14.7%
MOS	970.9	1,149.7	1,310.3	31.3%
Bipolar	525.1	491.8	474.9	(3.3%)
Cell-Based ICs	3,094.4	3,994.3	4,731.7	25.0%
MOS	2,843.1	3,553.8	4,015.8	22.1%
Bipolar	126.3	159.2	181.5	23.0%
BICMOS	125.0	281.3	534.4	154.6%
Full-Custom ICs	2,385.3	2,289.9	2,175.4	(3.5%)

Source: Dataquest
March 1989

As the ASIC market slows in the second half of 1989 and in 1990, we believe that suppliers will shift their focus from increasing market share to increasing profit margins. Some suppliers will elect to withdraw from the market because their margins will be so low and they will not have the capital or alliances required to develop leading-edge submicron products. We believe that gate arrays will be the dominant ASIC market through 1994. Major product trends to watch over the next five years include: field programmable gate arrays (FPGAs), BICMOS ASICs, RISC microprocessor ASIC cores, and the emergence of high-functionality structured arrays (megacells embedded in gate array base wafers).

ASICs have come a long way in the last five years. We believe, however, that the ASIC revolution has just begun.

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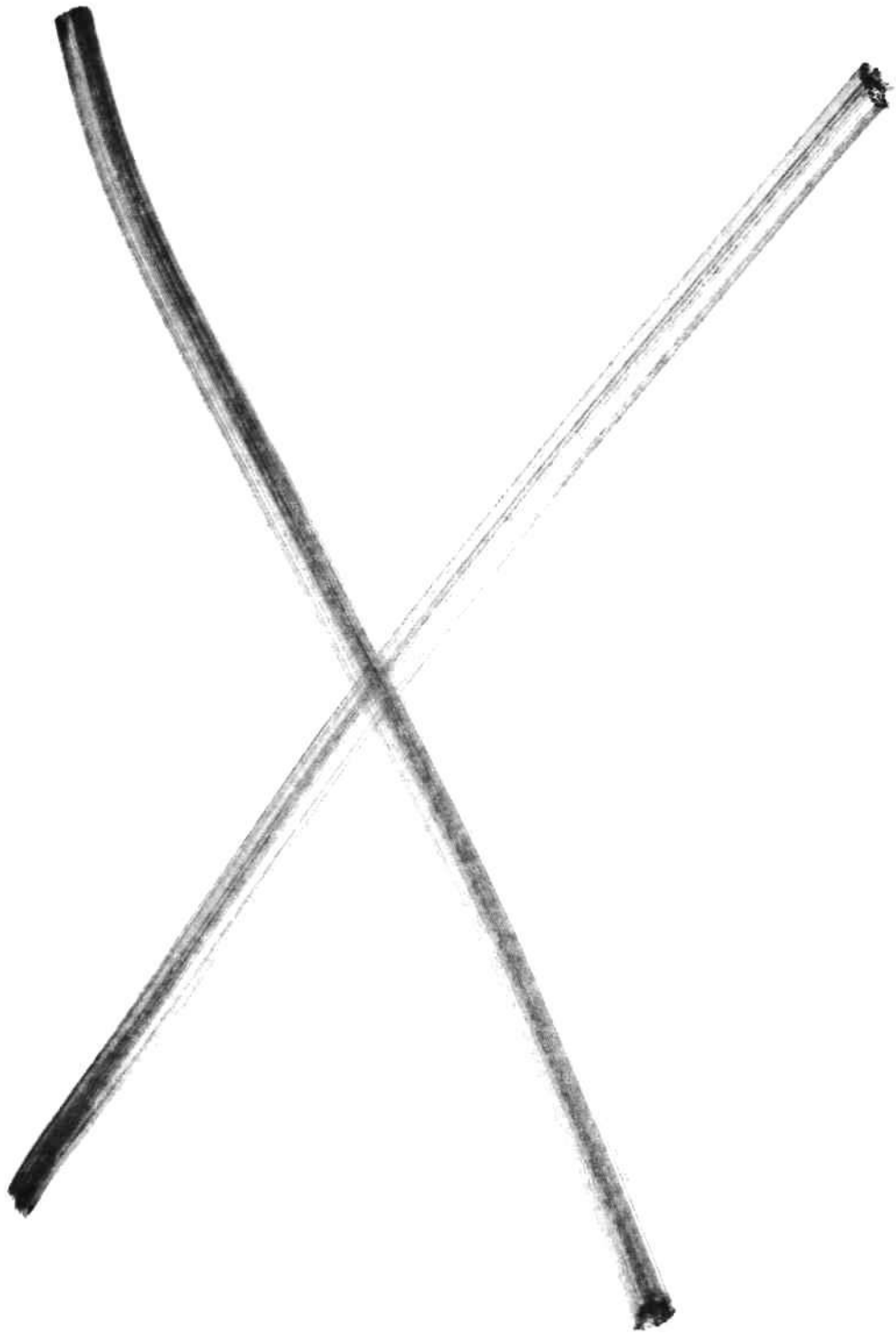
Tony Spadarella
Bryan Lewis



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Research Newsletter

GEOGRAPHIC INFORMATION SYSTEMS: THE EUROPEAN TERRAIN

EXECUTIVE SUMMARY

The fast-growing geographic information systems (GIS) market is sizzling in Europe, having grown 31 percent in 1990 to $478 million. We expect this growth to continue at a 27.7 percent compound annual growth rate (CAGR) through 1995, when the market is forecast to reach $1,619 million. Although the major factors both driving and limiting GIS market growth are similar around the world, Europe is enjoying a growth curve that is expected to make it the largest market region by 1992 (see Figure 1). This newsletter compares general European GIS market conditions with the currently larger North American market and examines conditions and outlook by country.

WORLDWIDE SNAPSHOT

Market conditions for GIS are unique in Europe despite the fact that core users and core applications have many of the same problems worldwide. Typical users are governments, utilities (such as gas, electric, and telecommunications), and purveyors of products such as forestry and oil, whose development occupies large areas. Buyers often work in large bureaucracies, which have a conservative approach to procurement and agonizingly extended sales cycles. Many installations in those organizations are pilot projects, and it remains to be seen if and when full implementation will take place.

Core applications are also similar around the world, extending far beyond simple digital storage and display of maps; applications typically involve an attempt to create an integrated data set of information pertinent to the land base for purposes of analysis and control of the area of scrutiny. Examples range from land and resource management to electric utility network analysis and new applications continually emerge. Applications under active development include environmental and resource monitoring; emergency response systems for police, fire, and rescue services; and market research.

Tasked with ambitious goals, GIS presents challenges. Creating adequate digital land-base data is costly and time-consuming; it is measured by years. Economical and effective development often requires cooperation among people working in different departments, different jurisdictions, and different companies. Considerable market growth has been based on the likelihood that GISs are required to manage an increasingly complex world rather than based on a history of proven successes.

GIS is becoming continuously more affordable because of the continuing decline in hardware prices. Because of the large growth potential in the GIS market, many CAD vendors, particularly those selling products for facilities management, are now positioning themselves as GIS vendors.

EUROPE VERSUS NORTH AMERICA

Table 1 summarizes the key differences between European and North American GIS markets. European countries generally have more accurate land-base data than does the United States, more often already in vector form. Additionally, gas, electric, and telecommunications utilities are more typically part of each country's government in Europe, significantly facilitating cooperation in large-scale GIS development compared with the legal issues raised in the United States over local governments sharing development costs with private utility companies. Even as privatization of utilities grows, the history of cooperation and high map accuracy will remain, and GIS funding for these private utilities is likely to grow. In

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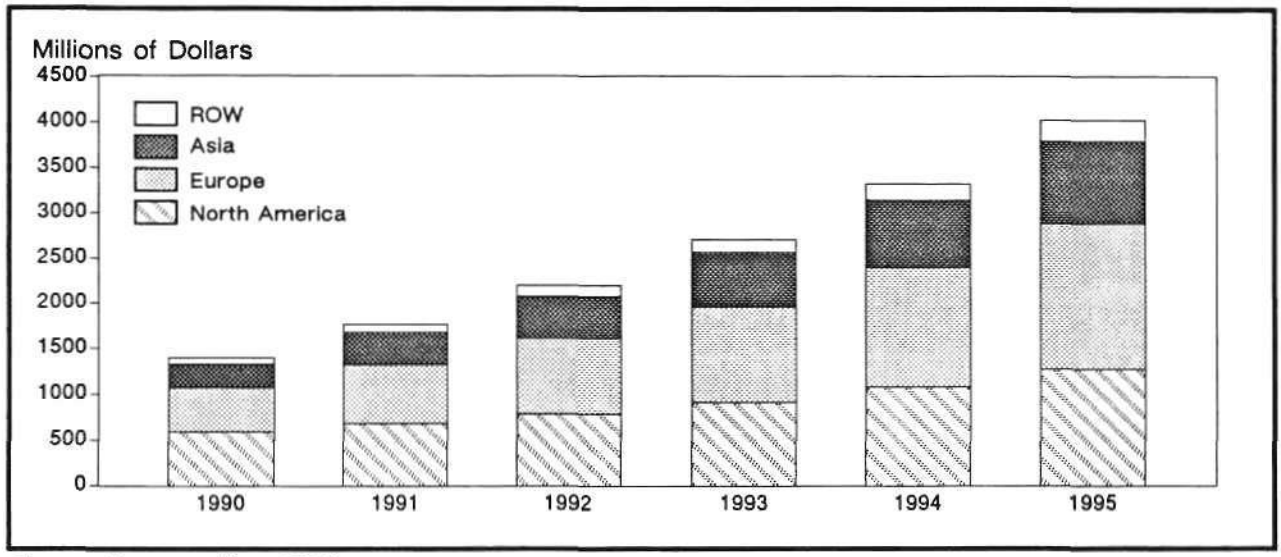
FIGURE 1
Worldwide Geographic Information Systems Market (Millions of Dollars)



Source: Dataquest (June 1991)

TABLE 1
Comparison of GIS Markets in Europe and the United States

Factor	Europe	United States
Data sources	Private companies increasingly compete with governments that sell copyrighted data sets	Government frequently the initial low-cost source of data, resold in enhanced form by private sector
Raster versus vector	Nearly all paper conversions are to vector data	Increasing acceptance of raster map conversions as an incremental solution
Price of government-supplied data	High; goal is cost recovery	Low; value placed on disseminating information
Multiparticipant projects	Few barriers within a country; most participants are government entities	Barriers to overcome in creating cooperative ventures between government and private utility companies
Third-party implementation	General shortage of consultants; some activity by larger corporations acting as systems integrators	Many small consulting/conversion companies
Political and legal issues	Liability across countries, especially as environmental information is released	Determining level of cooperation between public and private sector

Source: Dataquest (June 1991)

short, most European countries are better organized structurally for GIS development than is the United States, a key reason why European growth is forecast to be higher than North American growth.

Paper map conversions in Europe are more likely to be in vector form than in the United States, partly because of both the higher level of map accuracy and the hospitable organizational structure. Increasingly in the United States, users facing a mountain of maps are adopting the "scan it in now and worry later" philosophy of incremental conversion.

Unlike Europe, the United States has strong laws on "freedom of (low-cost government)

information." This legislation is a strong GIS market driver; new U.S. GIS markets are developing based on data originally supplied at low cost by the U.S. government. In contrast, most European government entities are charged with cost recovery for data development. Thus, land-base data in European countries is generally expensive to buy, may be copyrighted, and is sometimes regarded as a state secret. As a result, private companies, such as the United Kingdom's Automobile Association, directly compete with the government in Europe in developing and selling data.

Europewide data is almost nonexistent compared with data compiled by the U.S. government, and efforts by the European Commission to set up such Europewide data (such as the CORINE project) are limited by bureaucracy and politics. For example, the elemental decision on where to locate CORINE project headquarters remains stuck in a political quagmire.

Finally, the complexion of the experience base is different in Europe than in and the United States. Few universities in Europe offer comprehensive GIS instruction compared with facilities available in the United States. Also, North America is currently better supplied with experienced small consulting/implementation companies than is Europe, with the result that European GIS projects are more likely to be undertaken as systems integration projects by larger companies such as Digital Equipment Corporation.

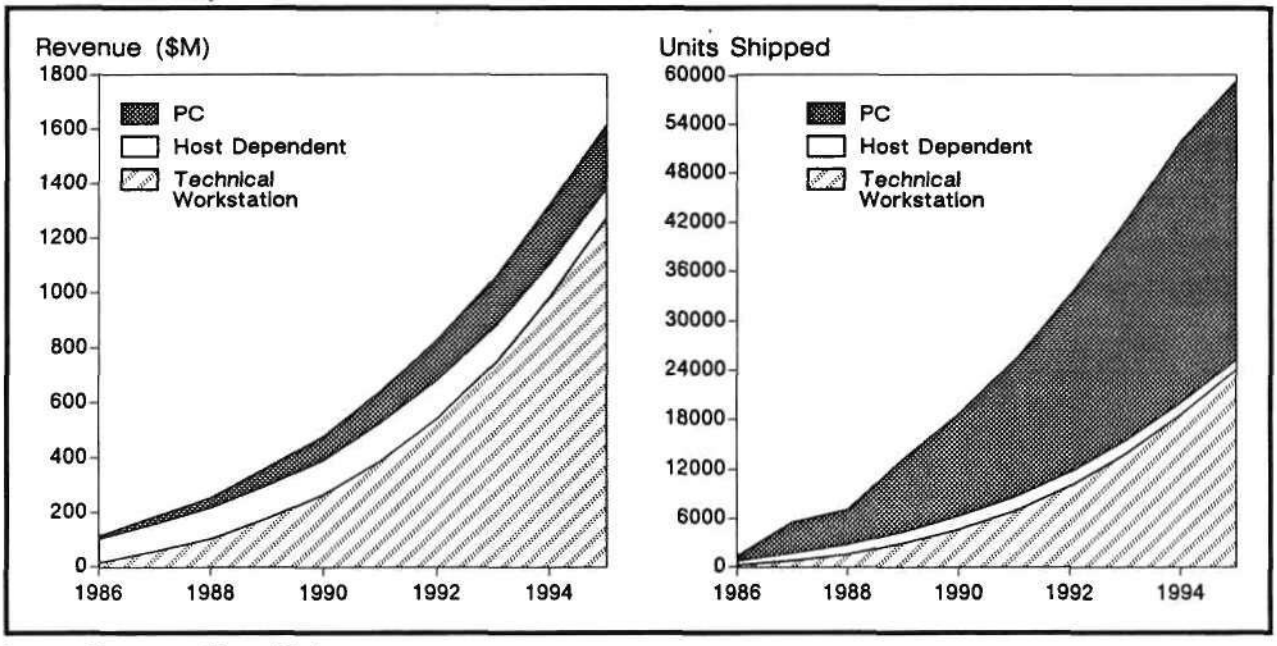
FORECAST

The European market for GIS is forecast to grow at a CAGR of 27.7 percent during the 1990 to 1995 time frame and is expected to equal the size of the North American market by 1992 (see Figure 1). The greatest growth potential lies with systems running on technical workstations and PC-based systems, with host-based systems' share of the GIS market declining rapidly. Figure 2 shows Dataquest's five-year forecast for GIS applications in terms of revenue and units.

A COUNTRY-LEVEL VIEW

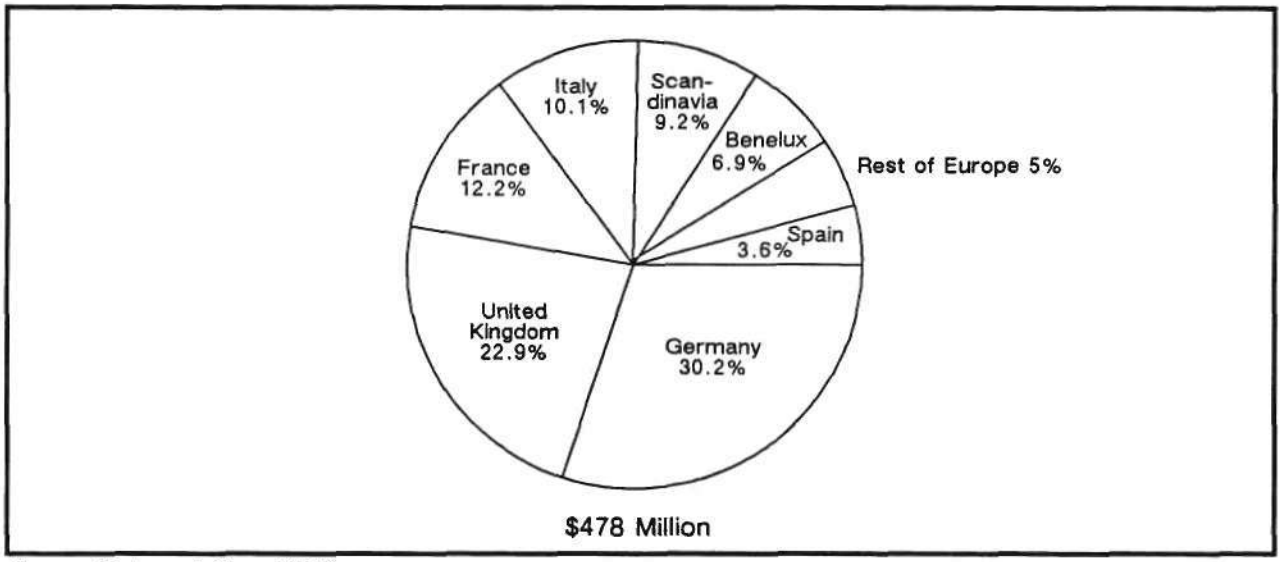
The 1990 European GIS market by country is shown in Figure 3. The following paragraphs provide an overview of the state of GIS development in the larger countries.

FIGURE 2
Geographic Information Systems Market History and Forecast—Europe



Source: Dataquest (June 1991)

FIGURE 3
1990 European Geographic Information Systems Market



Source: Dataquest (June 1991)

Germany

Germany is the largest market for GIS in Europe and offers considerable growth potential, especially since the unification of East and West Germany. Environmental applications are particularly strong in Germany, because of both the influence of the Green Party and environmental pollution and inferior infrastracture in eastern Germany.

Existing maps in western Germany are highly accurate, facilitating conversion to digital form. However, several data standards exist, inhibiting transfer of information among planning offices, utility companies, and the Institute of Geodesy in Frankfurt. Another challenging area has been the transfer of land ownership from the former Communist government back to the previous landowners in eastern Germany.

United Kingdom

A similar problem exists in the United Kingdom. Map data are available from various sources, but no single data standard is in place nor does a complete digitized map of the whole United Kingdom exist. The Ordnance Survey currently provides digitized map data for cities with more than 100,000 inhabitants, but a complete digitized map of the United Kingdom will not be available before the year 2000.

The U.K. GIS market experienced high growth in 1990 despite the economic downturn. This growth can be partly ascribed to the privatization of the water and electric utility companies in the United Kingdom, which created sources of funding for GIS development. The introduction of the poll tax was also expected to create an additional source of funds for the GIS market. However, this effect did not materialize because of the many problems the local authorities faced by implementing this tax. Councils failed to make the revenue they had expected and, therefore, did not have the necessary funds to install GIS, although in the long term this technology would significantly simplify and cut the costs of collecting this tax. This situation is not expected to improve in the near future, as the government is revising the poll tax system. The privatization of yet more utility companies in 1991, however, will ensure that growth rates for GIS in the United Kingdom remain high.

France

The GIS market in France grew 51 percent in 1990, reflecting a significant increase of interest in this region. France is one of the least mature markets for GIS in Europe for several reasons. In France, unlike in the United Kingdom, the Netherlands, and Germany, there is relatively little awareness among potential users of the benefits of GIS, creating a particularly tough educational sell. Compounding the problem, universities in France do not yet offer graduate courses that teach GIS use.

Land-base data is available from the Institut Geographique Nationale (IGN), but no countrywide data standard has been developed. Several state organizations are involved in defining a GIS standard, some originating from the defense industry.

The Netherlands

The Netherlands is one of the most mature GIS markets in Europe. The Netherlands is working to establish itself as the merchandise distribution center for Europe by the time the single European market is implemented in 1993. To achieve this goal, the use of GIS for route planning and logistics is vital. Establishments such as the land registry offices and utility companies are GIS database providers, and the Dutch government has made its geographic data available at low cost. There are moves in the Netherlands to combine these databases, the cost of which will be shared by land registry offices, utility companies, and municipalities.

DATAQUEST PERSPECTIVE

The European and U.S. GIS markets share most trends and issues; however, no true European market exists and one never will. Because many GIS applications are implemented by governments, as long as the core European government is the country, GIS in Europe will focus on country-based solutions. Meanwhile, the U.S. government continues to develop U.S.-wide geographical information (now moving to global, courtesy of the Defense Mapping Agency's Digital Chart of the World project and the NAVSTAR satellite global positioning system). In the long term, European vendors can be expected to develop product strength in integrating a variety of vector and attribute data for a local area. U.S. vendors can be expected to excel in large-scale applications. To use a facetious example, U.S.-based vendors are likely to better handle the requirement, "Provide a road map showing the fastest land and sea route from London to Sydney," and Europe-based vendors are likely to better handle the problem, "Hedgehogs need a safe crossing. Locate the site for the shortest possible tunnel under Peckham Lane that will also be convenient for the known hedgehog population." Underlying all comparisons, there is a competitive advantage in GIS industry development to be gained by countries that make their data freely available at low cost and encourage development of standards for data formats.

Petra Gartzen
Kathryn Hale

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Research *Bulletin*

GIS/LIS 1990: WORTH THE TRIP

Heading toward the November 1990 GIS/LIS show, the prevailing attitude among many attendees was that this was going to be just one more entry in the long line of GIS shows. Heading out the door upon its conclusion, many attendees had to eat their words. This industry is in fact dynamic and can keep news coming several times a year.

THE BIG BOMB

All conversations at the Anaheim, California, conference eventually led to analysis of the impact on other vendors of a new consulting firm called UGC Consulting, formed by IBM and Utility Graphics Consultants (UGC)—with IBM funding. The entity is designed to provide consulting staff at the many existing sites with IBM mainframe data. Obviously, UGC President Jim Montgomery has either just made the best or worst move of his life: He is risking a hard-earned reputation for vendor independence for a more guaranteed revenue stream from IBM installed sites. We assume that he's heard all the cautionary tales from others who have danced with the elephant.

More important is what this union means to the industry: GIS is now formally a market for the big players. IBM's entry into GIS systems integration business erects barriers to entering the market for vendors without either deep pockets or strong niche products. Consolidation and fallout among small players can also be anticipated, particularly among smaller GIS consultants.

THE LITTLE BOMB

Far less talked about at the show but potentially considerably more significant was the deal announced by ESRI and Autodesk, whereby the two companies agreed that ESRI will develop a product that allows easy exchange of files between its ARC/INFO and Autodesk's AutoCAD.

The two companies have been competitors in the rapidly growing state and local government market. This announcement forms the beginning of a truce, in that AutoCAD and ARC/INFO files should be able to coexist as separate CAD and GIS files, and ESRI should be able to leverage the tremendous amount of existing data in Autodesk's DXF file format.

However, this agreement is bad news for AutoCAD GIS add-on vendors, such as Generation 5, that have been trying to position themselves as serious competitors to ESRI. We believe that AutoCAD add-on companies are now likely to find themselves confined to the most budget-conscious buyers, looking for a very low-cost add-on for existing AutoCAD files. This apparent truce in file formats for both ESRI and Autodesk means that both companies have a stronger GIS market position, and both companies will be all the more difficult to unseat in their strongholds—civil engineering and state and local government.

THE STINK BOMB

Dataquest awards no kudos to presentations from the Defense Mapping Agency (DMA) on progress toward creating a MIL-SPEC vector standard for GIS. The project is laudable: a vector-based map of the world created in a new standard file format and available to all. However, we believe that DMA is not adequately addressing the needs of USGS and Census, despite both agencies' presence as advisors. Furthermore, Dataquest attempts to elicit DMA's interest in vector file formats within DOD's CALS initiative also fell on deaf ears. We expect that these two ships, DMA and CALS, will eventually go bump in the night, with DMA likely to sustain more damage because CALS is a larger effort and has more broad-based support in industry.

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We believe that it is to DMA's ultimate interests to listen better, for two reasons. First, the political tides favor accommodation to existing commercial standards, and USGS already has a vector standard. The last time Dataquest encountered a mission with a similar level of determination to "do it their way" was during the ill-fated US Navy CAD/CAM buy. There was a lesson there: The navy's top proponents were eventually either fired or retired as a result of their disregard of political realities outside their own sphere of influence.

Second, DMA itself could benefit from a widely accepted GIS vector file standard. We believe that the agency could ultimately acquire more geographic information by creating a standard that is useful to the more prosaic USGS data users—users who would then be in a position to create GIS data in one widely recognized file format. At some point, defense interests could actually require data from those prosaic users, because geographic data often have critical logistic implications. The diplomats at ESRI, who are executing this project for DMA, may well be able to open some dialog on the issues.

DATAQUEST PERSPECTIVE

GIS may be the only market that companies are trying to get into or keep others out of on the basis of semantics. Dataquest's approach is to include any company with a plausible GIS product line into our GIS market share analysis (subtracting, of course, market share in former market segments, to avoid double counting). With all the vendors pushing to get positioned within the GIS market, and with growing attendance at AM/FM International, URISA, and GIS/LIS, it is convenient that these shows exist. Otherwise, someone would have to create them for this fast-growing market.

Kathryn Hale

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Research Newsletter

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A/E/C SYSTEMS '89—THE GOOD TIMES ROLL

SUMMARY

It was elbow-to-elbow crowds at A/E/C Systems '89, which was held recently in Anaheim, California. Apparently, everyone with any interest in either AEC or PC-based CAD was in attendance. The vendor-oriented "neighborhoods," application-oriented mini-shows, and concurrent conferences sprawled even wider this year. Attendance was up 8 percent, to nearly 29,000. Foot traffic still centered around Autodesk and its third-party family, the traditional attention-getters.

Since the buoyant Autodesk has blessed A/E/C Systems as a key trade show, the event has continued to grow, at a time when many other national shows either are holding steady or shrinking. Next year's show is back-to-back with Comdex, virtually guaranteeing an even bigger A/E/C Systems in 1990.

SHOW STANDOUTS

Every show has its memorable events, and the following are our nominations for distinction.

Award for Creative Product Direction

Based on the relatively complete display of Autodesk's wide range of future products, we see the company's direction as creative, constructive, and crowd-pleasing. Coming from a position of immense strength in the CAD industry, and armed with more than $100 million in cash, Autodesk is moving to create new software markets while providing core development for its existing markets.

Rather than adding application-specific enhancements to AutoCAD, Autodesk appears to be investing in just what every computer manufacturer needs: new kinds of software that make the system more useful and productive. Audtodesk's CA Lab, the Cyberspace project, Xanadu, and an imminent animation product all offer the potential

to do something new to leverage or extend the core CAD product line. Although we do not know if the elusive "killer application" is lurking within Autodesk, the territory appears to be fertile.

Autodesk also promises necessary and sensible improvements for Release 11: reference files, networking, support for worldwide drafting standards (ANSI, DIN, JIS, ISO), C language support (instead of requiring developers to write in Lisp), and further enhancements to the product's already open architecture. Longer term development include better surfaces/rendering and a common data base and user interface for AutoCAD and AutoSolid. All of these core improvements support, rather than compete with, the company's add-on suppliers.

We believe that Autodesk's apparent decision to rely increasingly on third parties for subapplication software is a very constructive approach. Rather than going head-to-head with workstation-based CAD companies by developing modules suitable only for niche markets, Autodesk seems committed to expanding to new lines of business while continuing to nurture its add-on vendors. However, both the potential risks and rewards are greater with this approach, and thus very few companies have the funds and determination to try it.

Class Act Award

The Dataquest Class Act award goes to Prime Computer. With two strikes against it—appearing at a PC CAD show lugging a product conglomeration from three separate high-end AEC lines (Calma, Computervision, and Prime) and trying to sell at the peak of a highly publicized takeover attempt—the booth should have been a debacle. Instead, the display hummed with serious prospects.

Prime's secret? Existing customers staffed the well-located booth, displaying their own designs. Prime's staff functioned smoothly as the glue, both supporting each workstation and directing attendees toward the most appropriate design example. Obviously, customers staffing a vendor's booth lend credibility to the product, but more importantly, there were real designs to explore.

The typical canned demonstration is designed to send information in one direction only and any design samples are just that—unidimensional examples. But, examining a product with a real design/designer involves prospective customers in extensive, interactive product exploration, creating a sales environment that is more a consultation than a pitch. The activities in this booth are sure to be the origins of several Prime sales a few months from now.

Award for Creative Effort in Booth Design

The A.I.A. contingent awarded Calcomp the distinction of Creative Effort in Booth Design, and we can only agree, since the structure was well aimed at this AEC-oriented audience. The booth resembled a two-story Tinker Toy, with balls racing on a track to nowhere, and attracted plenty of visitors just for the chance to study the construction.

THE GRASS ROOTS CONTINGENT STIRS

Apparently tiring of collective low revenue, several of the AutoCAD third-party developers have banded together, creating at least three new entities promising shared marketing expenses, and a shared product user interface and development environment. The most formidable is ASG of Sausalito, California, which was formed by two strong developers, Archisoft Corp. (the creator of the architectural and mechanical modules currently sold by Autodesk) and Chase Systems of Westerville, Ohio. Archisoft's growth has been boosted considerably by its royalties from Autodesk, which have more than doubled in the last two years, reaching nearly $2 million in the last fiscal year.

Other alliances include the merger of D.C.A. Engineering Software (Henniker, New Hampshire) and Acuware (Portland, Oregon), which considerably expands the D.C.A. product line, and the formation of Applications Publishing (Sausalito, California). Applications Publishing has signed up six developers and is seeking more.

Pooling development and marketing costs makes a lot of sense for the approximately 300 AutoCAD developers, each of which addresses a relatively small market niche. Whereas we expect Autodesk to aid all developers in such universal concerns as the transition to standard window environments, it makes economic sense to share many expenses through a developer's alliance. For example, it is unlikely that any developer could independently support an adequate number of regional sales offices.

The concept of multiple alliances is also far better from Autodesk's point of view. If Autodesk were to form one company-sponsored alliance itself to cover all these issues, developers would be likely to cry foul, charging favoritism, heavyhandedness, and incompetence—no matter what Autodesk did. It would be too much like having your mother tell you how to write software. Software developers, free souls that they are, will probably respond better to a choice of independent alliances. These alliances will also reduce the absolute number of developers with which Autodesk will need to communicate.

Although Autodesk's reputation with its developers appears strong, and despite the show of strength from these developers, this group does represent Autodesk's entire source of application-specific software. Autodesk will need to watch its flanks here, making sure that these developers are building as close to state-of-the-art software as is possible.

Smaller PC-based software companies are probably considering Autodesk's relative distance from its subapplication software developers as a weakness they may be able to exploit. The strongest challenger here would be Cadkey, which announced its acquisition of Microtecture at the show. Microtecture's DataCADD is the product formerly sold by the A.I.A. Cadkey can now claim a strong installed base of both mechanical and architectural users, with software tailored for each group.

PRESENCE OR PRODUCT?

As usual, this show highlighted vendor participation rather than product announcements, as witness the incongruous but unforgettable picture of a classroom of "AEC" trainees learning to draw pixel happy faces—on Sun Microsystem workstations. The principal product announcements actually came from plotter companies, which have adopted this event as a primary announcement arena.

Facilities Management: Needs a Great Communicator

Two CAD product areas were showing a large number of relatively new products: facilities design/management products and drawing conversion products. Judging by the number of facilities management solutions displayed, including many small PC-based products and fewer workstation-based offerings, a large number of vendors have tapped facilities design/management as a growing market. However, some of these booths were poorly attended.

Eye appeal may have been part of the problem. There were just too many CRTs displaying different words inside of different boxes, all claiming to be the solution to good information management. The presentation did nothing to facilitate comparing one product with another. We believe that better product demonstrations are needed here, ones that clearly communicate the basic concepts behind the work being done. Until then, attendees accustomed to visually appealing displays will probably walk right on by.

Raster/Vector Drawings: A Hot Spot

Although the subject is neither new nor particularly exciting, raster/vector products (also known as hybrid images or composite drawings) generated strong interest among attendees. The economics make good sense. Now that design services have driven the price of creating a raster image of a paper drawing to less than $10, and the prices of desktop scanners and storage devices have dropped dramatically, a "make-do" solution has emerged for working with a combination of old and new drawings.

Using hybrid drawing products, an architectural or engineering firm can bring a raster image (such as an existing site plan) into the CAD package, erase parts of the raster image that are not wanted, overlay the raster image with vectors drawn on a separate layer, and plot the hybrid drawing as a merged image showing both raster and vector information. Although it is offered by some workstation-based companies, this capability has not been available to PC users in the past, except at much higher prices.

Maintenance and rework as a percent of design work is increasing, which should cause increased demand for hybrid drawings. Many clients (government entities, particularly) enter into contracts with their own existing paper drawings, and vector conversion is costly. Other good uses for merged raster and vector images include zoning reviews and presentations before planning bodies. The ability to mix vector and raster

layers as a design progresses means that, on demand, decisions can be made about which drawings or portions of drawings to use as vector versus raster, as opposed to paying for a complete set of vector drawings. The users we talked to clearly understood that they do not require vector data all at once, and that data might most economically be built over time, line-by-line, as needed.

The proliferation of hybrid drawings could mean that manufacturers of high-cost scanners/digitizers could find themselves increasingly bypassed by lower-cost, but adequate, solutions in the AEC market. The situation is parallel to Autodesk's entry into the CAD market five years ago, when the company offered adequate performance at a dramatically lower price. To quote an A.I.A. spokesman commenting on incorporating existing paper drawings into a new design, "The cost just went down 99.9 percent."

On the other hand, as more composite drawings appear, the demand to print them will also increase. The favored plotter for these drawings is most likely to be one that supports a popular standard (such as PostScript), has a low cost, and is not painfully slow. It is reasonable to generalize that many small A/E offices are relatively disinterested in computers, and are leaning toward solutions that have been proven successful by others. We believe that architects would stretch to afford a reasonably priced output device that offers PostScript hardcopy for their composite raster/vector drawings.

DATAQUEST ANALYSIS

We believe that the majority of the architectural and engineering community has finally accepted computers as being necessary to their competitive business positions and that many of the non-believers tend to be near retirement age. Thus, strong growth in AEC CAD should continue. However, these same prospective customers also demonstrate a keen eye for cheap, "good-enough" solutions, such as PC-based hybrid drawings, which makes them continue to be the CAD/CAE buyers most difficult to entice into high-profit, high-ticket sales.

We also see potential stumbling blocks for the emerging facilities design/management market, as many of the products shown at A/E/C Systems did not capture much interest. We can hope that the audience was not quite right, but the fact remains that these products need a better presentation of both what problems are being solved and how they are being solved.

And finally, for the remaining few who would like to believe that Autodesk is not a serious CAD competitor, or that the company is unlikely to get lucky twice with a major new product, or that it will surely stumble soon—it is time to discard those notions. We believe that the company's influence will grow.

Kathryn Hale

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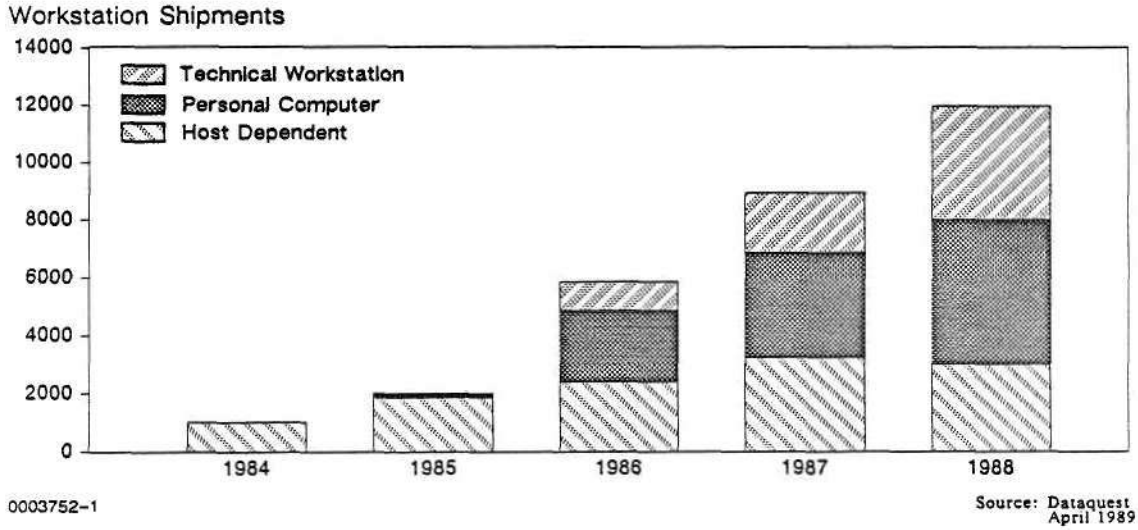
CAD MAPPING AND GIS MARKET REVITALIZED BY EXPLOSION IN DESKTOP SYSTEMS

SUMMARY

In what has historically been a rather slow-moving industry, dominated by mainframe and turnkey vendors selling automated map drafting systems, the mapping market has suddenly come alive. Dataquest recently completed its 1988 comprehensive mapping market review and forecast (see Tables 1 through 6 at the end of this document) and found that the market grew nearly 20 percent in revenue and by an astonishing 34 percent in units compared to 1987 (see Figure 1). The two major forces driving this industry revitalization are the influx of desktop systems and the emergence of a new class of systems called geographic information systems (GISs), which are used primarily to *analyze* geographic information rather than simply to create maps.

Figure 1

Worldwide CAD Mapping Market Growth by Platform



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Source: Dataquest
April 1989

This newsletter discusses current macrolevel issues affecting the mapping market during 1988, presents current market share data, and includes Dataquest's analysis of trends during the next five years.

CURRENT INDUSTRY TRENDS

Movement toward Distributed Desktop Platforms

By far, the most dominant trend in the mapping industry today is the growth and acceptance of personal computers and workstations as the platforms of choice for mapping and GIS applications. Although the movement toward distributed computing already has occurred in other CAD/CAM applications, such as mechanical and electronic CAD, this is a relatively recent phenomenon in mapping. Dataquest believes that mapping's sudden acceptance of distributed computing is due to the following:

- Availability of improved graphics performance and sufficient main memory on personal computers and low-end workstations to support the requirements of map drafting and GIS applications
- Growth of PC local area networks and workstation connectivity tools (e.g., IBM 5080 emulation, DECnet) that enable desktop devices to connect not only to mainframe-based mapping software, but also to corporate data bases
- Emergence of the Apple Macintosh as a viable mapping and GIS platform, which is due in large part to Apple's increased marketing and support efforts in this area
- Increasing availability of PC and workstation-based applications

The platform suppliers that have taken the early lead in this trend toward low-end distributed systems include Apollo, Apple, Digital, IBM (PC products), Intergraph, and Sun.

Introduction of New PC-Based Mapping Applications

Many new PC-based applications burst onto the scene during 1988, including the following:

- ESRI's PC ARC/Info, which is the PC-based version of the company's popular workstation and mainframe ARC/Info GIS software
- Autodesk's new and improved AutoCAD Release 10, which includes special features for mapping and GIS applications (e.g., entity handles) and several AutoCAD piggyback mapping products from Dennis Klein & Associates and Generation 5 Technology
- Several Apple Macintosh-based applications including Business FileVision, GeoQuery, MacAtlas, Mapgraphix, and MapMaker

Dataquest expects to see many more new PC-based mapping and GIS applications introduced in 1989, from existing vendors moving their applications down from mainframes and minicomputers as well as from new vendors entering the marketplace.

Availability of Inexpensive, Off-the-Shelf Map Data Bases

One of the obstacles to tapping the true potential of mapping and GIS has been the lack of inexpensive, commercially available MAP data bases. The market is starting to see evidence of inexpensive land bases being exploited by a whole host of new application users in fields such as real estate, marketing, and agriculture. Cheaper, higher-resolution data from Landsat as well as electronic road maps from companies such as ETAK and Geographic Data Technology will help accelerate the movement of these nontraditional applications into the mainstream.

Glare of the Media and a Glut of Trade Shows

The mapping market suddenly has emerged as a darling of the media and has attracted record levels of trade show activity. *Business Week* and *Fortune* recently have run extensive articles on the desktop mapping market. Unfortunately, all the media hype and attention cannot overcome the fact that there is an oversupply of mapping-related trade shows. In 1988, dozens of shows held in the United States at the national and local levels left vendors with a dizzying array of choices at which to display their latest mapping solutions. Dataquest believes that a major consolidation of mapping-related shows will begin in 1990.

MARKET SHARE

Table 1 lists mapping market shares for the leading vendors in the industry, ranked by revenue.

Intergraph

Intergraph continues to dominate the mapping market with a 25.4 percent share, which is more than twice the size of its next-largest competitor, Digital Equipment Corporation. The company's dominance in this area is due in part to its large, loyal installed base of mapping users that continue to add and upgrade to Intergraph's newer mapping systems (e.g., InterPro workstations and TIGRIS software). More recently, Intergraph has benefited from the rapidly growing international markets. In 1988, for example, Intergraph secured several large European mapping orders, including orders from British Telecom, valued at $35 million, and Post and Telecommunications of Finland, valued at more than $20 million.

Dataquest believes that Intergraph's prospects in this market will continue to grow brighter. This growth will be spurred in large part by the company's long-awaited introduction of its object-oriented TIGRIS GIS system. We believe that this system will be a big seller, particularly to existing users of Intergraph's older IGDS mapping system that want to migrate to the newer, more powerful GIS technology.

Digital

Digital continues to do well in the mapping market because its offering is one of the platforms of choice for many third-party mapping and GIS applications. The MicroVAX and VAXStations are major products for Digital in this market. Last year, Digital landed several large mapping platform orders, including the British Gas order in conjunction with Synercom.

The company also has aggressively pursued third-party application developers and has put together several targeted, integrated mapping solutions. For example, Digital recently announced a turnkey solution for utility AM/FM applications that combines Synercom's InforMap III, C-E Engineering Automation's PASCE software, and Power Technologies' PSS/U network analysis package. Dataquest believes that Digital recognizes the value of an integrated, solution-oriented approach to the mapping and GIS market, and that it will continue to emphasize this approach as a way of setting itself apart in the marketplace.

IBM

In the mapping market, 1988 was a year of rebuilding for IBM. The following key events highlight this point:

- IBM reorganized its GFIS effort, moving it out of the Utility Marketing Group and into its own area with the Application Software Division.

- IBM finally began to recognize the value and importance of third-party suppliers in this market, and it formed several marketing relationships with companies such as ACDS, Digital Matrix Systems, and ESRI for PC- and workstation-based software.

Dataquest believes that IBM will become much more aggressive in the mapping and GIS market in the future. However, it is doubtful that its mainframe GFIS offering will be competitive in this market, which is moving rapidly to distributed, workstation-based solutions. IBM may adopt Digital's approach of being a platform supplier and integrator for third-party mapping and GIS software.

ESRI

ESRI remains the premier GIS software supplier in the industry, with revenue growth of more than 36 percent. Dataquest believes that ESRI's success in this market is due to the following factors:

- It was a pioneer in the efforts to legitimize the use of GIS technology, and it is widely recognized as a company that fully understands the problems and solutions for building true GIS data bases.

- Its ARC/Info software is the most mature GIS software system on the market and is available on the widest array of platforms in the CAD/CAM industry.

Among several important events that have occurred recently at ESRI are the introduction of an IBM MVS mainframe version of ARC/Info, which could give IBM a run for its money against GFIS, as well as an innovative deal with EDS that allows its ARC/Info software to be used on a time-sharing basis.

Landmark Graphics

Landmark Graphics had 1988 revenue of $30 million and is growing rapidly in the Dataquest mapping market share rankings. The company dominates a niche segment of the mapping business that it terms computer-aided exploration (CAEX). Its systems have become the de facto standard among many of the major multinational oil companies. With the price of oil on the rise again, this company will be well positioned if oil exploration bounces back to late 1970 and early 1980 levels.

Other Companies

Synercom Technology rebounded nicely in 1988 with an impressive 49 percent increase in revenue and a much more stable profit picture. The company's new management team, its new MicroVAX-based InforMAP III product, and its several large overseas orders all contributed to the turnaround.

Despite the acquisitions of Computervision and Calma, the temptation to delay entering the fast-growing GIS market was too great for Prime Computer, and it decided to form a joint venture with the European-based GIS vendor, Wild Leitz. This strong GIS partnership is expected to complement Prime's CADDS 4X AM/FM product line.

Several Japanese vendors that took advantage of the rapidly growing mapping and infrastructure market in Japan emerged in 1988. Both Fujitsu with its ICAD mapping systems and Mitsubishi Electric with its MELCAD more than doubled their individual mapping revenue in 1988.

MARKET OUTLOOK ANALYSIS

Regional Forecast

Unlike other CAD/CAM applications, Dataquest expects the regional growth forecast for mapping to be relatively balanced between North America, Europe, and Asia. However, the international markets will be driven by large infrastructure-related purchases, while the North American market will be driven by the explosion in desktop mapping.

Platform Forecast

As the forecasts in Tables 1 through 6 indicate, Dataquest believes that technical workstations will dominate the mapping market during the next five years. Last year, technical workstations nearly equaled host-based systems in revenue. Vendors such as

Digital, Hewlett-Packard/Apollo, Intergraph, Silicon Graphics, and Sun will be major benefactors of the rapid growth in CAD/CAM workstations.

Apple and Compaq also should experience high growth rates in the personal computer/workstation area during the next several years. Apple's Macintosh has really taken off as a viable mapping platform, while Compaq's 386 machines are now outselling IBM in the CAD/CAM market.

Although the forecast shows personal computer revenue growth slowing down over time, this trend is a bit misleading. Dataquest believes that personal computers eventually will join the ranks of workstations in terms of functionality. Therefore, the personal computers of today will be made essentially obsolete by the new class of low-end workstations. In the future, we may do away with the term personal computer altogether and add further segmentation to our workstation forecast.

Average Selling Prices

Dataquest forecasts a continuing decline in mapping workstation selling prices, with an average drop of 7.6 percent per year during the next five years. Most of this drop is due to a changing mix that will favor lower-cost systems as opposed to real drops in the price of hardware or software.

Revenue Source Forecast

We continue to believe that mapping software and services will grow much faster than hardware. In 1988, software equaled 29 percent of total market revenue. Dataquest forecasts that software will grow to 41 percent of total market revenue by 1993.

We also believe that, while total personal computer revenue will decline substantially during the next five years, there will be a sizable CAD/CAM software aftermarket for PCs long after workstations have replaced this architecture, particularly in the non-traditional mapping applications.

Distribution Class Outlook

One of the most important trends Dataquest will be watching during the next several years is the change in the way CAD/CAM systems are distributed. Today, turnkey systems still account for the lion's share of the market, with a 61 percent share. Dataquest predicts that by 1993, turnkey system sales will fall to 56 percent of the market, with the balance made up of unbundled sales and sales made through dealers and distributors. We strongly believe that the most successful vendors in the future are likely to be those that have solved the low-end distribution puzzle by successfully managing a multitiered strategy that encompasses all three forms of distribution and strategic marketing alliances.

David Burdick

Table 1

1988 Worldwide Mapping Market Share
(Millions of Dollars, Actual Units)

	Revenue	Units	Revenue Share	Units Share
Intergraph	163.7	1,792	25.4%	15.0%
Digital	78.0	983	12.1%	8.2%
IBM	45.4	1,260	7.0%	10.5%
ESRI	32.4	44	5.0%	.4%
Landmark Graphics	30.0	233	4.7%	1.9%
Fujitsu	26.9	324	4.2%	2.7%
Prime Computer	18.6	150	2.9%	1.3%
Syscan	17.8	102	2.8%	.9%
Mitsubishi Electric	15.4	56	2.4%	.5%
Synercom	15.3	0	2.4%	.0%
McDonnell Douglas	14.6	162	2.3%	1.4%
Siemens	14.3	270	2.2%	2.3%
GeoVision Corp.	13.4	144	2.1%	1.2%
Autodesk	10.6	0	1.6%	.0%
ICL	10.5	198	1.6%	1.6%
ETAK	9.0	0	1.4%	.0%
Hitachi	7.7	75	1.2%	.6%
Sun	6.5	307	1.0%	2.6%
Apple Computer	6.0	1,400	.9%	11.7%
Mitsui Engineering	5.3	61	.8%	.5%
Other	103.6	4,413	16.1%	36.9%
All Companies	644.9	11,975	100.0%	100.0%
All U.S.-Based Companies	521.9	10,391	80.9%	86.8%
All Asian-Based Companies	68.1	654	10.6%	5.5%
All European-Based Companies	54.9	930	8.5%	7.8%
All Hardware Companies	118.6	6,536	18.4%	54.6%
All Turnkey & SW Companies	526.3	5,439	81.6%	45.4%

Source: Dataquest
April 1989

Table 2

Worldwide Mapping Forecast by Region
(Millions of Dollars, Actual Units)

	1988	1989	1990	1991	1992	1993	CAGR
Worldwide							
Revenue	645	787	932	1,071	1,203	1,380	16.4%
Systems	9,708	13,280	17,120	20,340	23,370	26,750	22.5%
Workstations	11,975	15,460	19,140	22,090	24,820	27,920	18.4%
North America							
Revenue	318	381	451	525	593	694	16.9%
Systems	4,969	6,720	8,690	10,060	11,260	12,680	20.6%
Workstations	6,135	7,750	9,590	10,810	11,870	13,150	16.5%
Europe							
Revenue	180	220	260	291	327	372	15.6%
Systems	2,899	4,080	5,300	6,510	7,730	8,980	25.4%
Workstations	3,596	4,820	6,010	7,130	8,240	9,390	21.2%
Far East							
Revenue	120	158	191	222	249	277	18.2%
Systems	1,474	2,020	2,580	3,110	3,630	4,220	23.4%
Workstations	1,787	2,340	2,900	3,410	3,890	4,450	20.0%
Rest of World							
Revenue	27	29	31	33	34	38	6.6%
Systems	367	460	550	660	750	870	18.9%
Workstations	457	540	630	730	820	920	15.0%

Source: Dataquest
April 1989

Table 3

Worldwide Mapping Forecast by Platform
(Millions of Dollars, Actual Units)

	1988	1989	1990	1991	1992	1993	CAGR
All Platforms							
Revenue	645	787	932	1,071	1,203	1,380	16.4%
Systems	9,708	13,280	17,120	20,340	23,370	26,750	22.5%
Workstations	11,975	15,460	19,140	22,090	24,820	27,920	18.4%
Technical Workstation							
Revenue	270	371	487	610	739	896	27.2%
Systems	3,977	5,680	7,830	10,370	13,240	16,550	33.0%
Workstations	3,977	5,680	7,830	10,370	13,240	16,550	33.0%
Host-Dependent							
Revenue	297	298	278	246	209	173	-10.2%
Systems	754	820	840	790	710	620	-3.8%
Workstations	3,021	3,000	2,860	2,530	2,160	1,790	-9.9%
Personal Computer							
Revenue	78	118	168	214	256	310	31.7%
Systems	4,977	6,780	8,450	9,190	9,430	9,580	14.0%
Workstations	4,977	6,780	8,450	9,190	9,430	9,580	14.0%

Source: Dataquest
April 1989

Table 4

Worldwide Mapping
Average Price per Seat Forecast by Platform
(Thousands of Dollars)

	1988	1989	1990	1991	1992	1993	CAGR
Turnkey & Hardware-Only							
Technical Workstation	50.4	47.8	44.7	42.0	39.8	38.7	-5.1%
Host-Dependent	260.2	236.1	220.7	210.8	200.5	190.8	-6.0%
Personal Computer	7.1	6.5	5.8	5.2	4.6	4.2	-10.0%
All Platforms	44.5	38.4	34.1	31.9	30.5	29.9	-7.6%
Turnkey							
Technical Workstation	66.1	64.8	61.6	58.0	54.8	53.1	-4.3%
Host-Dependent	359.3	335.3	316.0	299.8	280.9	266.7	-5.8%
Personal Computer	21.7	21.4	19.7	18.0	16.7	15.2	-6.9%
All Platforms	85.7	78.5	72.1	66.0	60.8	57.3	-7.7%
Hardware-Only							
Technical Workstation	21.5	19.5	17.7	16.0	14.6	13.9	-8.4%
Host-Dependent	154.6	140.7	128.5	117.7	107.6	98.4	-8.6%
Personal Computer	4.0	4.1	4.0	3.8	3.5	3.4	-3.2%
All Platforms	17.5	14.8	12.6	11.1	9.9	9.3	-11.9%

Source: Dataquest
April 1989

Table 5

Worldwide Mapping
Revenue Sources Forecast by Platform
(Millions of Dollars)

	1988	1989	1990	1991	1992	1993	CAGR
All Platforms							
Hardware	353	408	465	512	557	621	12.0%
Software	187	258	330	406	477	568	24.9%
Service	104	122	138	153	169	190	12.9%
Total	645	787	932	1,071	1,203	1,380	16.4%
Technical Workstation							
Hardware	161	214	274	339	407	492	25.1%
Software	63	96	132	171	210	256	32.5%
Service	45	62	80	101	122	148	27.0%
Total	270	371	487	610	739	896	27.2%
Host-Dependent							
Hardware	162	156	147	131	111	92	-10.7%
Software	79	87	80	71	60	50	-8.6%
Service	56	55	51	44	37	31	-11.2%
Total	297	298	278	246	209	173	-10.2%
Personal Computer							
Hardware	30	38	43	43	39	37	4.2%
Software	46	76	119	164	207	262	41.8%
Service	3	5	7	8	10	11	27.4%
Total	78	118	168	214	256	310	31.7%

Source: Dataquest
April 1989

Table 6

Worldwide Mapping
Forecast by Distribution Class
(Millions of Dollars, Actual Units)

	1988	1989	1990	1991	1992	1993	CAGR
Total Hardware and Software Revenue							
Turnkey	328	393	454	516	582	666	15.2%
Unbundled	212	273	340	401	452	524	19.8%
Total	540	666	795	918	1,035	1,189	17.1%
Hardware Revenue							
Turnkey	249	291	335	379	426	486	14.3%
Unbundled	104	117	130	132	131	135	5.4%
Total	353	408	465	512	557	621	12.0%
Software Revenue							
Turnkey	79	102	120	137	156	179	17.9%
Unbundled	109	156	210	269	322	389	29.0%
Total	187	258	330	406	477	568	24.9%
Workstation Shipments							
Turnkey	5,439	6,460	7,640	9,010	10,570	12,410	17.9%
Unbundled	6,536	9,000	11,500	13,080	14,260	15,500	18.9%
Total	11,975	15,460	19,140	22,090	24,820	27,920	18.4%

Source: Dataquest
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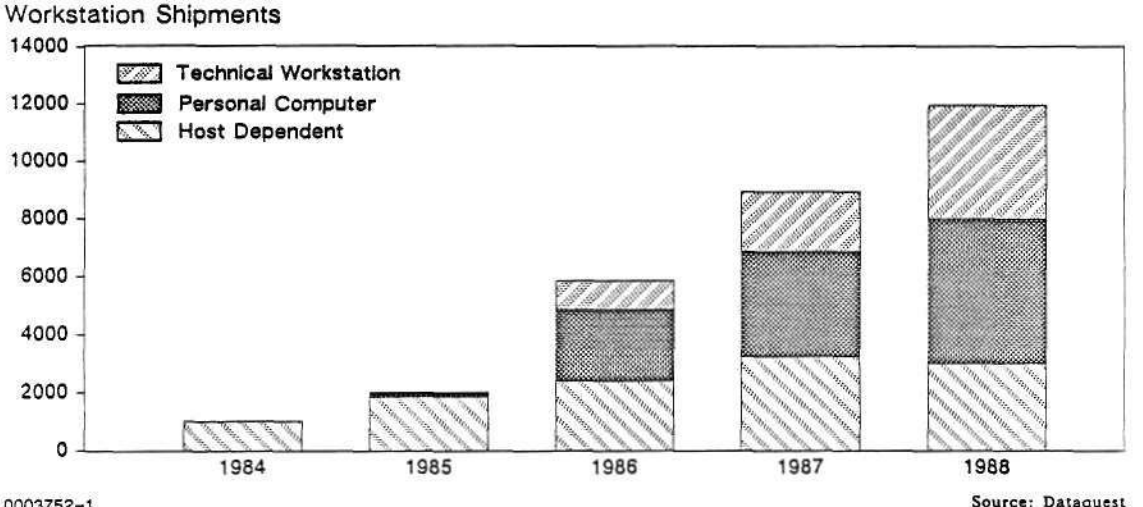

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Table 1 lists mapping market shares for the leading vendors in the industry, ranked by revenue.

Intergraph

Intergraph continues to dominate the mapping market with a 25.4 percent share, which is more than twice the size of its next-largest competitor, Digital Equipment Corporation. The company's dominance in this area is due in part to its large, loyal installed base of mapping users that continue to add and upgrade to Intergraph's newer mapping systems (e.g., InterPro workstations and TIGRIS software). More recently, Intergraph has benefited from the rapidly growing international markets. In 1988, for example, Intergraph secured several large European mapping orders, including orders from British Telecom, valued at $35 million, and Post and Telecommunications of Finland, valued at more than $20 million.

Dataquest believes that Intergraph's prospects in this market will continue to grow brighter. This growth will be spurred in large part by the company's long-awaited introduction of its object-oriented TIGRIS GIS system. We believe that this system will be a big seller, particularly to existing users of Intergraph's older IGDS mapping system that want to migrate to the newer, more powerful GIS technology.

Digital

Digital continues to do well in the mapping market because its offering is one of the platforms of choice for many third-party mapping and GIS applications. The MicroVAX and VAXStations are major products for Digital in this market. Last year, Digital landed several large mapping platform orders, including the British Gas order in conjunction with Synercom.

The company also has aggressively pursued third-party application developers and has put together several targeted, integrated mapping solutions. For example, Digital recently announced a turnkey solution for utility AM/FM applications that combines Synercom's InforMap III, C-E Engineering Automation's PASCE software, and Power Technologies' PSS/U network analysis package. Dataquest believes that Digital recognizes the value of an integrated, solution-oriented approach to the mapping and GIS market, and that it will continue to emphasize this approach as a way of setting itself apart in the marketplace.

IBM

In the mapping market, 1988 was a year of rebuilding for IBM. The following key events highlight this point:

- IBM reorganized its GFIS effort, moving it out of the Utility Marketing Group and into its own area with the Application Software Division.

- IBM finally began to recognize the value and importance of third-party suppliers in this market, and it formed several marketing relationships with companies such as ACDS, Digital Matrix Systems, and ESRI for PC- and workstation-based software.

Dataquest believes that IBM will become much more aggressive in the mapping and GIS market in the future. However, it is doubtful that its mainframe GFIS offering will be competitive in this market, which is moving rapidly to distributed, workstation-based solutions. IBM may adopt Digital's approach of being a platform supplier and integrator for third-party mapping and GIS software.

ESRI

ESRI remains the premier GIS software supplier in the industry, with revenue growth of more than 36 percent. Dataquest believes that ESRI's success in this market is due to the following factors:

- It was a pioneer in the efforts to legitimize the use of GIS technology, and it is widely recognized as a company that fully understands the problems and solutions for building true GIS data bases.

- Its ARC/Info software is the most mature GIS software system on the market and is available on the widest array of platforms in the CAD/CAM industry.

Among several important events that have occurred recently at ESRI are the introduction of an IBM MVS mainframe version of ARC/Info, which could give IBM a run for its money against GFIS, as well as an innovative deal with EDS that allows its ARC/Info software to be used on a time-sharing basis.

Landmark Graphics

Landmark Graphics had 1988 revenue of $30 million and is growing rapidly in the Dataquest mapping market share rankings. The company dominates a niche segment of the mapping business that it terms computer-aided exploration (CAEX). Its systems have become the de facto standard among many of the major multinational oil companies. With the price of oil on the rise again, this company will be well positioned if oil exploration bounces back to late 1970 and early 1980 levels.

Other Companies

Synercom Technology rebounded nicely in 1988 with an impressive 49 percent increase in revenue and a much more stable profit picture. The company's new management team, its new MicroVAX-based InforMAP III product, and its several large overseas orders all contributed to the turnaround.

Despite the acquisitions of Computervision and Calma, the temptation to delay entering the fast-growing GIS market was too great for Prime Computer, and it decided to form a joint venture with the European-based GIS vendor, Wild Leitz. This strong GIS partnership is expected to complement Prime's CADDS 4X AM/FM product line.

Several Japanese vendors that took advantage of the rapidly growing mapping and infrastructure market in Japan emerged in 1988. Both Fujitsu with its ICAD mapping systems and Mitsubishi Electric with its MELCAD more than doubled their individual mapping revenue in 1988.

MARKET OUTLOOK ANALYSIS

Regional Forecast

Unlike other CAD/CAM applications, Dataquest expects the regional growth forecast for mapping to be relatively balanced between North America, Europe, and Asia. However, the international markets will be driven by large infrastructure-related purchases, while the North American market will be driven by the explosion in desktop mapping.

Platform Forecast

As the forecasts in Tables 1 through 6 indicate, Dataquest believes that technical workstations will dominate the mapping market during the next five years. Last year, technical workstations nearly equaled host-based systems in revenue. Vendors such as

Digital, Hewlett-Packard/Apollo, Intergraph, Silicon Graphics, and Sun will be major benefactors of the rapid growth in CAD/CAM workstations.

Apple and Compaq also should experience high growth rates in the personal computer/workstation area during the next several years. Apple's Macintosh has really taken off as a viable mapping platform, while Compaq's 386 machines are now outselling IBM in the CAD/CAM market.

Although the forecast shows personal computer revenue growth slowing down over time, this trend is a bit misleading. Dataquest believes that personal computers eventually will join the ranks of workstations in terms of functionality. Therefore, the personal computers of today will be made essentially obsolete by the new class of low-end workstations. In the future, we may do away with the term personal computer altogether and add further segmentation to our workstation forecast.

Average Selling Prices

Dataquest forecasts a continuing decline in mapping workstation selling prices, with an average drop of 7.6 percent per year during the next five years. Most of this drop is due to a changing mix that will favor lower-cost systems as opposed to real drops in the price of hardware or software.

Revenue Source Forecast

We continue to believe that mapping software and services will grow much faster than hardware. In 1988, software equaled 29 percent of total market revenue. Dataquest forecasts that software will grow to 41 percent of total market revenue by 1993.

We also believe that, while total personal computer revenue will decline substantially during the next five years, there will be a sizable CAD/CAM software aftermarket for PCs long after workstations have replaced this architecture, particularly in the non-traditional mapping applications.

Distribution Class Outlook

One of the most important trends Dataquest will be watching during the next several years is the change in the way CAD/CAM systems are distributed. Today, turnkey systems still account for the lion's share of the market, with a 61 percent share. Dataquest predicts that by 1993, turnkey system sales will fall to 56 percent of the market, with the balance made up of unbundled sales and sales made through dealers and distributors. We strongly believe that the most successful vendors in the future are likely to be those that have solved the low-end distribution puzzle by successfully managing a multitiered strategy that encompasses all three forms of distribution and strategic marketing alliances.

David Burdick

Table 1

1988 Worldwide Mapping Market Share
(Millions of Dollars, Actual Units)

	Revenue	Units	Revenue Share	Units Share
Intergraph	163.7	1,792	25.4%	15.0%
Digital	78.0	983	12.1%	8.2%
IBM	45.4	1,260	7.0%	10.5%
ESRI	32.4	44	5.0%	.4%
Landmark Graphics	30.0	233	4.7%	1.9%
Fujitsu	26.9	324	4.2%	2.7%
Prime Computer	18.6	150	2.9%	1.3%
Sysscan	17.8	102	2.8%	.9%
Mitsubishi Electric	15.4	56	2.4%	.5%
Synercom	15.3	0	2.4%	.0%
McDonnell Douglas	14.6	162	2.3%	1.4%
Siemens	14.3	270	2.2%	2.3%
GeoVision Corp.	13.4	144	2.1%	1.2%
Autodesk	10.6	0	1.6%	.0%
ICL	10.5	198	1.6%	1.6%
ETAK	9.0	0	1.4%	.0%
Hitachi	7.7	75	1.2%	.6%
Sun	6.5	307	1.0%	2.6%
Apple Computer	6.0	1,400	.9%	11.7%
Mitsui Engineering	5.3	61	.8%	.5%
Other	103.6	4,413	16.1%	36.9%
All Companies	644.9	11,975	100.0%	100.0%
All U.S.-Based Companies	521.9	10,391	80.9%	86.8%
All Asian-Based Companies	68.1	654	10.6%	5.5%
All European-Based Companies	54.9	930	8.5%	7.8%
All Hardware Companies	118.6	6,536	18.4%	54.6%
All Turnkey & SW Companies	526.3	5,439	81.6%	45.4%

Source: Dataquest
April 1989

Table 2

Worldwide Mapping Forecast by Region
(Millions of Dollars, Actual Units)

	1988	1989	1990	1991	1992	1993	CAGR
Worldwide							
Revenue	645	787	932	1,071	1,203	1,380	16.4%
Systems	9,708	13,280	17,120	20,340	23,370	26,750	22.5%
Workstations	11,975	15,460	19,140	22,090	24,820	27,920	18.4%
North America							
Revenue	318	381	451	525	593	694	16.9%
Systems	4,969	6,720	8,690	10,060	11,260	12,680	20.6%
Workstations	6,135	7,750	9,590	10,810	11,870	13,150	16.5%
Europe							
Revenue	180	220	260	291	327	372	15.6%
Systems	2,899	4,080	5,300	6,510	7,730	8,980	25.4%
Workstations	3,596	4,820	6,010	7,130	8,240	9,390	21.2%
Far East							
Revenue	120	158	191	222	249	277	18.2%
Systems	1,474	2,020	2,580	3,110	3,630	4,220	23.4%
Workstations	1,787	2,340	2,900	3,410	3,890	4,450	20.0%
Rest of World							
Revenue	27	29	31	33	34	38	6.6%
Systems	367	460	550	660	750	870	18.9%
Workstations	457	540	630	730	820	920	15.0%

Source: Dataquest
April 1989

Table 3

Worldwide Mapping Forecast by Platform
(Millions of Dollars, Actual Units)

	1988	1989	1990	1991	1992	1993	CAGR
All Platforms							
Revenue	645	787	932	1,071	1,203	1,380	16.4%
Systems	9,708	13,280	17,120	20,340	23,370	26,750	22.5%
Workstations	11,975	15,460	19,140	22,090	24,820	27,920	18.4%
Technical Workstation							
Revenue	270	371	487	610	739	896	27.2%
Systems	3,977	5,680	7,830	10,370	13,240	16,550	33.0%
Workstations	3,977	5,680	7,830	10,370	13,240	16,550	33.0%
Host-Dependent							
Revenue	297	298	278	246	209	173	-10.2%
Systems	754	820	840	790	710	620	-3.8%
Workstations	3,021	3,000	2,860	2,530	2,160	1,790	-9.9%
Personal Computer							
Revenue	78	118	168	214	256	310	31.7%
Systems	4,977	6,780	8,450	9,190	9,430	9,580	14.0%
Workstations	4,977	6,780	8,450	9,190	9,430	9,580	14.0%

Source: Dataquest
April 1989

Table 4

Worldwide Mapping
Average Price per Seat Forecast by Platform
(Thousands of Dollars)

	1988	1989	1990	1991	1992	1993	CAGR
Turnkey & Hardware-Only							
Technical Workstation	50.4	47.8	44.7	42.0	39.8	38.7	-5.1%
Host-Dependent	260.2	236.1	220.7	210.8	200.5	190.8	-6.0%
Personal Computer	7.1	6.5	5.8	5.2	4.6	4.2	-10.0%
All Platforms	44.5	38.4	34.1	31.9	30.5	29.9	-7.6%
Turnkey							
Technical Workstation	66.1	64.8	61.6	58.0	54.8	53.1	-4.3%
Host-Dependent	359.3	335.3	316.0	299.8	280.9	266.7	-5.8%
Personal Computer	21.7	21.4	19.7	18.0	16.7	15.2	-6.9%
All Platforms	85.7	78.5	72.1	66.0	60.8	57.3	-7.7%
Hardware-Only							
Technical Workstation	21.5	19.5	17.7	16.0	14.6	13.9	-8.4%
Host-Dependent	154.6	140.7	128.5	117.7	107.6	98.4	-8.6%
Personal Computer	4.0	4.1	4.0	3.8	3.5	3.4	-3.2%
All Platforms	17.5	14.8	12.6	11.1	9.9	9.3	-11.9%

Source: Dataquest
April 1989

Table 5

Worldwide Mapping
Revenue Sources Forecast by Platform
(Millions of Dollars)

	1988	1989	1990	1991	1992	1993	CAGR
All Platforms							
Hardware	353	408	465	512	557	621	12.0%
Software	187	258	330	406	477	568	24.9%
Service	104	122	138	153	169	190	12.9%
Total	645	787	932	1,071	1,203	1,380	16.4%
Technical Workstation							
Hardware	161	214	274	339	407	492	25.1%
Software	63	96	132	171	210	256	32.5%
Service	45	62	80	101	122	148	27.0%
Total	270	371	487	610	739	896	27.2%
Host-Dependent							
Hardware	162	156	147	131	111	92	-10.7%
Software	79	87	80	71	60	50	-8.6%
Service	56	55	51	44	37	31	-11.2%
Total	297	298	278	246	209	173	-10.2%
Personal Computer							
Hardware	30	38	43	43	39	37	4.2%
Software	46	76	119	164	207	262	41.8%
Service	3	5	7	8	10	11	27.4%
Total	78	118	168	214	256	310	31.7%

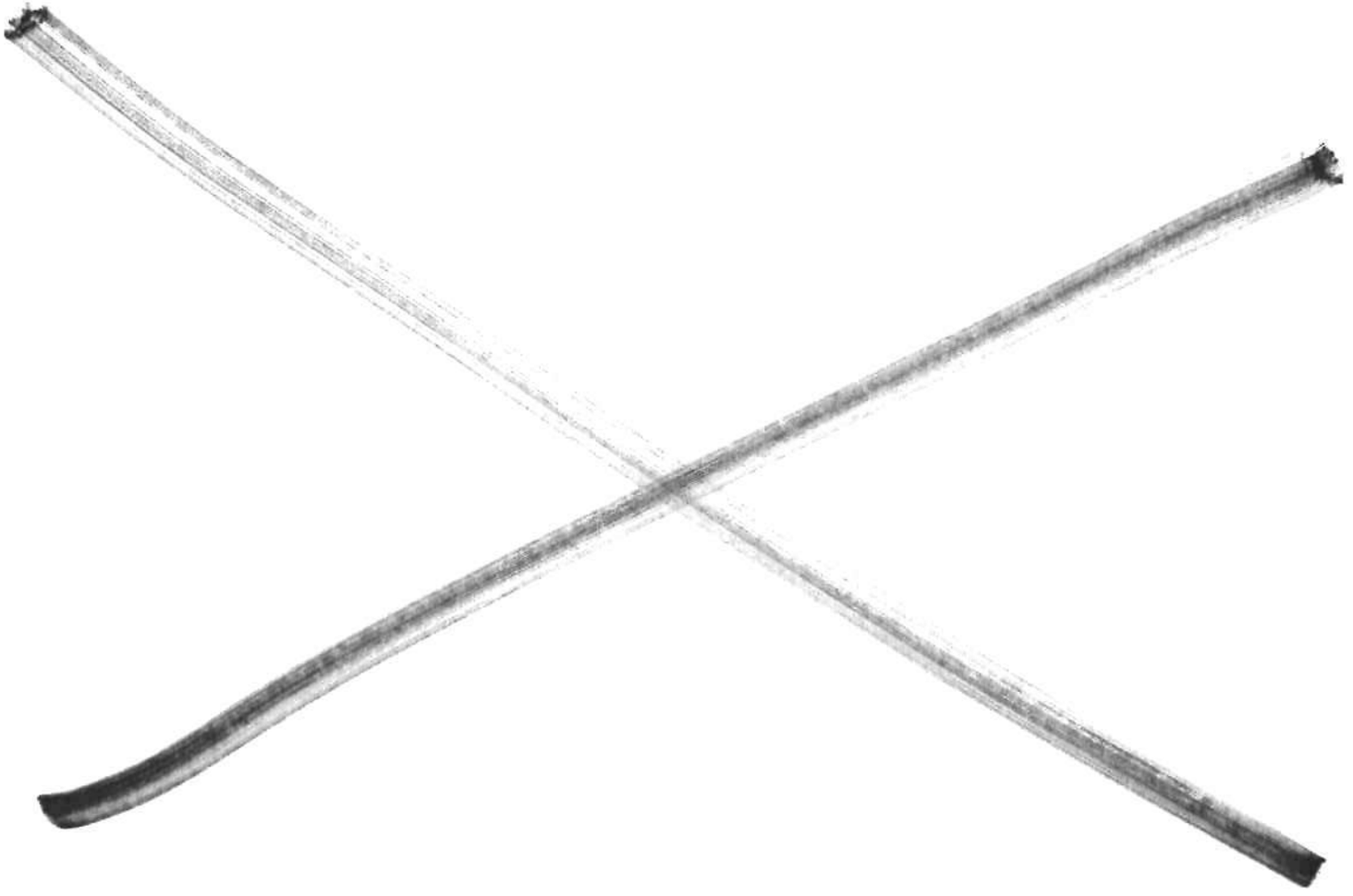
Source: Dataquest
April 1989

Table 6

Worldwide Mapping
Forecast by Distribution Class
(Millions of Dollars, Actual Units)

	1988	1989	1990	1991	1992	1993	CAGR
Total Hardware and Software Revenue							
Turnkey	328	393	454	516	582	666	15.2%
Unbundled	212	273	340	401	452	524	19.8%
Total	540	666	795	918	1,035	1,189	17.1%
Hardware Revenue							
Turnkey	249	291	335	379	426	486	14.3%
Unbundled	104	117	130	132	131	135	5.4%
Total	353	408	465	512	557	621	12.0%
Software Revenue							
Turnkey	79	102	120	137	156	179	17.9%
Unbundled	109	156	210	269	322	389	29.0%
Total	187	258	330	406	477	568	24.9%
Workstation Shipments							
Turnkey	5,439	6,460	7,640	9,010	10,570	12,410	17.9%
Unbundled	6,536	9,000	11,500	13,080	14,260	15,500	18.9%
Total	11,975	15,460	19,140	22,090	24,820	27,920	18.4%

Source: Dataquest
April 1989



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Research Newsletter

GEOGRAPHIC INFORMATION SYSTEMS: THE EUROPEAN TERRAIN

EXECUTIVE SUMMARY

The fast-growing geographic information systems (GIS) market is sizzling in Europe, having grown 31 percent in 1990 to $478 million. We expect this growth to continue at a 27.7 percent compound annual growth rate (CAGR) through 1995, when the market is forecast to reach $1,619 million. Although the major factors both driving and limiting GIS market growth are similar around the world, Europe is enjoying a growth curve that is expected to make it the largest market region by 1992 (see Figure 1). This newsletter compares general European GIS market conditions with the currently larger North American market and examines conditions and outlook by country.

WORLDWIDE SNAPSHOT

Market conditions for GIS are unique in Europe despite the fact that core users and core applications have many of the same problems worldwide. Typical users are governments, utilities (such as gas, electric, and telecommunications), and purveyors of products such as forestry and oil, whose development occupies large areas. Buyers often work in large bureaucracies, which have a conservative approach to procurement and agonizingly extended sales cycles. Many installations in those organizations are pilot projects, and it remains to be seen if and when full implementation will take place.

Core applications are also similar around the world, extending far beyond simple digital storage and display of maps; applications typically involve an attempt to create an integrated data set of information pertinent to the land base for purposes of analysis and control of the area of scrutiny. Examples range from land and resource management to electric utility network analysis and new applications continually emerge. Applications under active development include environmental and resource monitoring; emergency response systems for police, fire, and rescue services; and market research.

Tasked with ambitious goals, GIS presents challenges. Creating adequate digital land-base data is costly and time-consuming; it is measured by years. Economical and effective development often requires cooperation among people working in different departments, different jurisdictions, and different companies. Considerable market growth has been based on the likelihood that GISs are required to manage an increasingly complex world rather than based on a history of proven successes.

GIS is becoming continuously more affordable because of the continuing decline in hardware prices. Because of the large growth potential in the GIS market, many CAD vendors, particularly those selling products for facilities management, are now positioning themselves as GIS vendors.

EUROPE VERSUS NORTH AMERICA

Table 1 summarizes the key differences between European and North American GIS markets. European countries generally have more accurate land-base data than does the United States, more often already in vector form. Additionally, gas, electric, and telecommunications utilities are more typically part of each country's government in Europe, significantly facilitating cooperation in large-scale GIS development compared with the legal issues raised in the United States over local governments sharing development costs with private utility companies. Even as privatization of utilities grows, the history of cooperation and high map accuracy will remain, and GIS funding for these private utilities is likely to grow. In

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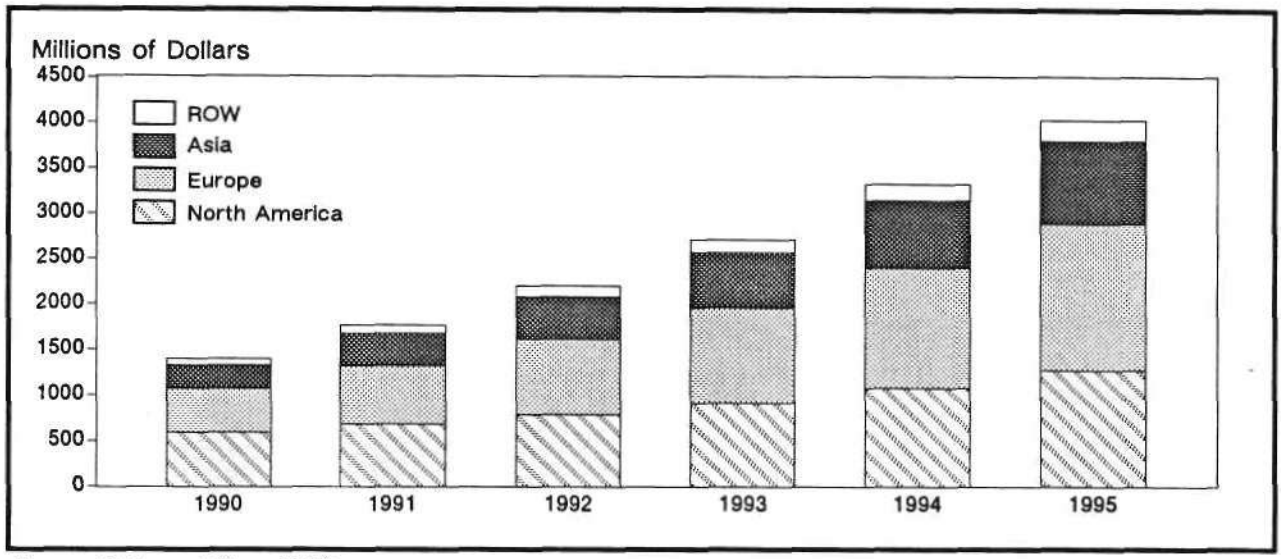
FIGURE 1
Worldwide Geographic Information Systems Market (Millions of Dollars)



Source: Dataquest (June 1991)

TABLE 1
Comparison of GIS Markets in Europe and the United States

Factor	Europe	United States
Data sources	Private companies increasingly compete with governments that sell copyrighted data sets	Government frequently the initial low-cost source of data, resold in enhanced form by private sector
Raster versus vector	Nearly all paper conversions are to vector data	Increasing acceptance of raster map conversions as an incremental solution
Price of government-supplied data	High; goal is cost recovery	Low; value placed on disseminating information
Multiparticipant projects	Few barriers within a country; most participants are government entities	Barriers to overcome in creating cooperative ventures between government and private utility companies
Third-party implementation	General shortage of consultants; some activity by larger corporations acting as systems integrators	Many small consulting/conversion companies
Political and legal issues	Liability across countries, especially as environmental information is released	Determining level of cooperation between public and private sector

Source: Dataquest (June 1991)

short, most European countries are better organized structurally for GIS development than is the United States, a key reason why European growth is forecast to be higher than North American growth.

Paper map conversions in Europe are more likely to be in vector form than in the United States, partly because of both the higher level of map accuracy and the hospitable organizational structure. Increasingly in the United States, users facing a mountain of maps are adopting the "scan it in now and worry later" philosophy of incremental conversion.

Unlike Europe, the United States has strong laws on "freedom of (low-cost government)

information." This legislation is a strong GIS market driver; new U.S. GIS markets are developing based on data originally supplied at low cost by the U.S. government. In contrast, most European government entities are charged with cost recovery for data development. Thus, land-base data in European countries is generally expensive to buy, may be copyrighted, and is sometimes regarded as a state secret. As a result, private companies, such as the United Kingdom's Automobile Association, directly compete with the government in Europe in developing and selling data.

Europewide data is almost nonexistent compared with data compiled by the U.S. government, and efforts by the European Commission to set up such Europewide data (such as the CORINE project) are limited by bureaucracy and politics. For example, the elemental decision on where to locate CORINE project headquarters remains stuck in a political quagmire.

Finally, the complexion of the experience base is different in Europe than in and the United States. Few universities in Europe offer comprehensive GIS instruction compared with facilities available in the United States. Also, North America is currently better supplied with experienced small consulting/implementation companies than is Europe, with the result that European GIS projects are more likely to be undertaken as systems integration projects by larger companies such as Digital Equipment Corporation.

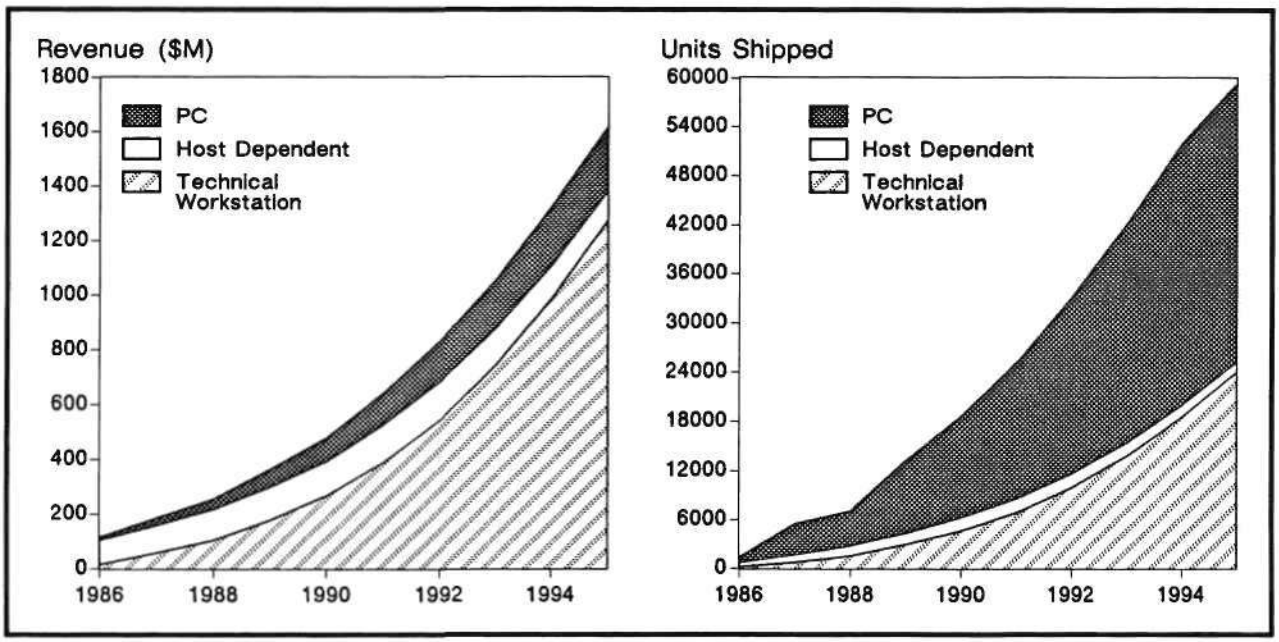
FORECAST

The European market for GIS is forecast to grow at a CAGR of 27.7 percent during the 1990 to 1995 time frame and is expected to equal the size of the North American market by 1992 (see Figure 1). The greatest growth potential lies with systems running on technical workstations and PC-based systems, with host-based systems' share of the GIS market declining rapidly. Figure 2 shows Dataquest's five-year forecast for GIS applications in terms of revenue and units.

A COUNTRY-LEVEL VIEW

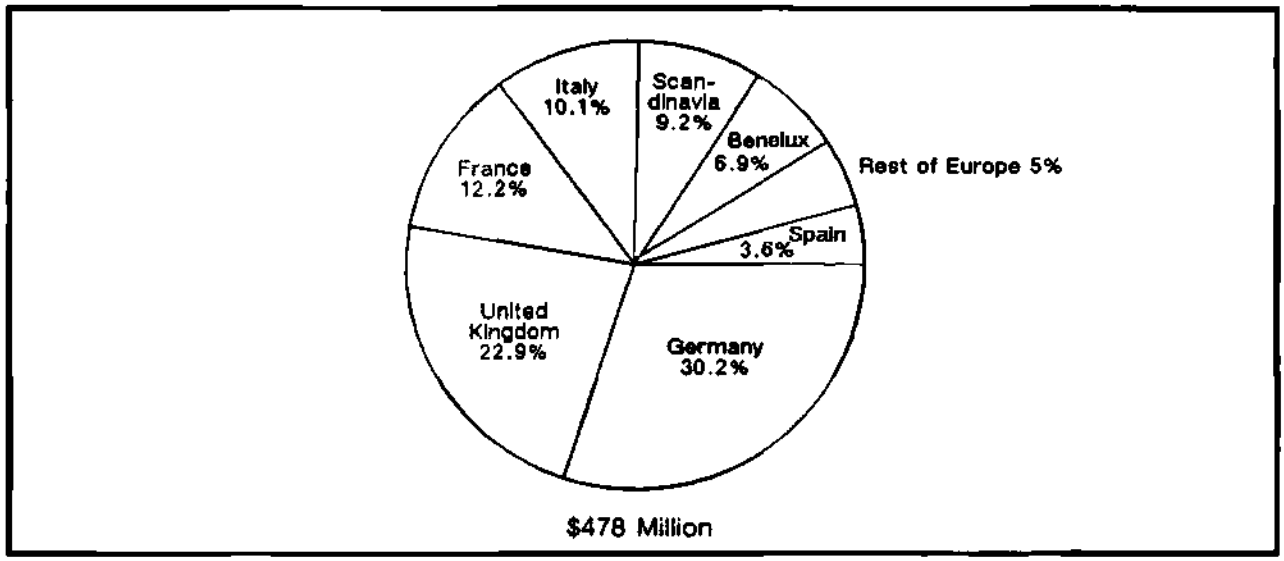
The 1990 European GIS market by country is shown in Figure 3. The following paragraphs provide an overview of the state of GIS development in the larger countries.

FIGURE 2
Geographic Information Systems Market History and Forecast—Europe



Source: Dataquest (June 1991)

FIGURE 3
1990 European Geographic Information Systems Market



Source: Dataquest (June 1991)

Germany

Germany is the largest market for GIS in Europe and offers considerable growth potential, especially since the unification of East and West Germany. Environmental applications are particularly strong in Germany, because of both the influence of the Green Party and environmental pollution and inferior infrastracture in eastern Germany.

Existing maps in western Germany are highly accurate, facilitating conversion to digital form. However, several data standards exist, inhibiting transfer of information among planning offices, utility companies, and the Institute of Geodesy in Frankfurt. Another challenging area has been the transfer of land ownership from the former Communist government back to the previous landowners in eastern Germany.

United Kingdom

A similar problem exists in the United Kingdom. Map data are available from various sources, but no single data standard is in place nor does a complete digitized map of the whole United Kingdom exist. The Ordnance Survey currently provides digitized map data for cities with more than 100,000 inhabitants, but a complete digitized map of the United Kingdom will not be available before the year 2000.

The U.K. GIS market experienced high growth in 1990 despite the economic downturn. This growth can be partly ascribed to the privatization of the water and electric utility companies in the United Kingdom, which created sources of funding for GIS development. The introduction of the poll tax was also expected to create an additional source of funds for the GIS market. However, this effect did not materialize because of the many problems the local authorities faced by implementing this tax. Councils failed to make the revenue they had expected and, therefore, did not have the necessary funds to install GIS, although in the long term this technology would significantly simplify and cut the costs of collecting this tax. This situation is not expected to improve in the near future, as the government is revising the poll tax system. The privatization of yet more utility companies in 1991, however, will ensure that growth rates for GIS in the United Kingdom remain high.

France

The GIS market in France grew 51 percent in 1990, reflecting a significant increase of interest in this region. France is one of the least mature markets for GIS in Europe for several reasons. In France, unlike in the United Kingdom, the Netherlands, and Germany, there is relatively little awareness among potential users of the benefits of GIS, creating a particularly tough educational sell. Compounding the problem, universities in France do not yet offer graduate courses that teach GIS use.

Land-base data is available from the Institut Geographique Nationale (IGN), but no countrywide data standard has been developed. Several state organizations are involved in defining a GIS standard, some originating from the defense industry.

The Netherlands

The Netherlands is one of the most mature GIS markets in Europe. The Netherlands is working to establish itself as the merchandise distribution center for Europe by the time the single European market is implemented in 1993. To achieve this goal, the use of GIS for route planning and logistics is vital. Establishments such as the land registry offices and utility companies are GIS database providers, and the Dutch government has made its geographic data available at low cost. There are moves in the Netherlands to combine these databases, the cost of which will be shared by land registry offices, utility companies, and municipalities.

DATAQUEST PERSPECTIVE

The European and U.S. GIS markets share most trends and issues; however, no true European market exists and one never will. Because many GIS applications are implemented by governments, as long as the core European government is the country, GIS in Europe will focus on country-based solutions. Meanwhile, the U.S. government continues to develop U.S.-wide geographical information (now moving to global, courtesy of the Defense Mapping Agency's Digital Chart of the World project and the NAVSTAR satellite global positioning system). In the long term, European vendors can be expected to develop product strength in integrating a variety of vector and attribute data for a local area. U.S. vendors can be expected to excel in large-scale applications. To use a facetious example, U.S.-based vendors are likely to better handle the requirement, "Provide a road map showing the fastest land and sea route from London to Sydney," and Europe-based vendors are likely to better handle the problem, "Hedgehogs need a safe crossing. Locate the site for the shortest possible tunnel under Peckham Lane that will also be convenient for the known hedgehog population." Underlying all comparisons, there is a competitive advantage in GIS industry development to be gained by countries that make their data freely available at low cost and encourage development of standards for data formats.

Petra Gartzen
Kathryn Hale

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Research Newsletter

CONSIDERING EASTERN EUROPE? DATAQUEST ADVISES CAUTION

SUMMARY

At first it seems deceptively alluring: A virtually untapped market with a population of over 393 million people, an area far larger than the United States that generated a gross national product (GNP) of over $3.2 trillion in 1989. The target market has a well-educated population with an almost insatiable curiosity for Western technology. It should be a sales opportunity beyond anyone's wildest dreams.

But don't believe it. For along with the potential, there is the reality. And the reality is countries in need of food, consumer products, housing, roads, machinery, competitive production facilities, a middle management infrastructure, a banking system, a reliable telephone system, a market-driven distribution system, a stable political environment—the list is almost endless. All of which means that computers, although a very important item on their shopping list, may not be as important to these nations as the basic necessities of life. Economic chaos and political instability have created a very fluid business environment.

Despite the risks, however, Dataquest believes that there are long-term investment opportunities within the six nations covered by this newsletter—Czechoslovakia, East Germany, Hungary, Poland, Yugoslavia, and the Soviet Union. Although each country needs to be assessed on its own merits, the European computer market is expanding to accommodate these countries as they adjust to a market-driven economy.

IS THIS A REAL OPPORTUNITY?

As shown by Table 1, these six countries had a combined GNP of over $3.2 billion in 1988. The Soviet Union accounted for 73 percent of GNP of this region. It also accounts for approximately 73 percent of the region's total population of 393.8 million. Unfortunately, although the Soviet Union is the largest target market, it is fragmented by a diversity of languages and social and religious customs. Hence, in dealing with these six countries, one needs to segregate them into separate cultural, political, and economic regions.

Of the companies interviewed for this newsletter, none expects to make a profit from its East European or Soviet operations for at least two years. The objective for most is to establish a stable presence in the market. They are building relationships for the future and learning how to do business under business conditions that remain extremely fluid. Software companies, for example, have found that in many cases their software already is being used within these countries by users who have pirated copies from Western sources. It turns out, however, that these users are (usually) willing to pay for updates and add-on packages if they can also get documentation, training, and support. They tend to use English language versions and become very loyal to the software developer. The problem: How does one repatriate the profits?

For the countries of Eastern Europe, the sale of state-owned assets provides a partial solution to the problem of generating hard currency. Individual enterprises then would have an opportunity to convert local currencies to foreign currencies in order to pay for goods and services. The sales will include thousands of retail and service establishments, along with larger manufacturing enterprises. The first wave of sales in East Germany, Poland, and Hungary could yield as much as $5 billion during 1990. Unfortunately, these sales will not go smoothly and many will produce decidedly unpleasant side effects. The state agencies responsible for these sales have a shortage of skilled managers, often are split by political infighting, and lack the legal framework necessary

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TABLE 1
Profiles of Six Countries

Country/ Population	Capital	Currency	Language(s)	Religion(s)	Cultural Breakdown	GNP 1988 (US$)	PCI* (US$)	Imports from United States 1989 (US$)
Czechoslovakia								
15,600,000	Prague	Koruna	Czech Slovak Hungarian	Roman Catholic—67%	Czech—64% Slovak—34%	160 billion	9,280 (1986)	54 million
German Democratic Republic								
16,700,000	East Berlin	Deutsche mark	German	Protestant—53% Roman Catholic—8%	-	215 billion	11,300 (1986)	94 million
Hungary								
10,600,000	Budapest	Forint	Magyar	Roman Catholic—67% Protestant—25%	-	90 billion	7,910 (1986)	122 million
Poland								
38,200,000	Warsaw	Zloty	Polish	Roman Catholic		255 billion	3,998 (1987)	414 million
Yugoslavia								
23,700,000	Belgrade	Dinar	Serbo-Croatian Slovene Macedonian	Eastern Orthodox—50% Roman Catholic—30% Islamic—10%	Serbian—36% Croatian—20%	160 billion	6,220 (1986)	501 million
Soviet Union								
289,000,000	Moscow	Ruble	48 languages	Russian Orthodox Islamic Roman Catholic Jewish Lutheran	Russian—52% Ukrainian—17%	2,357 billion	8,735 (1986)	4.3 billion

*PCI = Per capita income
Source: US Department of Commerce, Dataquest (September 1990)

to complete the sale of state property to private enterprise. Once sold, the larger enterprises will have to be completely restructured, which will lead to massive layoffs, social unrest, and political turmoil.

SIX COUNTRIES TO WATCH

Dataquest reviewed six Eastern Bloc countries for this newsletter: Czechoslovakia, the German Democratic Republic (GDR), Hungary, Poland, Yugoslavia, and the Soviet Union.

Czechoslovakia

Unlike most countries in this region, Czechoslovakia's hard currency debt is growing slowly and—at approximately $7 billion in 1989—is comparatively low. On the other hand, the Czechoslovak economy suffers from poor labor productivity, slow technological development, excessive consumption of energy and raw materials, and irrational prices. The manufacturing sector needs modernization. Czechoslovakia also needs to restructure its banking and trade systems, establish a more efficient distribution system, and create the Western equivalent of private companies. With one of the stronger economies of Eastern Europe, Czechoslovakia still is debating the pace of economic reform.

The German Democratic Republic

The political leaders of East and West Germany expect to combine the two countries into one nation by October 4, 1990. Existing West German commercial practices and law will be applied to transactions in the GDR by late spring 1991. The GDR is adopting the European Community (EC) Common Commercial Policy for trade, tariffs, shipping, labeling, and customs practices. Thus, for all intents and purposes, vendors need to view the GDR as belonging to the EC and transitioning to West German business practices.

The road to a unified commercial environment will be long and difficult. East Germany needs (among other things) a commercial banking system, channels of distribution for goods and services, a reliable telephone system, jobs, and training in the concepts of a market economy. Much of the GDR's plants and equipment are obsolete and cannot be operated at a profit. The country cannot complete its transition to a market economy until the issues of property ownership are settled. The USSR will leave its troops in East Germany for the immediate future if for no other reason than because there is no housing or jobs for the troops in the Soviet Union. This practice is bound to create social tension as the unification process moves forward.

Dataquest anticipates a long period of a painful, and at times politically difficult, process of adjustment. Labor costs will escalate rapidly. Heightened expectations, inflation, economic dislocation, and low productivity all will mitigate against using East Germany as a low-cost labor resource. The development of a middle management structure that can successfully function on a market economy will require massive amounts of training and cultural adjustment.

The West Germans have a very ambitious schedule for the development of a commercial infrastructure in East Germany. There will be little time to create new data processing applications. Instead, the West Germans simply will clone the hardware and software they already have and move it to East German locations. This move will create opportunities for vendors that have existing relationships with West German organizations, as they order equipment to replicate their applications into the eastern sector. In addition, Robotron, a holding company with 70,000 workers in 21 divisions throughout East Germany, is positioning itself to be the leading distributor of computer products into the eastern sector.

Hungary

Hungarian economic performance was weak in 1989, as it has been for much of the 1980s. Inflation climbed by 17 percent, external hard currency debt reached $20.7 billion, and the country's GNP stagnated with a growth rate of only 0.5 percent. Despite this poor performance, however, US exports to Hungary climbed by over 55 percent and more than 100 US joint ventures now are operating in the country. The new government has liberalized the ownership of Hungarian business enterprises, simplified the registration of foreign investments, and made it easier to convert profits into foreign exchange. Hungary has relatively low labor costs, a history of trading relationships, and is close to other European markets. The United States has granted Hungary continuous "Most Favored Nation" status and "Generalized System of Preferences" (GSP) tariff treatment. The

United States also has established loan, insurance, and guarantee programs for these efforts through the Overseas Private Investment Corporation, the Eximbank, and the $60 million Hungarian-American Enterprise Fund.

One of the problems of dealing with formerly socialist organizations is determining who is in charge and whether they will be in charge next week. For example, the move to a market-driven economy has been delayed by the lack of permanent leadership at the top of Hungary's state-owned companies. The management team of each company is elected by that company's employee advisory council. Managers elected under the old regime have postponed making decisions because they do not know if they will continue to be in charge. It is hoped that this situation will be cleared up when new management teams are elected this fall.

Poland

Very high rates of inflation, acute shortages of food and key consumer products, declining agricultural and industrial output, and a terrible load of external hard currency debt greeted the new Polish government in fall 1989. Poland has opted for an extreme program of conversion to a free market economy. Western nations, led by the United States, have launched a massive financial support program to Poland. The World Bank will grant up to $2.5 billion in loans through 1995. A $1 billion currency stabilization fund has been established. The United States also has established aid programs for Poland similar to those authorized for Hungary, including a $240 million Polish-American Enterprise Fund.

The privatization of industry will lead to massive unemployment and a split in the ranks of Solidarity between those that want reform and those that have been disenfranchised by reform. Support for Prime Minister Tadeusz Mazowiecki's government will be threatened and this could stall or stop the privatization process.

Yugoslavia

After several years of high inflation and economic stagnation, Yugoslavia has begun the painful process of reforming its economic infrastructure. Prices have been allowed to float freely and the dinar has been made fully convertible. The country now has a current account surplus and appears able to reduce its foreign debt. As the result of a new investment law, a number of US-Yugoslav joint ventures have been established. In addition to guarantees for capital and profit repatriation, the new law permits equity investments, foreign-dominated boards of managers, unlimited local borrowing, improved patent protection, and a broad spectrum of commercial reforms.

The Soviet Union

The USSR had a $3.6 billion trade deficit with the United States in 1989. The country's GNP declined 1 percent in the first half of 1990, while inflation, the trade deficit, debt, and unemployment all were up sharply. Soviet trading organizations are now more than $3 billion behind in payments to foreign suppliers. The key words are "hard currency," and the Soviets do not have enough of it to float their credit needs. Worse, there does not appear to be any way for them to recover. The Soviets will have about $36 billion in hard currency to spend in 1990 for all types of imports. Over 86 percent of these funds will be spent on agriculture and consumer products.

The remaining exports to the USSR will have to be financed by other means and the primary solution is called "countertrade." Under this scenario, the foreign company forms a joint venture or trading relationship with a Soviet organization. Foreign products are sold for rubles and the rubles then are used to buy Soviet goods that can be sold for hard currency in a foreign country. Thus, an American company might sell computers to a Soviet partner and then use the proceeds of this sale to buy leather that can then be sold to a South Korean shoe manufacturer. Dataquest anticipates that the nations of the Pacific Rim and Western Europe will have an initial advantage over the United States in the development of Soviet trading relationships because they have established trading companies that are used to making these kinds of deals work.

On the other hand, companies such as IBM, Control Data, Bull, Siemens, Hewlett-Packard, Ashton-Tate, AST, and Borland have determined that they want a presence in this market and appear willing to patiently pursue the business opportunities as they develop. The Soviets respect the stability of an established corporate identity. The problem for Western companies is that sales into the Soviet Union must be considered as long-term investment. TeleVideo, for example, entered three separate joint venture agreements in order to

establish a presence in the Soviet Union. In each case, the deal had to include a way to furnish the Soviet Union with hard currency in order for it to purchase computer technology. For other companies, the only logical plan is to be paid in rubles and then to reinvest this revenue into a further development of the Soviet market. Borland, which found that pirated copies of Turbo Pascal and Paradox had almost become a de facto standard in the USSR, decided that reinvestment was the best way to convert users into paying customers.

One of the dangers of dealing with the Soviet Union is its apparent fragmentation into semi-independent states or regions. For example, Boris Yeltsin's economic advisor, Vassili Salyunin, has determined that the Russian Republic no longer will mortgage its export revenue to pay for debt accumulated by the Soviet government. Salyunin criticized Mikhail Gorbachev for spending hard-currency loans on food for the general public. Much of the food had rotted because the Soviet transportation and marketing system was unable to provide for its distribution. This lack of an organized market-driven distribution network is symptomatic of the problems one will encounter in trying to sell products into the Soviet Union.

But the lack of a market-driven distribution system is only part of the fragmentation occurring within the USSR. According to the government newspaper *Izvestia,* shortages of food and consumer products of all types are "socially dangerous" to the continuation of perestroika. Faced with unrelenting shortages and poor leadership from Moscow, local leaders within the 15 Soviet republics are grabbing the economic decision-making power they need to survive. Eight republics already have issued declarations of sovereignty, and in some regions this move has been accompanied by a radical rise of self-direction. The critical issue is whether these pockets of free-enterprise and self-rule can save the Soviet economy.

The United States does not have the same level of support policies in place for the USSR that it has developed for other nations of the Eastern Bloc. The preferred method of doing business in the Soviet Union is through the vehicle of a joint venture and over 2,000 of these have been formed to participate in East-West commerce. The nations of Western Europe are being particularly aggressive in the development of commercial relationships with the USSR. The Soviets envision allowing joint ventures and foreign companies to participate in hard currency auctions. They also are planning to establish free trade zones where joint venture companies will be granted special tax and customs concessions.

The United States and the Soviet Union have signed a bilateral trade agreement that provides reciprocal Most Favored Nation (MFN) status and an improved business environment in the USSR. Before the agreement can be brought into force, the Soviet Legislature must pass an emigration law acceptable to the United States, President Bush must sign a waiver of the Jackson-Vanik Amendment, and Congress must approve the agreement's terms. The agreement's trade facilitation, intellectual property rights, and nondiscrimination provisions will contribute to protecting and advancing US trading interests as changes occur in the Soviet economic system. The agreement provides 60-day office representation accreditation for US companies, access to office space and living accommodations, and the right to hire Soviet citizens. The agreement stipulates the right to engage and serve as agents, and to engage authorized Soviet organizations as distributors.

DEVELOPING BUSINESS CONTACTS

Trade Shows and Exhibitions

Trade shows and exhibitions represent one of the better ways to make contacts with potential buyers and distributors. Upcoming events of possible interest to computer equipment manufacturers include the following:

- Moscow exhibition of Computer and Information Science Products, October 18 to 25, 1990
- Com Expo Hungary '90, October 10 to 12, 1990 (Budapest)
- Budapest International Fair, May 1991
- EXPO COMM Moscow 91, June 5 to 10, 1991
- Com Expo Poland '90, October 16 to 19, 1990 (Warsaw)
- Softool USSR, October 8 to 12, 1990 (Moscow)
- Zagreb Fall Fair, September 1990 (Zagreb, Yugoslavia)
- Trade Mission to Czechoslovakia and GDR, February 4 to 8, 1991

What Is the Role of the United States?

A debilitating budget deficit and the distance of geography will limit the role of the United States as it tries to respond to changing economic conditions within the Eastern Bloc. Western Europe, Japan, and the Southeast Asian nations are all in a better position to exploit trading opportunities as they develop, and they also can supply the long-term financial assistance the Eastern Bloc nations need in order to restructure their economies.

However, because US-based vendors currently constitute about three-fourths of the European CAD/CAM/CAE market, the following information on US government activity is included as a point of general interest.

US Department of Commerce

The International Trade Administration (ITA) of the US Department of Commerce helps with export licenses, finding trade, distribution and joint venture partners, and helps with product/business promotion. The ITA has a country desk for each country and a separate specialist for each industrial sector. The department also is active with the promotion of Trade Councils that assist with the development of commercial relationships between the United States and Eastern Bloc countries. The Eastern Europe Business Information Center (EEBIC) assists exporters and investors in doing business throughout Eastern Europe.

Export-Import Bank of the United States (Eximbank)

Eximbank helps to finance export sales of American goods through short- and medium-term loan, guarantee, and insurance programs. It extends direct loans to foreign buyers of US exports and intermediary loans to fund others that extend loans to foreign buyers. The guarantee program provides political and/or commercial risk repayment protection for private sector loans to buyers of US exports. The Foreign Credit Insurance Association operates in cooperation with the Eximbank to offer insurance policies that protect US exporters against the risk of nonpayment by foreign debtors. Eximbank offers insurance and guarantees for Hungary, Yugoslavia, Poland, and Czechoslovakia.

Overseas Private Investment Corp. (OPIC)

OPIC provides longer-term political risk insurance and opportunity financing for investment projects in Hungary, Poland, and Yugoslavia. Czechoslovakia is scheduled to be added to this program in November 1990.

US Agency for International Development (USAID)

USAID administers a variety of enterprise, trade credit, investment, and assistance programs, generally aimed at helping with the development of private enterprise within targeted countries. Under the 1989 Support for East European Democracy (SEED) Act, the US Congress authorized $240 million to be spent over three years for the Polish-American Enterprise Fund. Another $60 million has been earmarked to be spent over the next three years for the Hungarian-American Enterprise Fund. SEED2 has been proposed to target funds at Czechoslovakia and Yugoslavia.

US Department of State

The state department has been following events in the Eastern Bloc and is assisting with several initiatives to help with the transfer of technical and managerial skills to countries in Eastern and Central Europe.

DATAQUEST ANALYSIS

The Ultimate Risk

Dataquest believes that the opportunities for selling computer products into these six countries are limited by the political, economic, and social realities that brought about the collapse of socialism.

Czechoslovakia, Hungary, Poland, the GDR, Yugoslavia, and the western third of the USSR share some sense of European values. But these countries are hampered by poor distribution systems, unreliable transportation, unreliable and scarce telecommunication systems, and a paucity of workers with business skills. Fed up with the lack of food and consumer goods, high rates of inflation and unemployment, and unstable monetary system and deficient housing, these people could suddenly espouse a political cause that is unfriendly to Western interests.

Thus we are in a race to stabilize the socioeconomic structure of these countries before desperation overcomes human sensibility. Our chief tools are trade conducted with integrity, human relationships based on trust, and support with generosity.

Assessing Business Opportunities for CAD/CAM/CAE

The switch to a market economy will make it necessary to renovate and develop each country's infrastructure, which will create a demand for mapping/GIS systems. The manufacturing industry also will have to be upgraded in order to be competitive with Western markets. This upgrade will create opportunities for mechanical CAD/CAM vendors. The Soviet Union, for example, has instituted an integrated manufacturing program in the automotive, aviation, shipping and process industries. It has facilities at the Kamaz truck factory and plants that produce cars in Volga and Gorky using systems such as Pathtrace and Peps. Most of the major CAD/CAM vendors already have ties in Eastern Europe. A few examples of CAD/CAM vendor activities in the Eastern Bloc follow:

- In September 1990 Control Data announced that it received permission to ship six Cyber 960 mainframes to the Soviet Union. The $32 million order comes from the Soviet Research and Development Institute of Power Engineering.
- Computervision has been selling its products in Yugoslavia for the last five years and has plans to start joint ventures in Czechoslovakia, because of that country's large engineering base, and in Hungary, which is the one country moving most rapidly to a Western-style economy.
- McDonnell Douglas Information Systems has already signed a partnership agreement in Yugoslavia and has plans to do the same in Poland and Hungary in the near future.
- The UK-based vendor Cadcentre has an extensive installed base of its PDMS system running on DEC VAX machines both in Yugoslavia and Hungary.
- In February 1990 Digital Equipment Corporation entered a joint venture agreement with a computing services company and the Physics Research Institute in Hungary.
- Earlier this year Norsk Data, a Norwegian minicomputer group, signed a distribution agreement with East Germany and received a contract to sell new and used equipment to the Soviet Union.

PC-CAD vendors such as Autodesk or the UK company Robocom have long-standing relationships with Eastern European countries and already have a fairly large installed base there, as PC-CAD products have not been restricted by COCOM regulations in the same way as have the vendors of workstation or host-based systems. However, recent relaxations in those regulations, such as releasing Intel's 80386 chip and the latest version of UNIX for sale in the Eastern Bloc countries, provide an indication that more is to follow.

Given the risks and the problems, it would appear to be unwise to pursue opportunities in Eastern Europe without first setting up a good distribution network in Western Europe. Or, to put it another way, Dataquest believes that it is wise to explore all possible marketing opportunities in the established markets of Western Europe before taking on the high risks of the East. From this base, one can provide the training, sales and installation support, and trading infrastructure necessary to penetrate Eastern Europe.

Each Country Is Different

The potential market for computers in the Soviet Union is over three times larger than that posed by the combined needs of the other five nations mentioned in this newsletter. The problem, however, is that the Soviet market is not a homogeneous market. The country is fragmenting into separately managed regions or states and each of these areas will move forward at its own pace. Political turmoil, ethnic conflicts, and depressed economic conditions all will act to further hamper the development of a computer market. Dataquest believes that the best strategy for most companies is to find a Soviet joint venture partner. From the Soviet government's point of view, this is the preferred method of doing business. It provides a base of operations and gives the venture a way of dealing with the Soviet bureaucracy.

East Germany will become an active market for computer systems. According to the US Department of Commerce, this market will absorb over $3 billion of multiuser systems by 1995. The easiest distribution strategy is either to access this market through West German contacts or to follow established distributors as they set up shop in East Germany. Dataquest believes that opening branch offices in East Germany also is a viable strategy, as demonstrated by companies such as IBM, Apple, and Microsoft. Unification with West Germany will create a single geographic market that has (relatively) uniform commercial practices by the end of 1991.

Dataquest believes that Hungary and Poland eventually will become viable computer markets. Like East Germany, they have relatively cohesive ethnic cultures, a history of an entrepreneurial attitude, and established relationships with Western Europe. Hungary also appears to be a useful "back door" to doing business in the Soviet Union, and Budapest could emerge as a key trading center for all of Europe.

Yugoslavia has always had a somewhat open policy of trading with the West. This willingness provides a base of commercial ties from which to work in the development of new business opportunities. Both IBM and NCR, for example, have been selling low-technology products into this market and have shown that they can leverage these relationships into computer system sales.

DATAQUEST RECOMMENDATIONS

Dataquest offers the following recommendations for those planning to enter the Eastern Bloc markets:

- Enter the market with a clear idea of what you want to accomplish.
- Enter the market with a long-term view. This entry will be an investment of time, money, and energy that may not have any near-term payout.
- Be prepared to spend considerable time and attention to the issues of training, installation, maintenance, and support.
- Start small. Build your business in stages.
- Be creative. Financing, distribution, venture relationships, and government bureaucracy will be a challenge.
- If you are entering into a barter or countertrade arrangement, make sure that your partner has the legal right to do the deal and can actually deliver the goods promised.
- Learn about the needs of the company and the region you plan to enter. Social customs, ethnic background, languages used, and economic conditions (both personal and national) are all part of your business relationship.
- In a trade transaction, it is best to remember that getting paid can be the most challenging part of the deal.
- And don't forget, the political situation will continue to be very fluid.

DATAQUEST CONCLUSIONS

Dataquest believes that, despite the inherent risks and considerable difficulties, each of these six national markets should be viewed as a long-term business opportunity. Because each region is unique, each will require a separate business plan. Larger companies should approach these markets with a missionary effort to establish presence and build business relationships that eventually will permit the successful operation of a national subsidiary. Smaller companies will need to identify distribution or manufacturing partners with solid contacts within each market.

This investment is for the long term, and one certainly needs to be aware of the realities of the socioeconomic environment. But it will take copious quantities of computer power to complete the successful conversion of these nations to a market-driven economy—and therein lies the ultimate opportunity.

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Research Newsletter

VIVA ESPAÑA: SPAIN, THE EMERGING MARKET

INTRODUCTION

Spain's economic boom, which began in mid-1985, is almost directly attributable to its membership in the European Community (EC). Rising domestic demand—in particular, investment and private consumption—has been the engine of growth and is reflected in the strong growth in merchandise imports. Spain's gross domestic product (GDP) growth neared 5 percent in 1988 and is forecast to continue in the 4 to 6 percent range for the next five years.

In the CAD/CAM area, Spain has emerged as the fastest-growing market in Europe. Spain's CAD/CAM market grew 33.7 percent in 1988, compared with an average growth of 25 percent for the whole of Europe.

This newsletter provides an overview of Spain's general economic situation and presents Dataquest's analysis of the Spanish CAD/CAM market, highlighting the difference from the other major European regions in distribution of applications, distribution channels, and platforms.

GENERAL CONSIDERATIONS

Joining the EC at the beginning of 1986 has been instrumental in Spain's process of modernization. In the presence of EC regulations, Spain was compelled to reduce gradually its high trade barriers and other measures aimed at protecting the national industries. As a result, local companies are confronted with many foreign competitors tempted by the growth potential of the Spanish economy and its strategic position in the northern Mediterranean region.

The increased competition within Spain, combined with the outlook for potentially high export sales to the other EC member states, led to great concern among Spanish industrialists and policymakers about the competitiveness of Spanish industries and services. These leaders acted to boost the efficiency and competitiveness of Spanish companies. The government, being of a moderately socialist persuasion, has been particularly active in adapting the industrial structure to the requirements of international competition. Structurally weak sectors such as shipbuilding, the steel sector, and several of the state-owned companies were completely turned around. In addition, Spanish, as well as foreign, entrepreneurs have started to restructure Spanish corporations; the search for economies of scale for the small Spanish companies has been a driving force.

However, despite the high economic growth rate of the past few years, the level of unemployment has remained significantly high—the highest in Europe. Although new jobs are being created at a rapid pace, the economy is still unable to absorb the large number of young, and often incorrectly qualified, Spaniards. At the moment, the Spanish government faces the economic dilemma of maintaining the economic restructuring while curbing inflation, controlling money supply and interest rates, and continuing to reduce unemployment.

BUSINESS REGIONS

Business in Spain is concentrated in and around the two largest cities in the country—Madrid and Barcelona. The capital city of Madrid houses the government bureaucracies and most headquarters of multinational companies. Conversely, Barcelona and the surrounding region of Catalonia, known for its high level of entrepreneurship, are the locations for many small companies. (Barcelona will host the Olympic Games in 1992, resulting in the upgrading of the city's infrastructure.) Other important business areas,

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although of less weight than Madrid and Barcelona, are the Basque region in the north of the country, the region around Valencia on the east coast, and the region around the town of Seville in the south.

THE SPANISH CAD/CAM MARKET

Spain is not integrated fully into the EC, and it has a number of tariff and nontariff trade barriers including a provision that computer terminals and software must be capable of properly printing anomalous Spanish-language punctuation and orthography, such as the inverted question mark and the tilde for n, to help preserve Spanish language and culture. A centralized planning regime has created the National Plan for Electronics and Informatics (REDINSER), which is supported by a regional network of CAD/CAM awareness centers. A trade association with a strong user bias, called ASCAD, is active in Spain. Furthermore, Spain has always been the traditional trading gateway from Europe to the Latin American market.

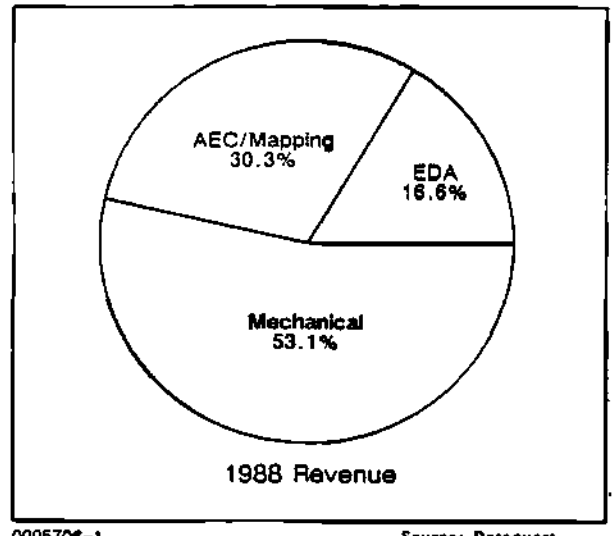
In 1988 the major European markets of Germany, France, and the United Kingdom lost market share, benefiting the developing regions. The Spanish CAD/CAM market grew approximately 33.7 percent over 1987, which is significantly higher than the average market growth of 25 percent for the whole of Europe. In revenue terms, the 1988 CAD/CAM market in Spain amounted to $85 million, representing more than 2.5 percent of the total European market. In the long term, Dataquest expects Spain to become the fifth largest market for CAD/CAM in Europe, with a total available market potential of approximately 160,000 seats. Dataquest estimates that 53 percent of the total available seats are in manufacturing (ECAD and MCAD); 30 percent are in construction, and 17 percent are in other areas, with a high proportion of these in geographic information systems (GIS).

Most of the major worldwide CAD/CAM vendors operate in Spain, and there are significant growth areas. However, penetration is very low; to date, only approximately 5 percent of the total available seats. At the moment the aerospace, automotive, and central government (which includes substantial military use of GIS) sectors are the main users of CAD/CAM. CAD/CAM use is increasing throughout industry, but the relatively high prices of specialist hardware and the lack of expert users are constraining rapid development. Only the largest companies, such as SEAT, use the main CAD/CAM systems available from computer and turnkey vendor suppliers; medium and even small companies have adopted solutions on personal computers (PCs) and low-cost technical workstations. Also, Spain's market penetration is being slowed by a lack of technical expertise in the marketing area.

As is often the case in new and developing markets, the general computer companies in Spain dominate the market using existing distribution channels. Most vendors sell into Spain via distributors or agents. Mainly, only the leading worldwide vendors have local representation there. German suppliers have done exceptionally well in this market, and U.S. computer vendors that have served the market from a German headquarters base, such as Control Data Corporation and the Hewlett-Packard Company, have had similar success.

The distribution of CAD/CAM in the different application segments in Spain differs from other European regions. Similar to other markets, the biggest sector is the mechanical sector with approximately 53 percent, followed by the AEC/Mapping sector accounting for about 30 percent of the market (see Figure 1). The electronic design automation (EDA) sector in Spain is very weak, with only 17 percent of the total market.

FIGURE 1
Spanish CAD/CAM Market by Application



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Source: Dataquest
December 1989

The unusually high share of AEC systems installed in Spain can be ascribed to the booming Spanish tourist industry, especially in the south of Spain (such as in Malaga and Marbella). In the north, the development of the site for the Olympic Games in Barcelona in 1992 increased the purchase of AEC systems. Most installed systems for AEC are PC-based solutions. Despite the fact that hardware prices, especially for technical workstations, are declining, even today's low prices are still relatively high in developing regions—this accounts for the relatively high proportion of PC-based solutions in Spain. The EDA sector, on the other hand, is not advancing as fast as any of the other sectors, mostly because Spain does not have any local semiconductor manufacture.

Looking at market shares, the top 54.4 percent of the Spanish CAD/CAM market is almost equally distributed among Hewlett-Packard, IBM, Intergraph, and Prime Computer (see Figure 2). The top 10 vendors account for almost 78 percent of the total Spanish market, leaving just 22 percent for the remaining vendors. Nearly all the vendors hold such relatively similar market shares that their positions easily could shift because of one or two sales.

DATAQUEST CONCLUSIONS

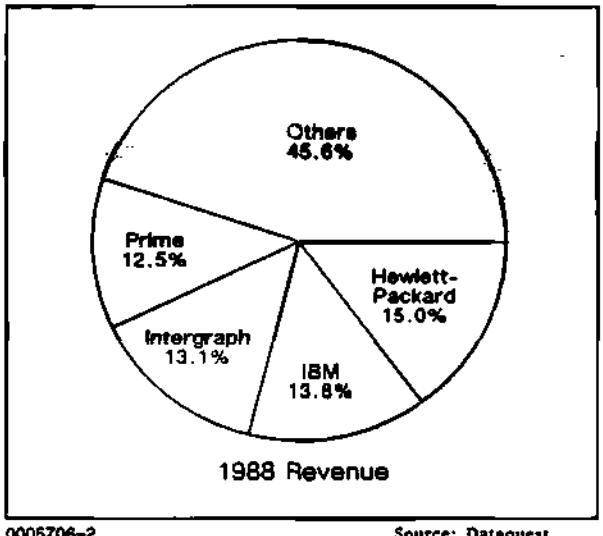
Dataquest believes that the Spanish CAD/CAM market offers good potential and will continue to show strong growth. To be competitive within the EC after 1992, the Spanish government and the EC offer incentives—for example, to refurbish factories. Such incentives are spurring the development in manufacturing and hence driving the CAD/CAM market. We believe that significant growth applications are for mechanical, architectural, and GIS systems.

Business opportunities exist for vendors exploiting the dealer/distributor channels in Spain. In Dataquest's opinion, the key to a leading position in the Spanish CAD/CAM market is the dealer/distributor channel, and vendors that understand and exploit this channel will reap the benefits of the Spanish market.

The greatest challenges the Spanish CAD/CAM market will face over the next few years are to overcome the skill shortages in the high-technology industries and to improve the EDA industry.

Petra Gartzen

FIGURE 2
Spanish CAD/CAM Market Share



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Source: Dataquest
December 1989

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Research Newsletter

THE EUROPEAN 1988 WORKSTATION MARKET

INTRODUCTION

The technical workstation market was in transition in 1988. Although the statistics have characteristics superficially similar to those of the two previous years, clear signs of competition from new players and products appeared. In particular, the PC workstation, based on new CPU technology, emerged and applications broadened. In addition, the power struggle between OSF and UNIX International has injected some urgency into the UNIX battlefield.

These trends have continued into 1989. The market has become even more competitive—the Apollo takeover, for example, predicted a first-time loss for Sun. Dataquest believes that the PC workstation will have an impact on the traditional workstation market.

1988 MARKET DATA

The Western European market grew 76 percent, reaching $1.38 billion on approximately 64,650 shipments. This strong growth rate matches the growth of the market worldwide. Indeed, the European share of the market is expected to remain fairly constant over the forecast period to 1992. Although the U.S. market is likely to slow down, sales in the rest of the world are expected to show strong growth.

At a national level, also, sales were in similar proportions to 1987 sales levels. Germany remained the leading country, at 26 percent of shipments by value, followed by the United Kingdom (21 percent), France (18 percent), and Italy (8 percent). This year, Dataquest is providing coverage of nine additional countries and can report that Switzerland (5 percent), Netherlands (4 percent), and Sweden (4 percent) were the next most important markets, trailed by Belgium (3 percent) and Austria, Finland, Spain, Norway, and Denmark, all at approximately 2 percent.

As indicated, 1988 was a good year for the market throughout Europe. As expected, the less mature markets, such as Italy and Spain, performed strongest. Figure 1 shows the 1987 to 1988 revenue growth rates in the four major countries.

Sun Microsystems and Digital Equipment Corporation were the big winners in 1988, especially in unit terms as shown in Figures 2 and 3. However, Hewlett-Packard retained a narrow leadership in revenue.

Sun has profited from its dedication to open standards, convincing customers of both security of investment and ease of use in a standardized environment. The new product line announced in April enables Sun to attack the potentially massive commercial marketplace, although recent reported delays in production have weakened the company's position.

Despite Digital's late entry into the workstation market, the company is now firmly positioned as one of the top four vendors (counting Hewlett-Packard and Apollo as two vendors). Dataquest believes that Digital Equipment has continued to gain share during the first half of 1989, and that this trend is likely to continue during the second half.

Apollo suffered a loss in the second quarter of 1988, largely because of under-target OEM sales in Germany, and it was further hit by the departure of senior management. However, the merger with Hewlett-Packard seems to have sufficient synergy to overcome these problems. Although Apollo and Hewlett-Packard product lines will initially overlap, the strong management and financial stability of Hewlett-Packard should well complement the large installed base and software portfolio of Apollo. (See the ECIS newsletter "Hewlett-Packard Buys Apollo—Vaults into Workstation Market Lead"

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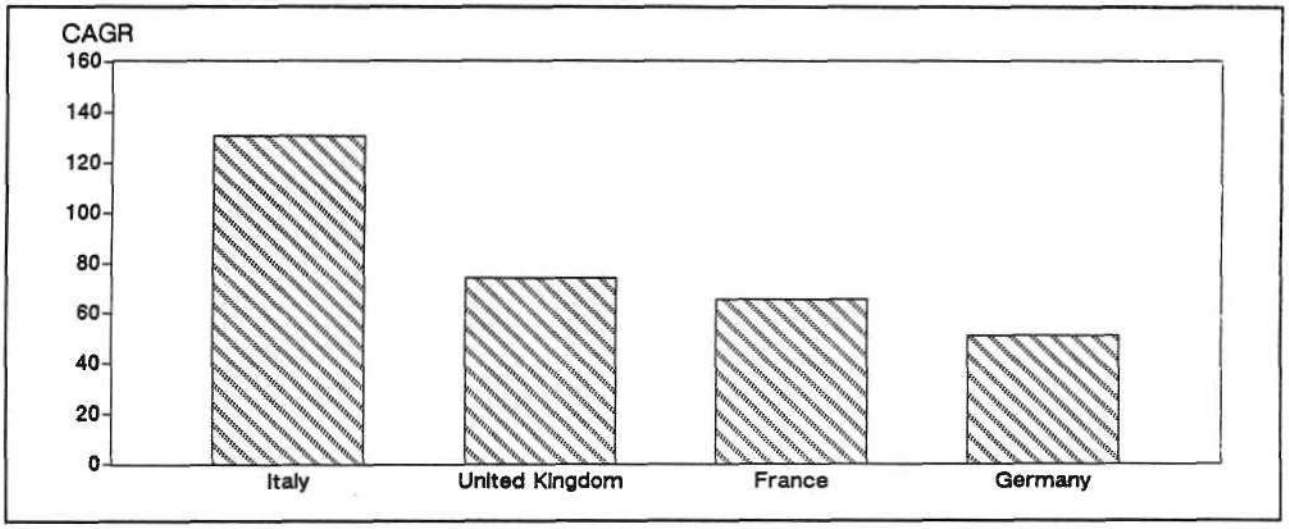
FIGURE 1
European Workstation Market Revenue, Growth Rates by Country, 1987-1988



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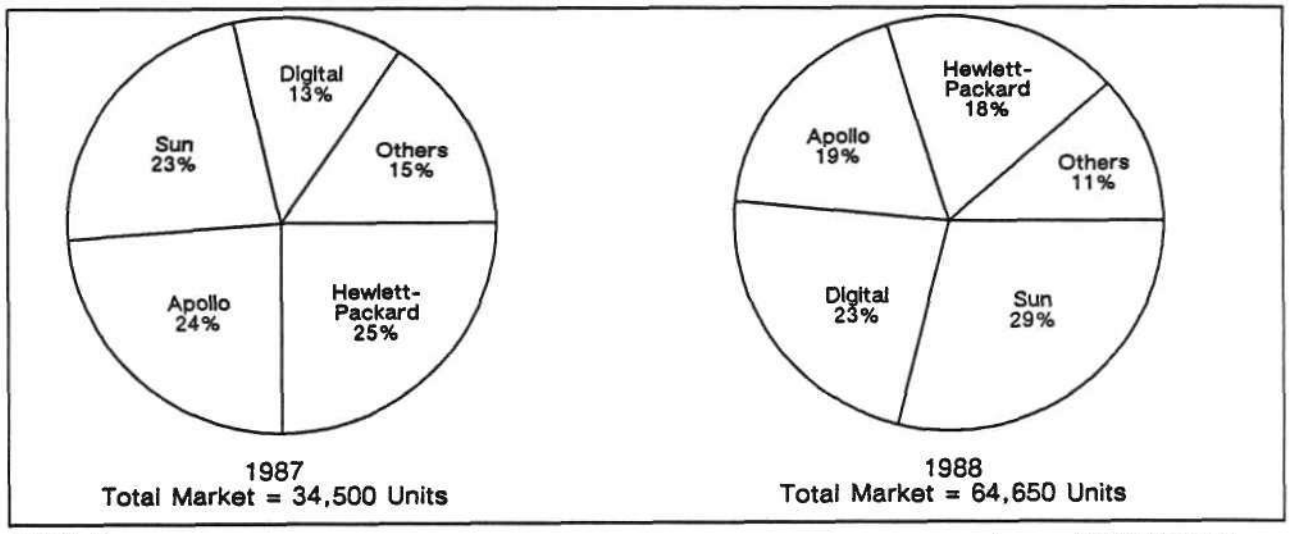
Source: Dataquest
November 1989

FIGURE 2
European Workstation Market, 1987 Vendor Share (Units)



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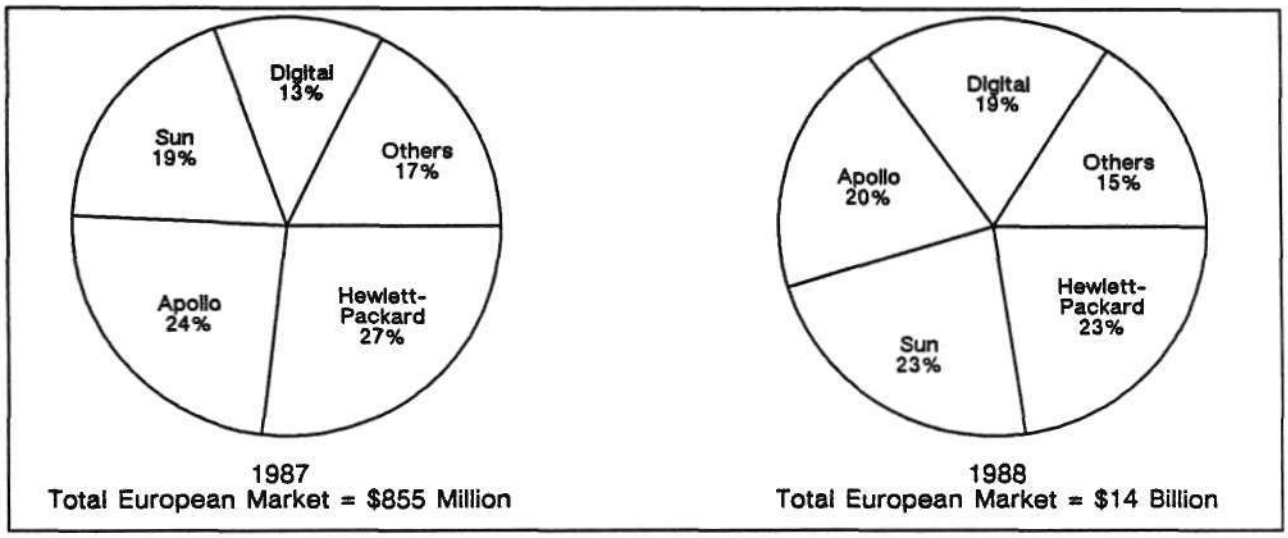
Source: Dataquest
November 1989

number 1989-4 for more details.) The enlarged group should maintain market leadership in Europe at least over the next 12 months.

It seems strange to speak of IBM as a new player in any market, but its attack on the workstation market, through the RT PC 6150 and the PS/2 Model 80, has emerged only quite recently. Its prominent role in Open Software Foundation (OSF) and recent U.S. government contracts underline how serious this challenge is. In addition, Europe has contributed substantially to the development of the RT PC 6150 through IBM's factory in Italy. New products expected from IBM in the second half of 1989 should position IBM as a serious contender in the workstation market. As an illustration of the shortcomings of the RT PC 6150, IBM U.K. initially chose to position this machine as a multiuser UNIX commercial system, a lead that has

FIGURE 3
European Workstation Market 1987 Vendor Share (Value)



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Source: Dataquest November 1989

been followed by IBM Italy, although with limited success. IBM U.K. is now repositioning this product as a workstation.

Currently leading the way among PC workstation vendors is Compaq, followed by Apple and IBM. This is an area in which determined localized competition may develop from the likes of Goupil in France, Apricot in the United Kingdom, Tulip in Netherlands, and Nokia Data in Scandinavia. These "minnow" companies will not be keen to surrender their home advantage but may be forced into international alliance to survive beyond 1992.

A feature common to all the market players is a new focus on indirect distribution channels in order to provide the geographic coverage and vertical strengths necessary for sustained growth. Sun is leading the way with its development of VAR channels throughout Europe, and Hewlett-Packard is particularly successful in the United Kingdom.

APPLICATIONS

As the nomenclature suggests, the technical workstation still is used overwhelmingly in technical environments. Commercial applications accounted for only 7 to 8 percent of shipments in 1988. However, even this amount represents a significant increase from the 5 percent 1987 portion.

The majority of commercial shipments to date have been for computer aided publishing (CAP) applications. Other commercial markets, such as financial services, have been slower to take off in the European market than in the United Kingdom, but this position should change rapidly. As in so many other aspects, Sun seems to be leading the way. Workstation vendors will increasingly have to seek out these new opportunities while at the same time contesting more traditional market segments.

The leading sector in 1988 was industrial and design automation (CAD/CAM/CIM) with 45 percent of the market, followed by software development (CASE) at 17 percent and graphics and image processing at 8 percent. However, diversification will account for much of overall market growth.

Thus, Dataquest forecasts that, in 1992, industrial and design automation applications will remain the leading sector but will have fallen to a 30 percent share, followed by financial and commercial applications, soaring up to 23 percent from 5 percent, and software development applications at 14 percent. CAP should progress to 8 percent and graphics to 11 percent at the expense of more finite and potentially saturated markets such as scientific, laboratory, and earth resources applications. This said, it must be emphasized that no market sectors will be actually in decline.

PC WORKSTATIONS

The market for PC workstations is as yet fledgling—just 4,000 units at a value of $57 million were shipped in Europe at the end of 1988.

However, sales are really picking up in 1989—$306 million has been forecast—and will continue to grow to more than $1 billion (141,000 units) in 1992.

The impetus for this massive growth will come not only from the upward mobility of companies such as Compaq, but also from downsized workstation platforms such as the Sun 386i.

Dataquest anticipates a clear trend within the traditional workstation market toward lower-price platforms in order to combat the threat of the PC workstation. Average selling price (ASP) is expected to decline from $24,000 in 1988 to $15,000 in 1992. This amount still will be roughly double the price of a PC workstation. Of course, a marked difference in functional specification will remain.

Within this scenario, much depends on the ramp-up of production of the newer processors, such as the Intel 80486 and the 33-MHz version of the 80386. Also crucial will be the emergence of software to support multichip architectures, in particular optimized utilization of RISC and numeric coprocessing.

Already apparent are the blurring distinctions between PC and workstation applications software, through the downward migration of such products as Interleaf, Informix, SAA Office Vision, and the UNIX operating system itself.

FUTURE OUTLOOK

During the next three to five years, room exists for the adoption of entirely new architectures in the workstation market. Products based on the new Intel i860 and parallel transputer-based machines will challenge existing superworkstations and graphics workstations at a fraction of the cost. The success of these machines will depend on the emergence of parallel algorithms and software.

Such machines would service the nascent markets for multimedia technology (implying intensive image processing), robotics, and artificial intelligence systems.

DATAQUEST CONCLUSIONS

As a consequence of downsizing to the PC workstation, the explosive growth currently taking place within the workstation market is set to slow down in value terms while remaining very strong in unit terms.

A clear shift to more commercial usage of the workstation will occur. This commercial usage may come to be regarded as part of the mainstream computing environment within distributed networks.

Although OSF and UNIX International remain at loggerheads, all the principal actors in both consortia are now members of X/Open. UNIX has come to be regarded by technical software developers as the only viable hardware-independent operating system and will remain the de facto standard for the workstation market, implicitly in both technical and commercial environments.

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Dr. Charles Clarke
Jane Doorly

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Research Newsletter

LESS BUOYANCY EXPECTED IN THE U.K. ECONOMY, MORE CONFIDENCE IN THE IRISH ECONOMY

SUMMARY

With the U.K. economy operating at close to full capacity and labor market conditions continuing to tighten, inflation in the United Kingdom has kept rising in 1989. Because import growth has remained strong, the current-account deficit has reached a high level by both international and past U.K. standards, running at an annual rate of nearly 4 percent of gross domestic product (GDP) in recent months.

The Irish economy has experienced recovery in 1987 and 1988. Exports have boomed, and, for the first time in 20 years, there is a current-account surplus. Unemployment remains very high, but inflation is at its lowest level in 25 years. Although Irish public spending has fallen, the national debt is one of the highest per capita in the world. The Irish government continues to encourage foreign investment in the Irish republic.

This newsletter presents an overview of the economic prospects for the United Kingdom and Ireland. It also highlights the political and technological factors contributing to the economic situations in both countries.

UNITED KINGDOM

Economic Prospects for the United Kingdom

The U.K. economy grew 3.7 percent in 1988, slightly less than in 1987. Dataquest forecasts that economic growth in the United Kingdom will be less buoyant in 1989 and 1990, at 2.3 percent and 2.0 percent, respectively. The slowdown in the economy is led by reduced consumer spending.

According to the Central Statistical Office, total investment in 1988 rose by 12 percent. Private nonresidential investment grew by 17 percent and is expected to expand by more than 9 percent in 1989, but 1990 expansion should be slightly less than 4 percent. The United Kingdom is the biggest single recipient of Japanese investment in Europe. The 1988 investment boom should help U.K. companies to compete internationally, although only 5 percent investment growth is expected in 1989, followed by 20 percent in 1990.

Profitability in British industry has improved considerably—from the lowest in the Organization for Economic Cooperation and Development (OECD) to one of the highest. With profit margins at their highest for a decade, investment can be financed by internal cash flow and might be less affected by high interest rates.

Buoyant economic growth supported by strong investment in 1988 has pushed the average national unemployment rate down to 6.5 percent in mid-1989, the lowest since 1980; however, unemployment in the second half of 1989 is expected to be 7.0 percent, rising to 7.5 percent by the end of 1990.

The traditional trade-off between unemployment and inflation manifests itself in the U.K. economy: lower unemployment but higher inflation. A tight labor market resulting from fewer people leaving school to enter the work force could lead to a further reduction in the unemployment rate.

Consumer spending, which increased by 6.5 percent in 1988, was the dominant growth factor in the U.K. economy. The downward trend in the household savings ratio and the upward trend in consumer borrowing continued. We expect borrowing to decline as a result of high interest rates, and the savings ratio may stop falling and start to rise. Consumer spending is forecast to grow by only 3.3 percent in 1989 and 2.5 percent in 1990.

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CCIS European Newsletters 1989-4

U.K. trade in goods other than oil has tumbled from a surplus of £245.0 million in 1981 to a deficit of £22.9 billion in 1988. The only sector in trade surplus among the metal-related industries is aerospace and defense equipment. In the new, high-technology industries such as computers and microchips, the United Kingdom is in a position of long-term structural imbalance. The U.K. trade deficit in electrical and electronic goods has continued to rise despite heavy investment by foreign producers.

The deficit on the current account of the balance of payments is lower than the trade deficit because of a surplus of the "invisible" balance. But the expected current-account deficit for 1989 has been revised upward to £18.0 billion or more from the previous forecast of £14.5 billion. In 1990, the current-account deficit might be reduced to £15.0 billion. Britain's external deficit as a proportion of GDP is approximately 4 percent, bigger than the U.S. ratio.

The buoyant U.K. economy has sucked in imports at an annual rate of close to 5.0 percent during the 1980s. During the 1990s, however, exports are expected to grow more strongly at 4.0 percent to 5.0 percent per annum, compared with 2.6 percent per annum between 1979 and 1988. Imports will increase by slightly less than 4.0 percent per annum in the 1990s.

Competitiveness

The strong sterling exchange rate has caused loss of market share in the United Kingdom and abroad. If interest and exchange rates remain high, British exporters expect a further loss of competitiveness.

Inflation rose to 8.5 percent in mid-1989 and is expected to rise further during 1989, although the treasury forecasts a reduction to 5.5 percent by the end of 1989. In the European Community (EC) only Portugal and Greece have higher inflation rates than the United Kingdom. Among the 24 OECD countries, only Turkey and Iceland, as well as Portugal and Greece, have higher rates.

The high inflation rate might lead to higher wage claims, which will further undermine competitiveness. The United Kingdom's rate of earnings growth has been persistently ahead of major competitors. Average earnings in the whole economy grew at an underlying annual rate of 9 percent at the beginning of 1989, and labor costs in the manufacturing industry are rising faster than productivity. At the rate of 9 percent, wage inflation is double the rate in most comparable countries.

Unit labor costs are likely to accelerate as output and productivity slow. If the pound sterling weakens, pushing up import prices, pressures on wages will increase. A weak pound also might cause further rises in interest rates, increasing inflation even more. If interest rates remain high, some companies may be forced to cut back on their investment, despite the fact that the cutback would be damaging to the competitiveness of British industry.

Productivity grew faster in the United Kingdom during the 1980s than in any of the Group of Seven big industrial economies except Japan. U.K. productivity growth has been fastest in manufacturing, where the use of labor was most inefficient. Productivity in manufacturing increased by 6.5 percent in 1987 and 5.3 percent in 1988. In the whole economy, productivity rose only 2.5 percent in 1987 and 1.1 percent in 1988; however, levels of productivity as opposed to growth rates are still low in the United Kingdom compared with the other big economies (GDP per worker as standard measure of productivity). British manufacturing industry is still far less efficient at using labor than France, West Germany, or the United States (the most productive country). Each manufacturing worker in the United Kingdom still produces roughly one-third less than his or her counterpart in the United States, Japan, or West Germany.

Government Policies

The U.K. government has pursued a firm industrial-relations policy that might have reduced the negative impact of trade union action on productivity growth. Increased output of the booming U.K. economy has provided the treasury with increased tax revenue. In the 1987/88 financial year, the government achieved a budget surplus of £3.6 billion that is expected to expand to £13.0 billion (2.8 percent of GDP) in 1988/89. An even larger budget surplus (now called public-sector debt repayment, PSDR) is anticipated for 1989/90. The U.K. government plans to reduce the national debt further. At the end of 1988, the United Kingdom's net national debt was slightly less than 40 percent of GDP, the lowest for 70 years. Although the ratio has dropped from a peak of 200 percent after World World II, it is still above the debt ratio of most OECD economies.

The steady decrease in unemployment has produced substantial savings in unemployment payments. Some £2 billion less is expected to be paid out in 1989 than in 1986/87. The employment department will continue its drive to get more people back to work, but it plans to spend 13 percent less over the next three years for employment programs. The Youth Training Scheme (YTS) will need less money because of the decreasing numbers of teenagers, and spending on adult employment training is not planned to increase over the next three years.

The U.K. government places more emphasis on industry's responsibility for investing in product development. The government sees its role in disseminating the results of basic research and encouraging companies to adopt a more adventurous approach to high technology. It wants British companies to do more collaborative research with companies on the continent.

In the spring of 1989, the U.K. government announced a £29 million three-year program to help small companies finance innovative products. The Small Firms Merit Awards for Research and Technology (SMART) is to support commercially viable projects that are unable to obtain conventional financial backing because they involve new technology. Information technology is one of the target areas in this program.

The EC's directorate of enterprise policy is trying to help small companies prepare for the single European market. It provides information about a network of 400 European business centers that can help to bring small businesses together in different countries for collaboration and joint ventures.

Technological Resources

Industry in the United Kingdom finances a smaller proportion of research and development (R&D) spending than industry in other industrial countries, according to an OECD study. Based on figures up to 1985, only 65.6 percent of U.K. business-sector R&D was financed by industry. In Japan and West Germany, the share of industry-financed R&D was much larger. In Japan, industry financed 98.0 percent of R&D devoted to the business sector; in West Germany, 82.0 percent. Among the "big five" countries—France, Japan, the United Kingdom, the United States, and West Germany—business-sector R&D as a proportion of total R&D spending is lowest in the United Kingdom.

The U.K. consumer electronics market experienced a boom in 1988 due to the general increase in consumer expenditure. In the first quarter of 1989, U.K. producers of color TV and videocassette recorders achieved a trading surplus after several years of heavy deficits, but the United Kingdom still records a substantial overall deficit in the consumer electronics sector.

Plessey has joined the European microchip research project JESSI (Joint European Submicron Silicon). Siemens of West Germany and SGS-Thomson are also part of the program. Government funding will be available according to the type of project chosen. It is likely also that the European Commission will provide funds for JESSI from the Esprit program for information technology R&D.

Thorn EMI sold its Inmos subsidiary to SGS-Thomson, Europe's second-largest semiconductor maker. This link will create a powerful European group to compete with the U.S. and Japanese leaders in the industry.

STC, the electronics and telecom group, has won a $200 million contract to supply one-half the fiber-optic submarine cable for a planned new telephone link between Japan and the western coast of the United States. The other half will be supplied by NEC. This contract follows a similar deal for a fiber-optic cable across the Atlantic on which installation work began in the autumn of 1988. Both cables are part of the high-speed digital telecom network that Cable & Wireless (C&W) is planning to develop between London, New York, and Tokyo. Partners of C&W will be International Digital Communications of Japan and Pacific Telecom Cable of the United States.

In the spring of 1988, Racal was chosen to install a government information system worth up to £300 million over the next 10 years. The network will link approximately 240,000 computer terminals in four of the largest government departments.

Toyota is to invest £700 million in an assembly plant to build 200,000 cars a year at Burnaston near Derby. This plant represents the biggest single Japanese investment made in Europe so far. The assembly plant will create 3,000 jobs directly and at least another 3,000 jobs in the automotive components industry.

Bosch of West Germany has plans to build a £100 million plant outside Cardiff to produce components for the motor industry. Production should start in 1991 with 560 employees, increasing to 1,230 people by 1995. The plant is expected to create 1,500 more jobs among components

suppliers. Bosch already employs 500 people in the United Kingdom at sales subsidiaries that have a combined turnover of more than £330 million.

IRELAND

Economic Prospects for Ireland

Dataquest now expects Ireland's economy to grow more than previously anticipated. GDP growth in 1988 was approximately 4 percent and is forecast to be more than 4 percent per annum in 1989 and more than 3 percent in 1990. We see evidence of increased investment. Gross fixed investment is predicted to rise by 8 percent in 1989 and by 7 percent in 1990. The Industrial Development Authority (IDA) expects substantial foreign investment in 1989, particularly from Japan.

We expect private consumption to increase by more than 3 percent in 1989 and by 3 percent in 1990. Unemployment affects 18 percent of the labor force. Ireland has an unemployment rate second only to Spain's in the EC, and Irish unemployment is forecast to rise even further.

Manufacturing has been the main growth factor in the Irish economy during the 1980s, and output has grown 47 percent in volume from 1980 to 1987. As a result, the volume of exports over that period nearly doubled, although this output growth was not enough to keep industrial employment from falling by 20 percent during the period. In 1988, however, Ireland registered the first annual increase in manufacturing employment since 1980.

The foreign-owned sector of Irish manufacturing employs 77,000 people, concentrated in a small number of business segments including electronics. Foreign companies have been attracted to Ireland by the IDA, using a mixture of capital and training grants combined with a special 10 percent tax rate for manufacturing profits. However, indigenous industry has declined. Inflation at 2 percent in 1988 and interest rates are well below those of the United Kingdom. Inflation in 1989 is expected to be more than 3 percent.

Exports have achieved their best performance ever during 1988, accounting for more than Ir£12 billion and resulting in a current-account surplus for the first time in 20 years. Exports are crucial for the Irish economy, because more than 70 percent of exports go to other EC countries. The United Kingdom has been the strongest growth market for Irish exports in 1988, with more than 35 percent of Ireland's total exports going to the United Kingdom. Continental EC countries together account for 39 percent of Irish exports, with strong recent growth in Spain and Italy. Ireland is concerned about the effects of the Channel Tunnel on its economy. The republic will be the only EC member state without a direct land connection to mainland Europe.

Government Policies

The Irish government plans to improve roads and links to air- and seaports to overcome Ireland's geographical disadvantage. These projects will qualify for 75 percent EC funding.

The IDA and the Shannon Free Airport Development Company offer state grants and direct taxation incentives to attract foreign investment to the country. The IDA has been trying to boost links between foreign-owned and indigenous companies. It would like to have more raw materials bought in Ireland than imported and more of the profits generated in Ireland invested in the country.

Traditionally, the Irish economy has been state led; however, the government faces the problem of how to achieve more growth while continuing to keep tight control on public expenditure. The government pursues its cost-cutting measures and has resisted reflation. Large-scale cutbacks in public expenditure have reduced the level of government borrowing by one-third, but the national debt—at more than Ir£26 billion or Ir£28,000 for every household in the country—is still one of the highest per capita in the world.

Tax rates in Ireland are among the highest in Europe, with corporation tax for domestic companies at 47 percent and capital gains tax at 60 percent. At the beginning of 1989, however, the Finance Minister announced the first reduction in the standard rate of income tax in 20 years—from 35 percent to 32 percent.

Technological Resources

In 1988, C&W obtained funding from Telecom Eireann, the Irish public telephone authority, for its transatlantic telecom cable. This Irish deal may persuade other publicly owned European telephone authorities to invest in the C&W cable, which is jointly financed with U.S. partners. Improved communications and the need for frequent transport services in and out of Ireland will be increasingly vital when the Channel Tunnel will link the United Kingdom to the transport system of mainland Europe.

Ireland has opened up more remote areas of the republic to aircraft traffic. A new airport at Knock, in the west of Ireland, was opened two years ago. Another airport at Sligo, in the northwest of the country, has seen a dramatic growth in traffic.

DATAQUEST ANALYSIS

United Kingdom

Business investment in the United Kingdom was very buoyant in 1987 and 1988. The United Kingdom is the biggest single European recipient of Japanese investment, although Dataquest believes that weaker consumer demand and pressure on profit margins will dampen investment growth in 1990. Productivity growth has been very positive in the 1980s, especially in manufacturing, and British industry now should improve productivity further to compete with France and West Germany.

Skill shortages continue to affect U.K. manufacturing, but recruitment difficulties appear to have eased. We believe that the use of skillful people will be vital for the success of British business in the 1990s. British managers will have to become more confident in their use of information technology and more prepared to exploit its potential to remain competitive in the next few years. Educational and vocational training will have to be improved because the United Kingdom ranks behind Japan, the United States, West Germany, and France. Growth rates in hourly earnings in the U.K. manufacturing industry are above the EC average and will affect U.K. competitiveness.

The high deficit on the current account of the U.K. balance of payments indicates a loss of competitiveness at home and abroad, but U.K. companies will be successful if they control costs, avoid debt, motivate workers, and channel R&D spending toward market needs. In their preparation for the single European market in 1993, large U.K. companies are ahead of their rivals on the Continent, according to a CBI survey. However, smaller companies need to take the same kinds of steps to prepare themselves.

Ireland

Ireland has relied excessively on foreign enterprises while indigenous industry remained weak. Too much dependence on the state and a lack of individual and local initiative hinder economic development. The high national debt is also a major constraint on further development.

Ireland still imports nearly 60 percent of goods used in the country, and the trade surplus quickly could revert to a deficit if spending gets out of control. With its small open economy, Ireland has no choice but to go for an export-led recovery. However, any significant drop in the pace of expansion in other economies, particularly in the United Kingdom, will affect the Irish economy greatly.

As one of the poorest countries in Western Europe, with only Greece and Portugal in inferior positions, Ireland might have to introduce some mild reflationary measures to stimulate the domestic economy. Otherwise, any sign of a recession in the western economies could bring serious problems.

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Tony Spadarella
Bipin Parmar

Dataquest
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Research Newsletter

MECHANICAL CAD/CAM FUTURESHOCK: HERE COME 3D VIDEOLASER DIGITIZERS

SUMMARY

Just when everyone begins thinking that real innovation in CAD/CAM is a thing of the past, along comes something truly revolutionary. For example, in 1987, solid 3-D plastic prototypes from 3D Systems startled the market (see CCIS Research Newsletter 1987-9). In 1989, there is Vision 3D's 3D Videolaser. It can create digitized images in minutes (which leads to the consequent productivity gains); this capability is product innovation on a scale that will match and capture the popular imagination. As a development that potentially can open the market to many applications previously closed to CAD/CAM and can service retrofit, testing, and in-process gauging applications, the 3D Videolaser represents a technology—and a whole product class—that vendors need to watch.

HOW IT WORKS

3D Videolaser is an industrial system from France's Vision 3D that permits three-dimensional data acquisition. The product consists of a video camera and monitor, a 2-D laser, a linear or turntable mount, proprietary control modules, and a data acquisition and processing system based on an IBM AT or compatible.

The laser harmlessly illuminates the object to be digitized in order to describe a profile of the object (see Figure 1). Equipped with a parallax lens, the video camera then records the profile traced by the laser. A 3-D data acquisition card retrieves the laser trace from the camera image, and corresponding points are stored by their coordinates in a camera reference frame. By rotating or otherwise moving the object, the system records all the profiles defining its shape.

In this manner, the system generates a profile that contains several hundred points arranged in meridians that are known by their coordinates within the camera reference frame and the position of the meridian relative to the movement applied to the object. The number of points acquired depends on the camera resolution, the number of profiles required to scan the geometry adequately, and the object's location in the camera's field of view. Vertical resolution is camera-dependent, while x, y resolution depends on the number of points in the meridian and on the angle between the camera axis and the laser axis.

The optics that convert the laser beam into a planar beam can be internal or external. An interference filter tuned to the laser frequency relieves the user of any dependency on ambient light. A second camera, as well as a second laser, can be used to resolve hidden area problems.

POINT ACQUISITION

Acquisition accuracy depends on the width of the laser beam at the point of intersection with the object. According to the types of optics used, the width may vary from a few hundredths of a millimeter to 1 millimeter for common lasers. Although in some cases accuracy does not match direct contact measurement methods, it is usually within +0.15 to +0.02 millimeters.

The physical specifications of the table mount vary with the application. The table mount can range from a record-deck-size arrangement to a 10-meter diameter table that is capable of moving 10 tons.

Regardless of the mechanics of any individual configuration, the 3-D data acquisition card is at the heart of the system. When the card receives the video signal, it performs signal windowing so that

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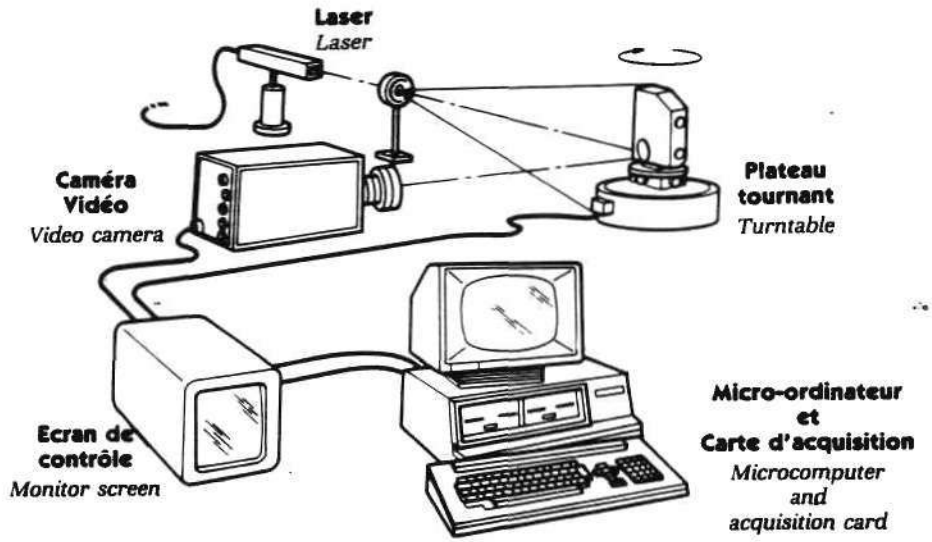
Dataquest Incorporated, 1290 Ridder Park Drive, San Jose, CA 95131-2398 / (408) 437-8000 / Telex 171973 / Fax (408) 437-0292

FIGURE 1
3D Videolaser System Configuration



The System Includes:
- 1 or 2 laser sources
- 1 or 2 video cameras
- 1 electronic acquisition card
- 1 IBM AT microcomputer
- All acquisition and processing software
- A system for moving the objects to be digitized:
  - Linear table
  - Turntable

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Source: Dataquest
September 1989

only the most useful signal points are retained. It digitizes the video signal, which sets threshold levels that pick up the laser trace. The laser trace coordinates are then transferred to the CPU.

The proprietary software consists of 7 modules:

- Autotest—The autotest module allows the user to test the main board functions.
- Configuration—The configuration module sets the parameters for motor-stepping changes and adjusts for varying conditions: interlaced or non-interlaced scanning, internal or external sync, internal or external clock, and European or U.S. video standards. This module also selects the threshold for meridian points.
- Calibration—The calibration module links camera pixels to points in space via the patented calibration process.
- Acquisition—The acquisition module ensures interactive operator acquisition of geometric data that relate to the object being digitized. It also handles meridian point reception, mass storage, and control of motor movement. Up to 100,000 points per minute can be captured.
- Raw display—The raw display module redisplays the file so that the operator can estimate the quality of meridian acquisition. The result of coordinate calculation is an ASCII file in which the points are arranged by meridians.

- Coordinate calculation
- Fast perspective—Using the fast perspective module, the operator can display an image of the digitized object from any angle. The module defines the line of sight and performs rotation (on all three axes), scaling, and windowing.

Optional software modules can be employed for data filtering, z-sampling, wire frame display, variable calculations (surface area, volume, inertia), file overlays (when more than one laser is used to capture data from hidden areas), downstream communications, and output drivers.

The system itself is a front-end acquisition and processing tool that is meant to be used in conjunction with other tools for specific CAD/CAM, robotics/dimensional control, animation, and other applications.

In a computer-integrated manufacturing (CIM) scenario, the problem usually is how to generate a CAD data base for physical models that have irregular shapes and curves (which are created by designers for esthetic reasons). After capturing the raw data, the 3D Videolaser system performs the smoothing, filtering, and surface and volume calculations needed for useful 3-D CAD input.

The system also can be used downstream in the manufacturing process to provide dimensional verification and shape control in space through either sampling or screening inspections.

For CAD applications, Vision 3D has developed two kinds of interfaces, by sections and subsampled points on the surface.

The data base of points is organized by sections along x, y, or z axes. In each section, points are ordered continuously and the number of points is reduced by intelligent subsampling of the section. This ordering allows the distance between the curve and polygon to be obtained independently of the curvature.

A detection of sharp edges is done on the surface, and a skeleton of edges is determined in order to split the complete surface in continuous surfaces without edges. Then, points in the subsurface are subsampled in a homogeneous network with regard to the curvature of the subsurface.

In either of the two cases, the result is an ASCII file of x, y, z points in a format acceptable by any CAD software.

Vision 3D already has systems linked with IEMS (Intergraph), UNIGRAPHICS (McDonnell Douglas), CADDS 4X (Computervision), STRIM 100 (Cisigraph), EUCLID (Matra Data Vision), CADKEY, IRIS (Silicon Graphics), and CUBI7 (Caption).

This technology is not unique to Vision 3D. Cyberware, a U.S.-based vendor, uses similar technology to produce "sculpted heads" by NC machining after first scanning the subject with a low intensity laser in this kind of fashion.

The 3D Videolaser is unique because it can be adjusted to the size of the object in order to optimize the acquisition. An object in a 400mm cube can be digitized in several ways, as follows:

- In 1 time, with the static field of acquisition being 400mm x 600mm. Accuracy will be 0.3mm.
- In 4 time, with the static field of acquisition being 120mm x 180mm. Accuracy will be 0.1mm and the number of points will be three times greater than with 1 time.

APPLICATIONS

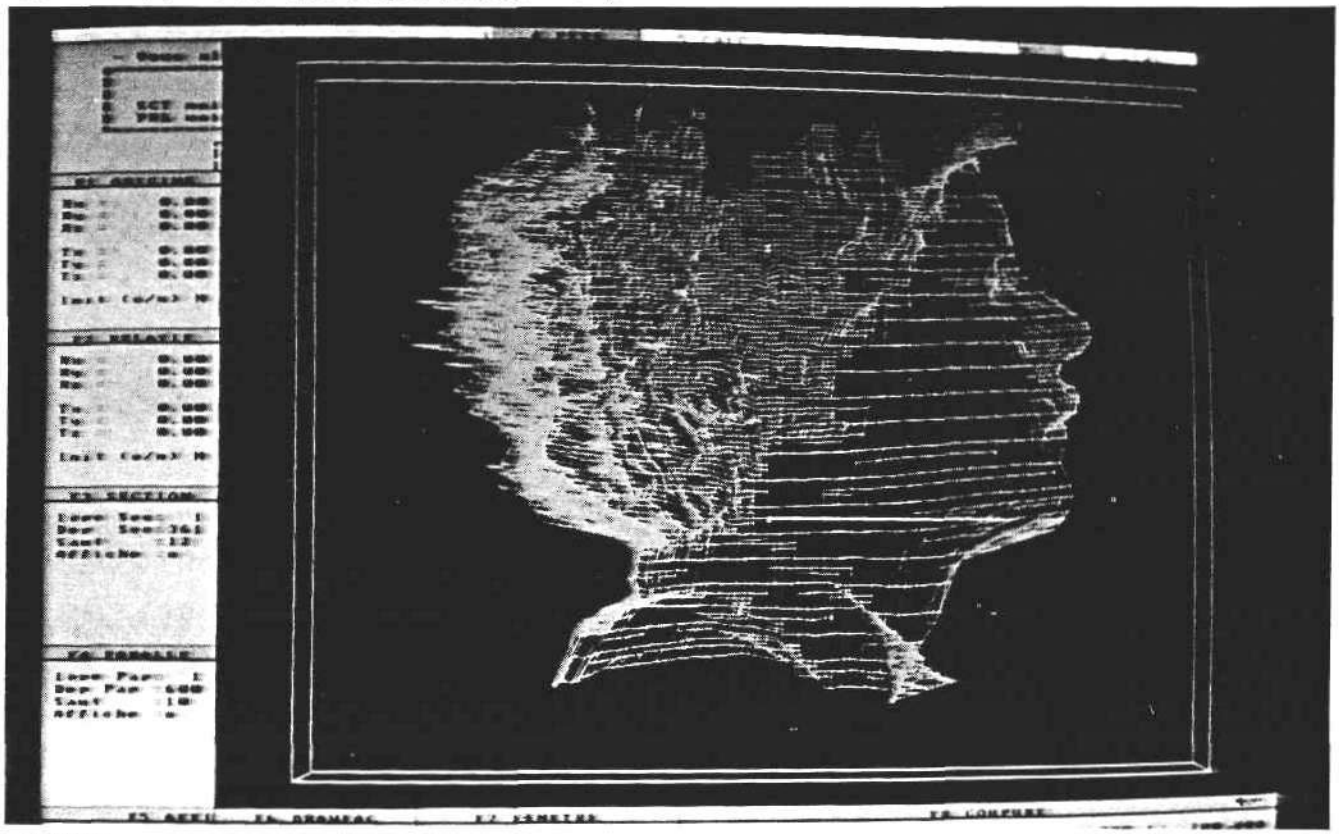
What is unique to Vision 3D's product is the range of applications provided. Key among these are the applications related to digitizing the human frame for use in both the fashion industry and the medical field (see Figure 2).

Rapid, noncontact digitization is essential when dealing with the relatively soft, resilient character of the surface of the human frame. These techniques have been used effectively in shoe design, the construction and fit of various types of safety helmets, and garment design.

In the medical field, whole body scans are possible and, using X-ray lasers, it is possible to establish skeletal geometry in CAD systems. With this and MCAE analysis techniques, it is possible, for example, to establish the optimum magnitude and direction of corrective forces for spinal deformities.

Other applications include scanning of the complex surface geometry used in the automotive industry, such as remedial testing for water erosion of turbine buckets. In the packaging area, establishing the envelope parameters of printed circuit boards can be done in minutes using this technique.

FIGURE 2
3D Videolaser 1/400/Head Output (Faceted View).



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Source: Dataquest
September 1989

DATAQUEST CONCLUSIONS

The 3D Videolaser provides an easy, fast, and relatively accurate noncontact digitizing technique and has broad applicability. It is important in digitizing the human frame and has a significant future in inspection and quality control applications. It provides a possible complement to Valysis verification and "in-process" gauging. And, coupled with the technology from 3D Systems, it may be possible to produce a copy in plastic of any object with minimum interaction on a CAD system, thus completely eliminating the need for a machine tool. Innovation in CAD/CAM is by no means dead. Judging by the 3D Videolaser introduction, it is just warming up.

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BACK TO THE FUTURE: 1992 BEGINS TO DRIVE EUROPEAN CAD/CAM MARKET

SUMMARY

Europe is CAD/CAM's largest market outside North America and the fastest-growing CAD/CAM market worldwide. In 1988, Europe grew by 28 percent in dollar revenue to $3.8 billion. When currency is adjusted, growth in real terms was approximately 25 percent. A more meaningful measure of market growth, and the real strength of Europe, is the growth of workstation shipments.

The compound annual growth rate (CAGR) in shipments for 1988 was 48 percent, contrasted with 71 percent growth the previous year. This slowdown is one indication that the European CAD market is beginning to consolidate. The fact that workstation shipments are growing faster than overall revenue underscores the global trend toward price erosion.

Currently, Europe accounts for 33 percent of the CAD/CAM market. Dataquest projects that Europe will not only retain this market share during the next five years, but will increase it slightly. As 1992 and the reality of a unified European market approach, emerging CAD/CAM opportunities in Europe's developing regions will only bolster this already robust market.

This newsletter presents Dataquest's analysis of this dynamic market, highlighting country-by-country market leaders, prices, applications, buying patterns, trends, and issues, as well as our forecasts and analysis of the impact of 1992.

MARKET SHARE LEADERS

The top four European market leaders—IBM, Prime/Computervision, Digital, and Intergraph—control 44 percent of the European market in terms of revenue (see Table 1 at the end of this newsletter). The remaining vendors hold such relatively similar market shares that their positions could easily shift because of one or two sales. The more significant issue is that, across all regions in Europe, the top 10 vendors account for about 61 percent of the market.

On balance, however, the top vendors are losing their grip on the lion's share of the market as a greater proportion of the market is available for the smaller vendors. As with most maturing markets, the number of competitors is increasing. In 1988, the market consisted of 200 vendors chasing 39 percent of the market, compared with 90 vendors chasing 30 percent of the market in 1987. A point worth noting is that the new HP/Apollo entity, plus all its OEMs, represents the most serious competitive challenge to IBM in Europe in 1989.

IBM performed better in 1988 particularly because it increased its share by three percentage points. However, in reality, this increase represents a recovery of three points as the company had slipped by six percentage points between 1986 and 1987. New products and the promise of a much improved 6150 (RT PC) were largely responsible for this change.

Prime/Computervision had a bad year across Europe in 1988, due mainly to the product line confusion that delayed buying decisions immediately following the merger, but also due in part to the indecision caused by the MAI Basic Four bid for acquisition.

Digital also fared badly in 1988 because of its lack of a viable non-VMS workstation and the conflicts arising with its Cooperative Marketing Partners over the DDS program.

Of the leading vendors, only Hewlett-Packard showed significant positive growth, a conclusion reinforced by an examination of year-to-year changes in the company's revenue. Here we see Hewlett-Packard standing out from the crowd. Hewlett-Packard's growth rate also exposes both Prime and Digital's relatively vulnerable position.

REGIONAL MARKETS

The German Region

The German Region (which includes Austria, Switzerland, and West Germany) leads the pack with 32 percent of the market (see Table 2 at the end of this newsletter). This region also has the highest growth rate of any European region—35 percent. This is about the same as last year, underlining the strength of the German market.

The leading vendors in Germany in 1988 (in terms of revenue) were IBM (14.6 percent market share), Siemens (7.9 percent), Prime (7.5 percent), Hewlett-Packard (6.0 percent), and Intergraph (6.0 percent).

The main characteristic of the German market during 1988 was the importance placed on networking information systems. The German market is focused very heavily on CIM techniques. The implementation of CIM in Germany encompasses a multitude of disciplines. Many vendors in Germany sell solutions that integrate CAD, CAE, CAM, CAT, CAQ, and CATP.

In general, there is a broad trend in Germany toward customized systems for individual solutions. Many of the system vendors concentrate their development and marketing on ready-to-use solutions with very friendly user interfaces. The trend in Germany is to offer the basic hardware and software combination, plus a complete service package from initial installation through user training to system maintenance.

The United Kingdom

The United Kingdom garnered a 21 percent share of the European CAD/CAM market in 1988. This regional share represents a slight decrease, with growth being slightly below the average at 26 percent.

The leading vendors (in revenue terms) in the United Kingdom are IBM (14.3 percent), Prime (14.0 percent), Intergraph (9.2 percent), Digital (6.9 percent), and Hewlett-Packard (6.3 percent). Both IBM and Intergraph are growing much faster than the overall market.

The introduction of architectural and engineering software for the 6150 (RT PC) has contributed to IBM's recent growth in the United Kingdom. Intergraph's revenue in the United Kingdom is derived mainly from the mapping and construction industries, rather than the manufacturing sector.

Although electronics vendors were plagued by merger and acquisition activity during 1988, most vendors appeared to prosper despite the market uncertainty. Electronics companies comprise the second largest industrial sector in the United Kingdom, after machinery.

CAD/CAM software developed in the United Kingdom is an important export. Many U.K.-developed software packages are exported worldwide, either as standalone systems or embedded in other systems, representing a large, global user base. Internationally known products, such as Medusa, Visula, Romulus, GNC, and PDMS, are key packages in this category. Although more than $2 million to $3 million are spent each year on solutions based around these packages, very little of this money finds its way back to the developers because of the complicated distribution system for this software and the fact that most of these products are now owned by U.S. companies.

Although the United Kingdom is mature relative to other markets in Europe, approximately 88 percent of all potential desktops in the United Kingdom are still without a CAD/CAM system.

France

France had a 16 percent share of the European CAD/CAM market in 1988. Although down slightly again from 1987, France still represents a buoyant, stabilizing, and far from consolidated market. Growth in 1988 was less than in recent years and below the average of about 20 percent.

Leading vendors (in terms of revenue) in France in 1988 were IBM (22.6 percent), Prime (12.8 percent), Digital (7.6 percent), Control Data (4.9 percent), and Intergraph (4.3 percent).

Traditionally, the French market has been a French-speaking CAD/CAM market exclusively, with the major French CAD/CAM developers dominating the market. A major sector in France is the military sector, and since the 1986 election, the liberal attitudes of the new government have affected the way the military sector selects CAD/CAM systems. The resulting liberalization has led to an increase in the number of U.S.-based CAD systems being purchased by the French military. Approximately 54 percent of CAD/CAM spending in France is for mechanical, electromechanical, and molding applications, with just under 20 percent spent on electronic applications and about 26 percent on AEC and mapping applications.

Italy

For the last several years, Italy has had a constant 10 percent share of the market, with strong growth in 1988 of 29 percent.

The leading vendors (in terms of revenue) in Italy in 1988 were IBM (23.7 percent), Prime (13.6 percent), Digital (8.9 percent), ItalCAD (3.9 percent), and Intergraph (3.1 percent). Italy is a very strong marketplace for PC- and workstation-based software, and electronic applications experienced strong growth there in 1988. Italy still is dominated by the dealer distributor channel, which is indicated by the presence of ItalCAD among the top five vendors.

Scandinavia

Scandinavia, slightly up in terms of market share from 1987, experienced healthy growth of 29 percent in 1988.

The leading vendors in the Scandinavian region are IBM (22.6 percent), Prime (16.6 percent), Intergraph (10.5 percent), Digital (8.7 percent), and Norsk Data (3.2 percent).

User preferences differ from country to country in Scandinavia. In Denmark, 2-D drafting applications are strong, while in Norway 3-D predominates. In Sweden, the strongest application type is sculptured surfaces. These preferences are really a reflection of the types of industry in the different regions. Denmark concentrates on the production of high-quality products, such as the world-renowned Danish furniture, which is based on traditional manufacturing techniques and natural materials. Because of this, drawings are far more important than automated manufacture. Thus, there is a tendency to focus on 2-D applications rather than 3-D.

The automotive sector is the strongest in Sweden, with companies like Volvo and Saab dominating this sector, thus accounting for the preference in Sweden for surface techniques. Mapping is very strong in Norway. SysScan, a Norwegian company, is one of the few remaining European computer graphics companies that sells European software on the international market place.

Benelux

The Benelux countries, although at the bottom of the table in terms of market share in 1988, experienced above-average growth of 30 percent over 1987.

The leading vendors in the Benelux region are Prime (24.1 percent), IBM (19.5 percent), Intergraph (9.0 percent), Digital (7.0 percent), and Mentor (3.9 percent).

Rest of Europe

In 1988 the major markets lost market share, benefiting the developing regions. Rest of Europe, predominantly Spain, is currently exhibiting a 33 percent growth.

As is often the case in new and developing markets, the computer companies in Spain, which use existing distribution channels, tend to dominate the market rather than the specialists. German suppliers have done exceptionally well in this market, and U.S. computer vendors that have served the market from the German headquarters base, such as Control Data and Hewlett-Packard, have had similar success.

Spain is not fully integrated into the European Communities (EC), and it has a number of tariff and nontariff barriers including a provision that terminals and software must be capable of properly printing anomalous Spanish-language punctuation and orthography, such as the inverted question mark and the tilde, to help preserve Spanish language and culture. A centralized planning regime has created the National Plan for Electronics and Informatics (REDUSA), which is generated by a regional network of CAD/CAM awareness centers. A trade association with a strong user bias, called ASCAD, is active in Spain, and Spain is a traditional gateway to the Latin American market.

AVERAGE SELLING PRICE/APPLICATIONS/BUYING PATTERNS

The average price per CAD/CAM seat continued to fall in 1988 (see Table 3 at the end of this document). Dataquest forecasts that the average seat price in Europe will decline by 8.7 percent compounded annually, to $16,800 in 1993 as against $26,500 in 1988.

The proportional split by application is similar to that in 1987 in distribution, with actual percentages varying only by one percentage point or two from last year's picture or from the general worldwide pattern. Mechanical, AEC, and IC layout showed a slight gain, whereas PCB layout and mapping remained static and electronic CAE showed a slight loss (see Table 4 at the end of this document).

The main characteristic of every region is the increase in the number of repeat buyers. First-time buyers are beginning to dwindle. The market is becoming more penetrated and sophisticated. Many of the leading vendors are reporting between 50 and 80 percent repeat business. Increased buyer/user sophistication also is reflected in the high growth of software revenue (see Table 5) and in the growing popularity of unbundled purchase channels (see Table 6).

EUROPEAN FORECASTS

Dataquest believes that the European market growth will continue and reach $5.8 billion in 1993 at a CAGR of 11 percent. This is significantly slower than the 16 to 17 percent growth in previous years, due mainly to the predominance, in all markets, of PC and low-cost workstations, but it still is slightly higher than the worldwide average.

Currency fluctuations that complicated the picture in recent years should stabilize. Currency appreciated at 3 percent in 1988—significantly slower than the 13 percent rate in 1987.

Workstation shipments in Europe will grow at a CAGR of 15.1 percent, to approximately 207,000 units in 1993 (see Table 7). Technical workstation shipments are expected to grow by a 32 percent CAGR, largely at the expense of host-dependent system shipments, which are expected to decline by a 2.3 percent CAGR, underlining the worldwide trend toward distributed architecture. PC shipments also are expected to slow to 9.3 percent growth.

The distribution of application market growth in Europe is similar to that of the worldwide average, plus or minus one or two percentage points. AEC and mapping are 3 percent below the mean, and mechanical CAD/CAM and MCAE is 4 percent above the worldwide average. The slow growth of AEC and mapping in Europe can be ascribed to the downturn in the North Sea oil industry and the reluctance of the European architectural professions to embrace computer automation tools.

The apparent boom in mechanical CAD and MCAE is due to the emergence of new market segments such as PC drafting and computer-aided styling.

TRENDS AND ISSUES

Of all the market segments in Europe, mechanical computer-aided engineering (MCAE) shows the strongest growth potential—in particular the industrial design, styling, and conceptual analysis applications.

Real 3-D applications are vastly underutilized. Drafting remains the most popular function. Dataquest believes that during the next 12 to 18 months, interest in real 3-D solids modeling applications will increase.

Today, engineers look for the total engineering solution. Hence the enormous interest in more sophisticated, object-oriented data bases and full document-management systems that link the design process, the drafting process, and the report and manual production process.

In the electronics arena, logic design automation is currently the hottest application opportunity. In this stage of evolution in the CAD industry, it is critical that the new tools be integrated with existing CAD/CAM technology. Logic design automation is a prime example of this new generation of tools.

With the general availability of digital mapping systems, geographic information systems (GIS) are becoming far more popular on a worldwide basis. These systems possess significant potential across all markets in Europe—particularly in the highly centralized government markets of countries such as the Scandinavian nations and the United Kingdom. The British government, for example, will be introducing what is called the "Community Charge" or poll tax, which will replace the current housing taxes. Rather than tax the owner of a dwelling, this new tax will be levied on all persons over the age of 18 who occupy a dwelling. Sophisticated GIS systems will play a significant part in administering this tax.

DATAQUEST CONCLUSIONS: THE REALITY OF 1992

Europe is a leader in worldwide CAD/CAM, although the character of the European market is beginning to change. The major regions—Germany, United Kingdom, France, and Italy—gradually are losing share to the developing regions. As the market consolidates, the leading vendors lose share to an increasing number of small competitors. Of the major vendors, only Hewlett-Packard is still exhibiting strong growth.

As January 1, 1993, and the unified European market approach, competition is increasing. The focus on the 1992 deadline is spurring development in manufacturing, and hence is driving the CAD/CAM market. Business opportunities exist for vendors offering integration services and products. Significant growth applications are MCAE products and geographic information systems.

A lot of confusion exists about 1992, about what it means and what can be achieved. It seems that, so far, the only winners are the paper manufacturers and the printers—so staggering is the amount of published information about "Europe 1992."

Make no mistake about it: Europe *will* become a unified market after 1992. Restrictive trade barriers will be illegal. The market size will be 330 million people—very nearly as many people as in the United States and Japan combined. New European standards will emerge, especially in the areas of consumer electronics, telecommunications, and data processing. Companies that fail to recognize this prospective reality will have a tough time in 1993.

The resultant economies of scale will drive down operating costs, and Europe will become more competitive in its own market and be positioned strategically and tactically to exploit the export opportunities from a base of strength and equality with other world competitors.

As we move toward the December 31, 1992, deadline, competition within Europe will increase as countries outside the 12 member nations move into Europe in order to compete in that market post 1992. Most noticeable are the Japanese printer and automobile manufacturers.

The 1992 focus will spur market development. As Europe drives for more productivity, the need for computer automation will increase. The CAD/CAM industry will prosper under this influence.

The essence of 1992 is defined by the Single European Act that came into effect July 1, 1987, which states:

> "The Community shall adopt measures with the aim of progressively establishing the internal market over a period expiring on 31 December 1992 . . . The internal market shall comprise an area without internal frontiers in which the free movement of goods, persons, and capital is ensured in accordance with the provisions of the Treaty."

This is all it says. There is nothing that speaks of a federal government for Europe or the imposition of the European monetary system for the European Economic Community (EEC) states. Some of the popular press in the United Kingdom has drawn parallels between 1992 and George Orwell's *1984*, suggesting that British armed forces would have to take orders in French and German, British courts would be powerless under the European Court, Brussels would interfere with the TV programs that Britons watch, all EEC athletes would compete in international events in European colors, and so forth.

This scenario could not be further from the truth. All the Single European Act seeks to do is to ratify the provisions of the original Treaty of Rome in 1957, which was responsible for the setting up of the EC. The Single European Act also has the provision that the implementation of 1992 should be consistent with the Treaty of Rome. This qualification is important, because it defines the scope of the Single European Act.

For example, issues such as the control of traffic in illicit drugs and immigration from non-EC countries are not covered by the treaty.

Moreover, while member states are working to reduce or abolish the barriers to the legitimate movement of goods and people, safeguards—such as those on firearms and plant and animal diseases—will continue for security, social, and health reasons, which makes the comparison with *1984* even less appropriate.

The goal of 1992 is to lower the hidden barriers that serve to separate the individual countries of Europe. But 1992 is a reality today, nevertheless—a reality that Europeans have grown up with and prepared for, and a reality around which they have organized activities, factories, marketing plans, business strategies, and end products.

Charles Clarke
Tony Spadarella

Table 1

1988 European CAD/CAM Market Share
(Millions of Dollars and Actual Units)

	Revenue	Units	Revenue Share	Units Share
IBM	604.0	17,015	17.8%	16.6%
Prime Computer	421.1	3,974	12.4%	3.9%
Digital	234.0	2,950	6.9%	2.9%
Intergraph	232.5	2,545	6.9%	2.5%
Hewlett-Packard	127.3	6,296	3.8%	6.2%
Siemens	105.6	2,238	3.1%	2.2%
Control Data	93.4	1,092	2.8%	1.1%
Apollo	83.0	3,635	2.5%	3.6%
Mentor Graphics	78.3	986	2.3%	1.0%
Daisy Systems	77.3	761	2.3%	.7%
McDonnell Douglas	75.6	1,545	2.2%	1.5%
Schlumberger (Applicon)	67.2	936	2.0%	.9%
Compaq	61.5	11,798	1.8%	11.5%
Racal-Redac	53.9	105	1.6%	.1%
Matra Datavision	50.3	428	1.5%	.4%
Norsk Data	43.5	484	1.3%	.5%
Valid	41.4	356	1.2%	.3%
Calma	39.2	331	1.2%	.3%
Autodesk	35.6	0	1.1%	.0%
Sun	33.9	1,614	1.0%	1.6%
Other	828.3	43,191	24.5%	42.2%
All Companies	3,386.9	102,281	100.0%	100.0%
All U.S.-Based Companies	2,720.7	90,824	80.3%	88.8%
All Asian-Based Companies	.0	0	.0%	.0%
All European-Based Companies	666.2	11,457	19.7%	11.2%
All Hardware Companies	735.4	67,322	21.7%	65.8%
All Turnkey & SW Companies	2,651.5	34,959	78.3%	34.2%

Source: Dataquest
June 1989

Table 2

European CAD/CAM Forecast by Region
(Millions of Dollars and Actual Units)

	1988	1989	1990	1991	1992	1993	CAGR
Europe							
Revenue	3,387	3,987	4,497	4,853	5,288	5,766	11.2%
Systems	90,895	115,880	140,600	162,330	182,630	200,850	17.2%
Workstations	102,281	126,350	149,800	169,530	189,120	206,630	15.1%
Benelux							
Revenue	243	277	317	347	381	419	11.5%
Systems	7,938	10,240	12,300	14,170	15,710	17,060	16.5%
Workstations	9,483	11,350	13,280	14,940	16,400	17,690	13.3%
France							
Revenue	531	593	665	718	779	844	9.7%
Systems	13,045	17,300	20,950	24,400	27,290	29,800	18.0%
Workstations	14,977	18,760	22,240	25,420	28,240	30,660	15.4%
German Region							
Revenue	1,183	1,443	1,599	1,694	1,828	1,987	10.9%
Systems	36,788	45,590	55,370	63,520	71,710	79,530	16.7%
Workstations	39,590	49,020	58,360	65,830	73,740	81,300	15.5%
Italy							
Revenue	333	426	489	534	595	653	14.4%
Systems	10,371	13,710	16,660	19,360	22,000	24,100	18.4%
Workstations	12,117	15,190	17,980	20,410	22,980	24,980	15.6%
Scandinavia							
Revenue	319	389	443	485	525	570	12.3%
Systems	9,414	12,150	14,782	17,102	19,118	20,842	17.2%
Workstations	10,730	13,124	15,637	17,773	19,720	21,380	14.8%
United Kingdom							
Revenue	683	724	820	881	952	1,028	8.5%
Systems	11,341	14,269	17,353	19,859	22,294	24,418	16.6%
Workstations	13,238	15,992	18,869	21,030	23,332	25,321	13.9%
Rest of Europe							
Revenue	91	135	163	195	227	264	23.6%
Systems	1,995	2,612	3,175	3,909	4,505	5,102	20.7%
Workstations	2,275	2,909	3,440	4,133	4,715	5,298	18.4%

Source: Dataquest
June 1989

Table 3

European CAD/CAM Average Selling Price Forecast by Platform (Thousands of Dollars)

	1988	1989	1990	1991	1992	1993	CAGR
Turnkey & Hardware-Only							
Technical Workstation	40.2	35.7	31.8	28.3	25.3	23.5	-10.2%
Host-Dependent/Server	272.7	248.2	226.8	207.1	194.1	178.0	-8.2%
Personal Computer	4.9	4.8	4.6	4.3	3.9	3.7	-5.5%
All Platforms	26.5	23.5	21.0	18.8	17.5	16.8	-8.7%
Turnkey							
Technical Workstation	49.7	45.9	42.8	40.0	38.0	37.4	-5.5%
Host-Dependent/Server	337.1	316.3	294.3	273.9	256.8	240.5	-6.5%
Personal Computer	10.1	11.0	9.6	8.4	7.7	6.9	-7.3%
All Platforms	66.9	61.6	55.5	48.3	44.8	43.0	-8.5%
Hardware-Only							
Technical Workstation	21.5	20.2	18.4	16.6	15.1	14.4	-7.7%
Host-Dependent/Server	175.8	155.8	144.6	135.6	131.4	125.1	-6.6%
Personal Computer	4.3	4.4	4.3	4.1	3.8	3.6	-3.5%
All Platforms	10.8	10.2	9.8	9.4	9.2	9.3	-2.9%

Source: Dataquest
June 1989

Table 4

European CAD/CAM Forecast by Application
(Millions of Dollars and Actual Units)

	1988	1989	1990	1991	1992	1993	CAGR
All Applications							
Revenue	3,387	3,987	4,497	4,853	5,288	5,766	11.2%
Systems	90,895	115,880	140,600	162,330	182,630	200,850	17.2%
Workstations	102,281	126,350	149,800	169,530	189,120	206,630	15.1%
Mechanical							
Revenue	2,116	2,454	2,743	2,857	3,107	3,357	9.7%
Systems	54,817	68,340	81,500	91,790	100,340	107,470	14.4%
Workstations	63,948	76,470	88,780	97,520	105,770	112,520	12.0%
AEC							
Revenue	413	516	561	599	620	659	9.8%
Systems	17,383	25,180	31,000	36,820	41,940	46,180	21.6%
Workstations	18,474	26,350	31,860	37,430	42,350	46,460	20.3%
Mapping							
Revenue	180	220	260	291	327	372	15.6%
Systems	2,899	4,080	5,300	6,510	7,730	8,980	25.4%
Workstations	3,596	4,820	6,010	7,130	8,240	9,390	21.2%
Electronic CAE							
Revenue	334	390	465	563	601	654	14.4%
Systems	8,638	9,860	12,860	15,540	18,320	21,030	19.5%
Workstations	8,731	9,940	12,920	15,600	18,350	21,040	19.2%
IC Layout							
Revenue	72	92	107	125	145	166	18.3%
Systems	942	1,300	1,690	2,070	2,390	2,780	24.2%
Workstations	991	1,350	1,730	2,090	2,400	2,790	23.0%
PCB Layout							
Revenue	272	316	360	419	487	559	15.4%
Systems	6,216	7,110	8,250	9,600	11,910	14,400	18.3%
Workstations	6,542	7,410	8,500	9,770	12,010	14,440	17.2%

Source: Dataquest
June 1989

Table 5

European CAD/CAM Revenue Sources
Forecast by Platform
(Millions of Dollars)

	1988	1989	1990	1991	1992	1993	CAGR
All Platforms							
Hardware	1,995	2,242	2,441	2,537	2,660	2,816	7.1%
Software	886	1,127	1,357	1,556	1,791	2,031	18.0%
Service	526	617	699	760	836	919	11.8%
Total	3,387	3,987	4,497	4,853	5,288	5,766	11.2%
Technical Workstation							
Hardware	816	1,061	1,318	1,558	1,747	1,959	19.1%
Software	438	638	873	1,110	1,352	1,598	29.5%
Service	278	375	481	580	669	763	22.4%
Total	1,538	2,075	2,671	3,248	3,768	4,320	22.9%
Host-Dependent/Server							
Hardware	890	837	746	601	551	511	-10.5%
Software	295	310	288	243	233	225	-5.2%
Service	229	220	196	158	145	133	-10.2%
Total	1,394	1,367	1,230	1,001	928	870	-9.0%
Personal Computer							
Hardware	289	344	377	379	362	346	3.6%
Software	153	179	196	204	207	208	6.2%
Service	19	21	22	23	22	22	2.7%
Total	455	545	595	605	591	575	4.8%

Source: Dataquest
June 1989

Table 6

European CAD/CAM Forecast by Distribution Class
(Millions of Dollars and Actual Units)

	1988	1989	1990	1991	1992	1993	CAGR
Total Hardware and Software Revenue							
Turnkey	1,706	1,886	1,953	1,951	1,965	1,984	3.1%
Unbundled	1,175	1,483	1,844	2,142	2,486	2,863	19.5%
Total	2,881	3,370	3,798	4,093	4,451	4,847	11.0%
Hardware Revenue							
Turnkey	1,303	1,407	1,445	1,431	1,428	1,427	1.8%
Unbundled	692	835	996	1,107	1,232	1,389	14.9%
Total	1,995	2,242	2,441	2,537	2,660	2,816	7.1%
Software Revenue							
Turnkey	403	479	508	521	537	556	6.6%
Unbundled	483	648	848	1,035	1,254	1,474	25.0%
Total	886	1,127	1,357	1,556	1,791	2,031	18.0%
Workstation Shipments							
Turnkey	34,959	38,600	41,800	45,030	47,500	48,820	6.9%
Unbundled	67,322	87,740	108,000	124,510	141,620	157,820	18.6%
Total	102,281	126,350	149,800	169,530	189,120	206,630	15.1%

Source: Dataquest
June 1989

Table 7

European CAD/CAM Forecast by Platform
(Millions of Dollars and Actual Units)

	1988	1989	1990	1991	1992	1993	CAGR
All Platforms							
Revenue	3,387	3,987	4,497	4,853	5,288	5,766	11.2%
Systems	90,895	115,880	140,600	162,330	182,630	200,850	17.2%
Workstations	102,281	126,350	149,800	169,530	189,120	206,630	15.1%
Technical Workstation							
Revenue	1,538	2,075	2,671	3,248	3,768	4,320	22.9%
Systems	25,404	36,900	51,260	67,790	84,670	101,520	31.9%
Workstations	25,404	36,900	51,260	67,790	84,670	101,520	31.9%
Host-Dependent/Server							
Revenue	1,394	1,367	1,230	1,001	928	870	-9.0%
Systems	4,007	4,200	4,110	3,620	3,540	3,570	-2.3%
Workstations	15,393	14,670	13,310	10,820	10,030	9,360	-9.5%
Personal Computer							
Revenue	455	545	595	605	591	575	4.8%
Systems	61,484	74,770	85,230	90,920	94,410	95,760	9.3%
Workstations	61,484	74,770	85,230	90,920	94,410	95,760	9.3%

Source: Dataquest
June 1989

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SUPERCOMPUTING EUROPE 1989
NEW TECHNOLOGY IN THE HIGH-PERFORMANCE COMPUTING MARKET

SUMMARY

Superperformance vendors are becoming increasingly aware of the potential for growth in the European marketplace, and this awareness was reflected in a strong presence at the Supercomputing Europe '89 Exhibition, held in February, in Utrecht, The Netherlands. The Exhibition was characterized not only by the presence of the industry's major players, but also by many relatively new entrants, especially in the areas of novel architectures and technologies.

More than 45 exhibitors participated, representing a wide range of the high-performance computing market, as follows:

- Top-end performers, such as Cray Research
- Augmented mainframes, such as add-on array processors from FPS and add-on vector processors from IBM
- Minisupercomputers from Convex and Gould
- Superworkstations from Ardent and Silicon Graphics
- Massively parallel architectures
- The software-based approach to supercomputing, in the form of Multiflow

Many of the exhibiting vendors opened new subsidiaries in Europe during 1988. In this newsletter, Dataquest profiles a selection of the emerging players in some of these areas, and offers a brief analysis of the market prospects in these areas.

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MASSIVELY PARALLEL AND TRANSPUTER TECHNOLOGY

The massively parallel market still is restricted mostly to scientific research institutes and university environments, but the vastly reduced cost for supercomputing performance now is proving attractive to industrial users. Increasing numbers of organizations now are providing programming and implementation services for these novel architectures.

Meiko

Meiko, manufacturer of the Computing Surface, was founded in 1985; since then, more than 200 systems have been sold worldwide. The majority of these have been in Great Britain, with a few large installations in Japan, the United States, and the rest of Europe.

The Computing Surface is based on one of the most powerful, very large scale integration (VLSI) processors available, with floating-point capabilities and a sustained performance of 10 mips and 1 mflops (64-bit). Each computing element conforms to the same generic model, is based on a transputer with its own interface to the global Supervisor Bus, and has a quantity of private local memory. The architecture starts with one processor and can grow to an unlimited number of processors. The Computing Surface installed at the Edinburgh Concurrent Supercomputer Facility has more than 400 processors and almost 1GB of local memory. The operating system is UNIX-like for multiprocessors and multiusers, and compilers for FORTRAN, C, Pascal, LISP, and OCCAM are available. Applications are in the areas of computer-aided engineering (CAE), graphics, signal and image processing, computational fluid dynamics, and seismic processing, where the price/performance benefits of parallel computing are significant.

NCUBE Corporation

NCUBE was founded in 1983 by three engineers from Intel. In November 1985, the company introduced its first product, the NCUBE/ten, based on the hypercube technology, i.e., massively parallel, MIMD computer technology.

The NCUBE-designed VLSI node processor contains a VAX-style central processor, a fast scalar floating-point unit, and a memory management unit. The NCUBE family of parallel computer systems ranges from the NCUBE/four using a PC AT as host with 4 to 16 nodes, up to the standalone NCUBE/ten with up to 1,024 nodes, giving a maximum performance of 2,500 mips, or more than 500 mflops. The operating system is Axis, an implementation of UNIX version V. FORTRAN-77 and C compilers, developed by an external vendor, are available. NCUBE has distributors in Great Britain, Southern Europe, Scandinavia, and Japan, and has been distributing in Europe for about a year. The total installed base worldwide is approximately 150 systems, of which half a dozen are in Europe. The average number of nodes per system installed is 64, at a cost of approximately £150,000. At present, about 50 percent of the applications are in universities, and the remainder is split between government, weather, and industrial scientific applications.

Parsys

Parsys is a member of the Thorn-EMI group of companies. Its SN1000 series of parallel processing computers is based around the Inmos IMS T800 transputer. The SN1000 series has a highly modular, flexible architecture, which is capable of yielding performance levels of between 25 mflops and 1,500 mflops (240 to 15,000 mips). The basic node can be run on its own, or coupled with other nodes to form a multinode system, with up to 64 nodes. Each node contains up to 16 transputers; the largest configuration therefore contains 1,024 transputers. The series is unusual in that, unlike traditional processor arrays with fixed connections between the processors, the user can actually define the connections between the processors, thus making the system dynamically reconfigurable. The SN1000 series can be run either under an enhanced version of Inmos TDS or under IDRIS, a UNIX-like operating system. The languages available include C, FORTRAN, and OCCAM.

SUPERWORKSTATIONS AND GRAPHICS SUPERCOMPUTERS

Dataquest forecasts that the total European market for workstations will grow from about $1.5 billion in 1988 to more than $3.5 billion by 1991, in spite of agressive price-cutting at the lower end of the market. At the high end of the market, Dataquest believes that one of the main issues differentiating the graphics supercomputer from the technical workstation is the price/performance issue. In general, graphics supercomputer vendors, such as Stellar Computer and Ardent Computer, are striving to provide the highest performance possible for a given price (for example, $100,000), and as such are aimed at the performance-conscious market. In contrast, technical workstation vendors, such as Silicon Graphics, Sun, and Apollo are striving to provide a relatively economical system for the majority of users. Nevertheless, high-end systems from these mainstream workstation vendors are already encroaching on the graphics supercomputer market.

Silicon Graphics

Silicon Graphics was founded in 1981 and designs, manufactures, and markets high-performance workstations with particular applications in mechanical computer-aided engineering (MCAE), animation, and visual simulation in various scientific applications including molecular modeling and computational fluid dynamics. The company has its European headquarters in Switzerland and has subsidiaries in Great Britain, Sweden, West Germany, France, Italy, and the Benelux countries. Silicon Graphics markets the RISC-based IRIS superworkstations, which range from the series 3000 with 2-mips performance, to the latest IRIS 4D/GTX with a performance of 20 mips. The POWER IRIS, introduced in October 1988, is a series of superworkstations based on the multiprocessing architecture called POWERpath. The system supports up to four RISC processors and is capable of performing at 25 mips and 12.5 mflops (peak).

Silicon Graphics' revenue from international sales is approximately 40 percent of its total revenue ($152.6 million in 1988). Consequently, with the European revenue providing about 25 percent of total revenue, Silicon Graphics won approximately 4 percent of the European workstation market in 1988.

Ardent Computer Corporation

Ardent was founded in 1985 by computer industry executives from Convergent Technologies, Digital Equipment Corporation, and Hewlett-Packard and is funded by venture capital. In March 1988, Ardent announced the first graphics supercomputer dedicated to a single user. The Titan family of graphics supercomputers combines high-level graphics capabilities with the compute-intensive capabilities of a supercomputer. The series consists of four 64-bit machines based on a parallel and vector architecture. Each CPU comprises an Ardent-designed 64-bit vector processor rated at 16 mflops and a 32-bit RISC integer processor designed by MIPS Computer Systems rated at 16 mips (peak). Ardent's graphics software is a critical element of the Titan system. The DORE (Dynamic Object Rendering Environment) system allows users to visualize interactively the results of supercomputer-class applications.

Ardent has more than 200 systems installed worldwide, with more than 25 in Europe. In 1988, subsidiaries were opened in Germany and France. The major applications are computational chemistry, with about one-third of Ardent's market, followed by computational fluid dynamics, MCAE, simulation, and imaging.

CRAY COMPATIBLES

The attraction of being "Cray-compatible" has encouraged some new entrants in the marketplace. Cray compatibility enables users to employ an enormous range of application software available off-the-shelf. Existing Cray users can also run user-written software unchanged. These machines generally offer high price/performance advantages, and are very interesting to users requiring minisupercomputer performance with a wide range of software.

Supertek

Supertek was formed in 1985 and started shipping its low-cost Cray-compatible computer (the S-1) last year. The machine delivers 36 mflops peak vector performance and 18 mips peak scalar performance and is binary-code compatible with the Cray X-MP/416 instruction set. The operating system, VECTRIX, is derived from UNIX version V, with BSD extensions and supercomputing extensions such as asynchronous disk I/O. Typically, the S-1 offers about one-quarter to one-third of the performance of a Cray 1-S, for considerably less cost. At present, the company has about six machines installed worldwide.

Scientific Computer Systems

Scientific Computer Systems (SCS), developer of the SCS-40 series of minisupercomputers, was founded in 1983. The SCS-40 64-bit minisupercomputer was introduced in 1986 and uses the Cray X-MP instruction set, the Cray Time Sharing System, and standard ECL components. Peak performance is rated at 44 mflops for vector processing, and 18 mips for scalar processing.

SCS has subsidiaries in Great Britain, France, and West Germany, and installed three systems in Europe in 1988. Dataquest believes that SCS placed a hold on all its computer division's operations, and is directing most of its effort toward VectorNET. Thus, SCS will not market the SCS-40 actively, but will fulfill its support obligations for systems currently installed. SCS is, however, maintaining its production capability and could sell systems on request.

SOFTWARE-BASED APPROACH TO SUPERCOMPUTING

Traditional sequential, or von-Neumann, architectures have been approaching power limitations as a result of fundamental physical limits on technology. Computer vendors have adopted various methods to permit concurrent execution of several instructions, and Multiflow is the pioneer of the very long instruction word (VLIW) architecture, which takes the concept of overlapped instructions to an extreme.

Multiflow Computer

Multiflow Computer was founded in 1984 by three members of a research team from Yale University. The company introduced its first minisupercomputer, the Trace system, in April 1987. It is based on VLIW architecture and uses Trace-scheduling to exploit parallelism in application programs. Individual operations, such as would be generated from source code by traditional compilers, are rearranged by Multiflow's Trace-scheduling compacting compilers to execute simultaneously.

Multiflow has recently announced the opening of its European headquarters in Louvain, Belgium, in response to increased activity in the European market. Presently, the company is privately owned, financed by approximately $18 million of venture capital funds.

Where typical vector or multiprocessor systems might improve the performance of vectorizable and/or parallelizable sections of a program, many real applications contain sections of sequential code, which dominate program performance. The Trace handles both the sequential sections and the vectorizable/parallelizable sections in the same way, which results in greater potential for improvements in performance. Dataquest believes that the Trace will prove attractive to end users that have considerable investments in existing software.

In March, Adage announced that it had signed a merger agreement with Multiflow. Adage designs, manufactures, and markets high-performance computer graphics workstations, terminals, display processors, and board sets. Dataquest believes that the merger is a new financing tactic for Multiflow, due to Adage's strong balance sheet.

DATAQUEST CONCLUSIONS

Massively Parallel and Transputer Technology

The market for these specialized products is still small, but it is growing rapidly. Traditionally, applications for massively parallel architectures and supercomputing based on novel architectures have been restricted due to the user-unfriendliness of the supporting software. To date, users have been restricted mainly to research establishments initially using the OCCAM language. Recent developments of parallel FORTRAN and C compilers and moves toward UNIX-like operating systems now provide users with viable alternatives to OCCAM. The major barrier to their uptake has been, until recently, the difficulty of programming. In view of these latest developments, however, Dataquest expects these products to grow in popularity and start to gain measurable market share outside of academia in the 1990s. The price/performance advantage of these systems over a traditional supercomputer such as Cray is significant.

Superworkstations and Graphics Supercomputers

This is an emerging area, attacking minisupers from below on the compute-power side, and providing, in addition, high-quality graphics. These products are of particular interest to engineers, designers, and scientists requiring a complete standalone, desktop solution at relatively low cost, combining visualization and medium-level computational power. Dataquest believes that there is significant potential for growth in this area. This has been recognized by some of the minisupercomputer vendors, which now are trying to combine visualization capabilities with high CPU power.

Cray Compatibles

The recent problems of SCS highlight the stiff price competition and difficulties that relationships with Cray bring for competitors in this marketplace. Increasing availability of software applications on other minisupers is now eroding some of the traditional advantages that Cray compatibility brings.

Software-Based Approach to Supercomputing

Many users require high performance without modifying their codes, and Dataquest believes that the approach of Multiflow will prove increasingly attractive in the market. The recent merger of Multiflow and Adage will broaden sales and distribution channels, and should help Multiflow reach these potential users.

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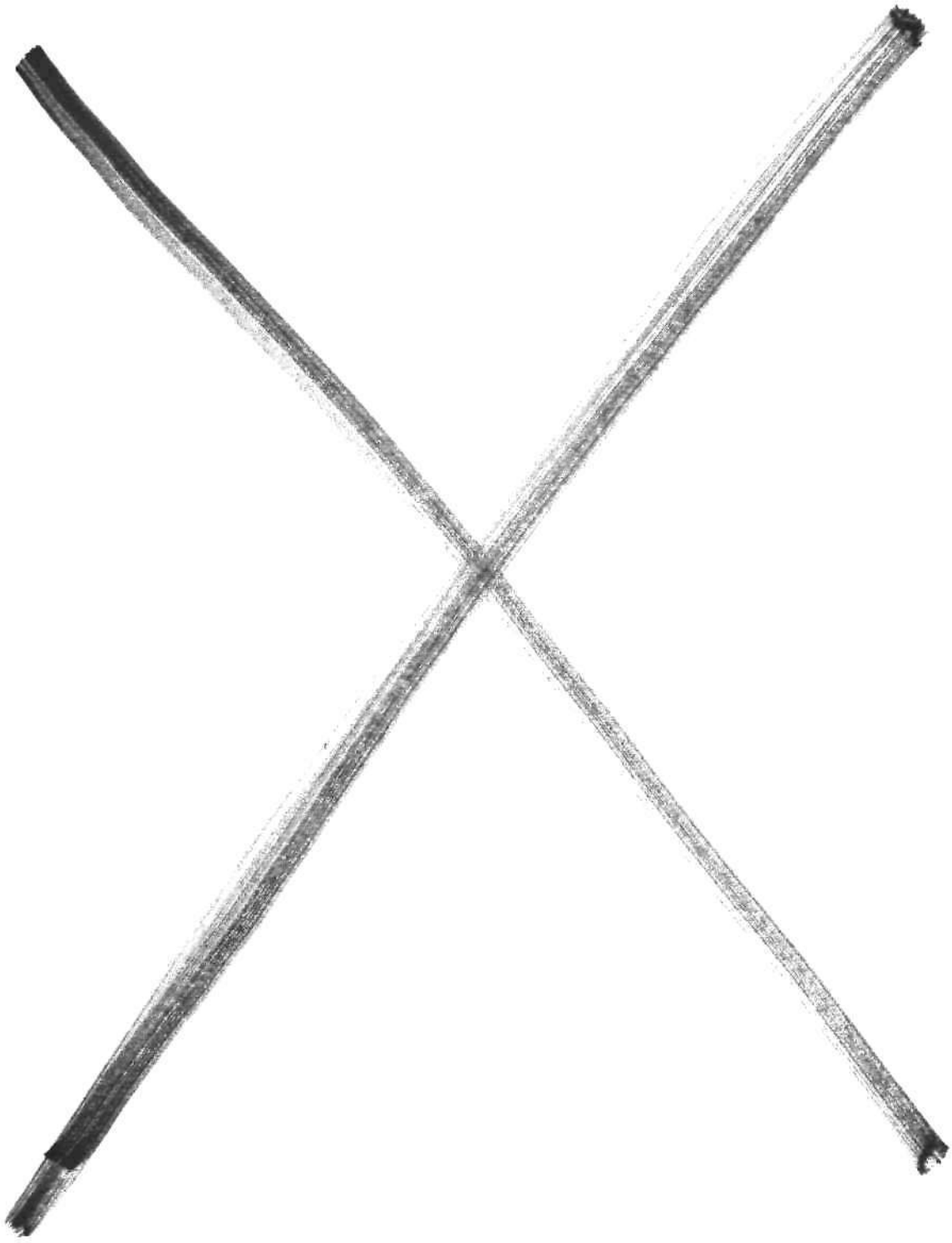
Charles Clarke
Philippe de Marcillac



Dataquest
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Research Newsletter

QUARTERLY ECONOMIC OUTLOOK: PERSIAN GULF CRISIS ADDS TO AN ALREADY LACKLUSTER ECONOMY

SUMMARY

Although the nearly three-month-old Persian Gulf crisis has further slowed what was an already sluggish rate of economic growth and increased the probability of recession, recession will likely be averted. The Dun & Bradstreet Corporation (D&B) forecasts US real gross national product (GNP) growth of 1.0 percent in 1990 and 1.9 percent in 1991 (see Figure 1). The crisis' adverse effects notwithstanding, the current slow-growth period may last longer than is implied ordinarily by a purely cyclical downturn. This possibility is because, independently of the Gulf crisis, *potential* GNP growth has fallen significantly in the past few years as a result of decelerating labor force and productivity growth. Given that high-technology companies continue to provide among the most productive investment solutions, *internationally* competitive companies should fare comparatively well during the next few years.

INTRODUCTION

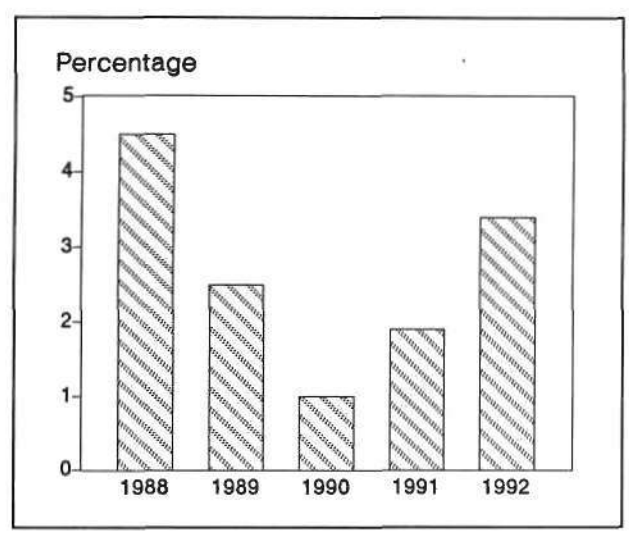
Iraq's invasion of Kuwait in August dramatically illustrated how vulnerable the world economy is to unexpected events. Despite an immediate response by the United Nations, other Arab countries, the United States, and the Western allies, many uncertainties about the short-range and long-range implications of the Persian Gulf crisis remain.

It is *possible* that the largest oil inventories in nine years, a slowing world economy, additional available oil-production capacity, and an unprecedented amount of international cooperation together can provide a sufficient shock absorber for lost Iraqi/Kuwaiti oil production. However, the current volatility in oil prices is obvious evidence that the final outcome remains unclear. Memories of previous recessions caused by earlier oil crises caused stock markets throughout the world to tumble in August.

Will these events push the US economy into recession in the near term? Probably not. Can we dismiss all the negative anecdotal evidence of economic weakness as misleading? Again, probably not. Will the oil crisis in the Middle East hurt the economy? Most definitely yes, but the redistributional effects of higher oil prices on income and economic growth are far more significant than the weakness caused directly by higher oil prices.

In the absence of an outright war or some other severe economic shock, most recession scenarios involve an especially adverse psychological reaction by consumers and producers, triggering cutbacks in spending. But whether a recession is

FIGURE 1
US Real GNP Growth Annual Percent Change



Source: The Dun & Bradstreet Corporation

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imminent may not be the right question to ask. Events in the Middle East may obscure a more important issue: *Is the current economic malaise the result of a "normal" business cycle downturn, or is there something else fundamentally wrong with the US economy?*

This newsletter addresses these issues, relying heavily upon the recent analyses of The Dun & Bradstreet Corporation (Dataquest's corporate parent). The newsletter provides some economic perspectives for business planners by reviewing current economic conditions and providing a framework for interpreting the impact of the unfolding events.

ARE WE IN A RECESSION? WHO CARES!

Perhaps the most often-asked question in the business community these days is, "Is the economy in a recession?" Technically speaking, a recession is defined as two consecutive quarters of declining real GNP. So whether the US economy currently is contracting is, and will continue to be for several months, a debatable point until the US Department of Commerce (DOC) releases statistics of *current* and short-term future business activity in the coming months. Whether or not the economy is in recession is a moot point: As a practical matter, there is no doubt that current economic conditions in the United States clearly are weak, as shown in the following:

- The unemployment rate has risen to 5.7 percent after remaining at nearly 5.0 percent for almost two years.
- Employment levels currently are about where they were at the beginning of the year.
- New orders for durable goods have fallen in four of the last eight months.
- Consumer spending barely has budged since the third quarter of 1989.

This same weakness shows up clearly in the following D&B economic statistics:

- Based on a third-quarter survey of fourth-quarter expectations, business expectations for higher sales have dropped to their lowest level since early 1983. D&B's sales optimism index has fallen to 50, which historically has been the dividing line between economic growth and recession. Expectations for new jobs and profit also are weak.
- Through mid-August of this year, business failures had risen 10.8 percent over the same period in 1989. Until this past April, failures had been declining since 1987. Most of this increase in failures occurred in the New England and Mid-Atlantic regions.
- During the first half of 1990, new incorporations were 3.4 percent below 1989 levels. Again, New England and the Mid-Atlantic states showed the most weakness. In addition, new incorporations in California were down 15.5 percent from year-earlier levels, signaling a slowdown in this heretofore fast-growing region.

WHAT THE PERSIAN GULF CRISIS MEANS TO THE US ECONOMY

Tensions in the Middle East add another layer of uncertainty to the economic outlook. According to many economists' models, the impact of $30 per barrel of oil (a high price, given current supply and demand conditions) is not very significant. Most economic forecasters have trimmed their original forecasts of real GNP by less than one-half a percentage point for 1990 and 1991. Similarly, future inflation rates were reestimated upward by about one-half a percentage point. Of course, if war breaks out in the Middle East or other circumstances drive the price of oil far above $30 per barrel, then in the words of many economists, "all bets are off."

There are many reasons why today's higher oil prices should not impact the economy as severely as did the oil shocks of 1974 and 1979, including the following:

- World oil inventories are relatively high.
- Some of the supply shortfall may be offset by other countries' pumping more oil—particularly Saudi Arabia, Mexico, and Venezuela.
- Stated as a percentage, the current oil-price increase is much less than in 1974 and 1979.
- OPEC economies now are much more geared toward importing goods from industrialized countries than in the 1970s. Thus, some of those petrodollars would be recirculated more quickly.
- Through efficiency gains, industrial economies use about 40 percent less energy per dollar of output than in 1979.
- The US economy was already experiencing accelerating inflation before the oil-price shocks of 1974 and 1979. By comparison, although inflation today is positive, it is not accelerating.

Unfortunately, economists' models do not perform very well in the presence of an "unexpected" geopolitical disturbance, particularly in the midst of one that continues to propagate copious amounts of uncertainty. Uncertainties in the Middle East contributed to a sharp drop in consumer confidence in August, according to data from the University of Michigan's Survey Research Center. When consumers lose confidence in the economy, they tend to postpone expenditure on big-ticket items such as vacations, food consumed away from home, apparel, and home electronics. This one-month plunge is not sufficient to conclude that a recession is imminent—it takes only two points to determine a line, but it takes several points to *estimate a trend*—but it certainly is a signal worth noting. This is especially true in view of the fact that we are entering the holiday buying season.

Similarly, D&B's business expectations survey provides an indicator of business confidence in the economy. When executives are confident about future business conditions, they tend to increase their companies' equipment investment spending. The D&B and University of Michigan surveys both point to an economy on the *cusp of recession*. In both cases, however, more data are needed to forecast more conclusively that a recession is imminent.

One distinguishing characteristic of the current situation is the wealth of the oil states and their willingness to underwrite some of the incremental costs of supporting US forces in the Middle East. President George Bush also is pressuring other oil-dependent allies such as the United Kingdom, France, Germany, and Japan to help foot the bill for these military operations. This financial support would, in effect, pump billions of dollars into the US economy through various categories of spending, such as for munitions, fuel for military support, wages for National Guard troops, and transportation services to ship large volumes of food and supplies thousands of miles.

LONG-TERM IMPLICATIONS

If the current standoff continues for any length of time, there will be other economic consequences. Increased military costs will hinder efforts to reduce the federal budget deficit. Increased expenditure for oil would add at least $25 billion in current dollars to the US trade deficit. Worldwide, increased expenditure and military energy will add to inflationary pressures, prompting interest rates to remain high or go higher still.

On the positive side, increased defense spending provides at least a temporary bailout of many defense-related industries. The volume of oil imports will be reduced, helping the trade deficit in real terms. Capital spending to develop domestic oil supplies will be modestly increased, partially reversing some of the 1986 declines in the oil patch regions caused by sub-$10-per-barrel oil. Consumers also will spend more for energy and energy conservation equipment. Although this type of spending will definitely "crowd out" purchases of other goods, overall consumer spending should decline only slightly.

POTENTIAL VERSUS ACTUAL ECONOMIC GROWTH

Although a near-term recession is possible, business planners cannot ignore their long-range responsibilities. In planning for the long term, an important concept of economic analysis is *potential* economic growth, which normally is viewed as the additional output that comes from an increasing labor force, plus the growth in productivity of this labor force. Thus, if the labor force grows 2 percent in a given year and productivity increases 1 percent, potential GNP increases by 3 percent. If actual GNP is less than potential GNP, then, by definition, unemployment is above its "natural" or equilibrium rate. When actual growth in actual GNP exceeds potential growth, unemployment is (temporarily) reduced below its natural rate, and inflation accelerates.

In recent years, the measurement of potential growth has been hampered by weakness in productivity measures, particularly in the services areas, and by some controversy about demographic trends in measuring the size of the labor force. Nevertheless, as seen in Table 1, potential GNP growth has been slowing markedly. In addition, the gap between potential and actual GNP has been narrowing.

The claim that the economy is operating near its full potential is confirmed in Figure 2, which shows recent unemployment and capacity utilization rates in the region of "full resource employment."

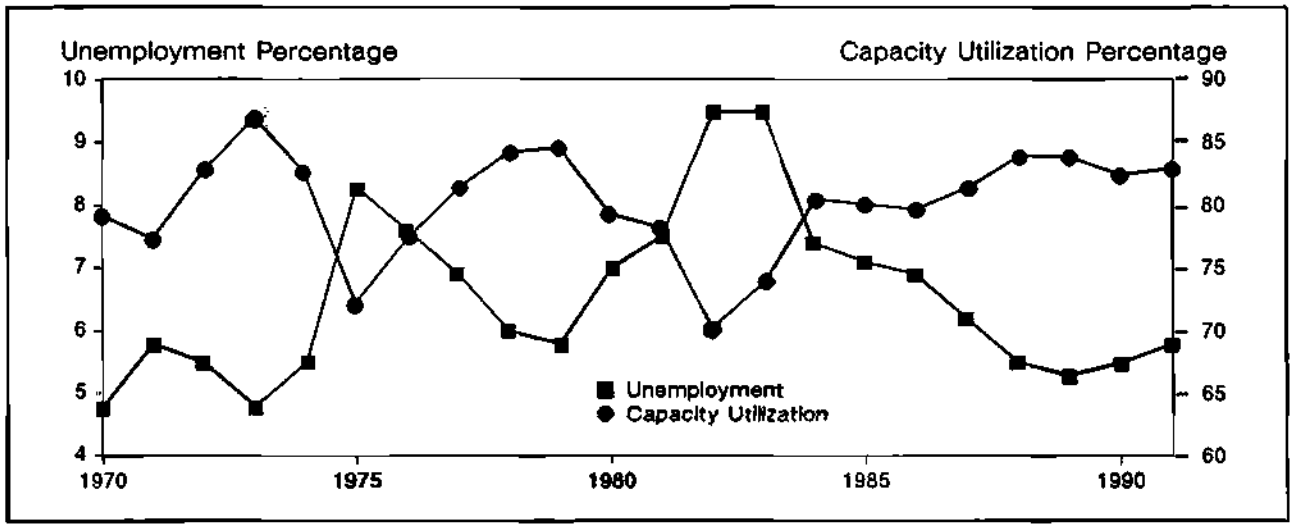
The Federal Reserve's policy of limiting demand to bring down the rate of inflation has been contributing to the recent slow rate of expansion. The approximately 1.5 percent rate of GNP growth during the first half of the year has been in line with the Fed's implicit goal for the current year.

TABLE 1
Potential versus Actual Real US GNP Growth

Year	Productivity (% Change)	Labor Force (% Change)	Potential GNP (% Change)	Actual GNP (% Change)	Unemployment Rate (%)
1986	2.1	2.1	4.2	2.7	6.9
1987	1.1	1.7	2.8	3.4	6.1
1988	2.1	1.5	3.6	4.5	5.4
1989	0.9	1.8	2.7	2.5	5.2
1990 (Est.)	0.5	1.1	1.6	1.0	5.5

Source: The Dun & Bradstreet Corporation

FIGURE 2
US Factor Utilization



Source: US Department of Commerce, US Department of Labor, The Dun & Bradstreet Corporation, Dataquest (October 1990)

The important point is that the current slow-growth period may last longer than is ordinarily implied by a purely cyclical downturn. Furthermore, for the past two years, much of the economic growth in the United States has been driven by external demand—that is, exports. Hence, a pickup of domestic demand could actually lead to an acceleration of inflation unless significant productivity gains can be made.

DATAQUEST CONCLUSIONS AND RECOMMENDATIONS

Dataquest believes that the chances of a recession are substantial, but this outcome still is not the odds-on favorite. The negative economic factors associated with the crisis in the Persian Gulf are probably not enough to cause a recession *at this stage of development*. The most significant risks associated with this disturbance are psychological. Steep declines in consumer and business sentiment can provoke a recession very quickly. Although declines in sentiment have indeed occurred as an immediate response to the Gulf crisis, we must wait to see if they move to the lower levels that typically are associated with pending recessions.

Whether we are in a recession or about to enter one is almost irrelevant. For many sectors, real declines have occurred and the strong growth of the recent years has disappeared, and it may be naive to blame these downturns on events in the Persian Gulf or an adverse turn in the business cycle. Potential GNP growth has fallen precipitously in the past few years as labor force and

productivity growth have decelerated. Labor force growth is influenced heavily by participation rates, whose growth will be hindered by adverse demographic factors in the coming years. In particular, the baby-boom generation's maturity will be only partially offset by young recruits to the labor force, which means that increases in potential economic growth will be most influenced by improvements in productivity. Without productivity gains, potential GNP growth may be only about 2.0 percent. So, the current 1.0 to 1.5 percent actual GNP growth may be almost as good as we can expect over the next few years.

For electronic systems and semiconductor manufacturers, there is a silver lining to this otherwise gloomy outlook. Some years ago, very large scale (semiconductor) integration ushered in a period of unprecedented growth in workplace productivity. Now, granted, past high-technology investment has raised the rate-of-return hurdle for future incremental additions to the capital stock. By the same token, however, the most-productive investments continue to come from technologies that rely increasingly on electronic systems and semiconductors. In an environment where economic growth is fueled primarily by productivity growth, high-technology businesses will have a distinct advantage over industries that offer relatively less-productive investment solutions.

Dataquest cautions its clients not to misconstrue this positive outlook to mean that doing business and making a profit in the future are going to become easier. Much of the most easily accessible opportunities have been taken: When was the last time you walked into a workplace where the information systems were not at least partially automated? As high technology matures, it will inevitably become more pervasive and generic. *Internationally competitive* manufacturers that deliver the most cost-effective and productive investment solutions will be the ones to come out intact and strong on the other side of the expected economic doldrums.

Terrance A. Birkholz

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Research Newsletter

DATAQUEST'S OUTLOOK FOR 1990 AND 1991: SLOWING BUT POSITIVE GROWTH

INTRODUCTION

Each year, in the third quarter, Dataquest reexamines its near-term forecasts. Additionally, a number of Dataquest industry services perform a midyear survey to verify predicted trends. This newsletter, which combines information from a variety of Dataquest services, presents a summary of our near-term industry forecasts and the results of our ongoing examination of major high-technology industries. We begin with an examination of the current US economic outlook, followed by an overview of semiconductors, business and technical computers, computer storage, electronic printers, display terminals, CAD/CAM/CAE, personal computer software, and telecommunications.

US ECONOMIC OUTLOOK, SEPTEMBER 1990: THE SKY IS NOT FALLING

GNP Economic Outlook

Contrary to popular belief, the sky is not falling; nor is it expected to do so anytime soon. That is, although the rate of real economic growth has been decelerating over the past several months, no recession is forecast. In the wake of Iraq's invasion of Kuwait, The Dun & Bradstreet Corporation (D&B) forecasts real gross national product (GNP) growth of 1.3 percent in 1990, down from 2.5 percent forecast for the year in April; 2.8 percent in 1991, down from 3.4 percent; and 2.9 percent in 1992, down from 3.0 percent.

The unemployment rate is at 5.6 percent, lower than this rate was for any year from 1974 to 1987. Factory capacity utilization is more than 83 percent, exceeded in only 6 of the past 20 years. These measurements reflect relatively tight labor and product markets; there is little slack in the economy. Recent slowing of economic growth is a result of the Fed's policy of limiting aggregate demand to lower the rate of inflation.

The rise in world oil prices is not likely to push the economy into recession. Indeed, if world oil prices—currently just over $30 per barrel (bbl)—settle at about $27 bbl during the next 12 months, which is a likely scenario, GNP would decrease by one-half of 1 percent. Similarly, should the recent oil price increase stick, this would slice, at the most, about one-half of 1 percentage point from economic growth.

Capital Spending

Spending that can be postponed (e.g., business capital investment and consumer durables expenditure) shows the greatest exposure to the recent slowdown in overall economic growth. Indeed, as of August, D&B's forecast of real growth of business equipment investment is 1.6 percent in 1990, down from 4.9 percent forecast in April; and 6.8 percent in 1991, down from 9.0 percent. Similarly, real growth of consumer durables expenditure has been revised down to 0.6 percent in 1990, from 2.8 percent in April; and to 1.1 percent in 1991, down from 3.4 percent. Note that real growth in these areas is forecast to remain positive. Almost without exception, real investment spending growth is negative during a recession. Not all investment spending will be postponed; projects that will be postponed are the marginal ones—that is, those projects that are not sufficiently profitable, given the expectation of slower real economic growth.

US Electronics Production and Economic Outlook

Capital spending on electronics equipment has not been immune to recent economic slowing.

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Indeed, for US electronics equipment as a whole, 3-month-ended-orders growth has shown a decelerating trend compared with earlier figures; from 10.3 percent in January 1990 down to 6.2 percent in July 1990. July 1990 12-month-ended- and year-to-date-shipments growth figures are in the 6 to 7 percent range.

THE SEMICONDUCTOR EQUIPMENT, MANUFACTURING, AND MATERIALS MARKET

Dataquest anticipates that a silicon wafer shortage will occur in the 1990 to 1991 time frame, with ramifications likely to last until 1992. An explanation for this occurrence is that few new capital investments were made in the area of silicon wafer manufacturing since 1985. One consequence of this material shortage is increased lead times to semiconductor manufacturers. Dataquest does not expect this material undersupply to affect the semiconductor market adversely; the market presently is oversupplied. Yet, such a shortage may influence the strategic alliances of wafer suppliers and semiconductor manufacturers, especially second-tier semiconductor manufacturers that have not yet built long-term relationships with material suppliers.

SEMICONDUCTOR DEVICES

The PC market represents the single largest microcomponent application for the microcomponent device market. So far, the year 1990 has been characterized by high demand for 386SX and 386DX processors. Recently, reports indicate that an oversupply of these processors may exist. Additionally, some PC logic chip set vendors are experiencing a slowdown in PC AT chip set demand, particularly for 286 AT products. Combined, these indicators point to a slowdown in microcomponent revenue in the fourth quarter of 1990, possibly carrying over into the first quarter of 1991.

In the logic device market, major ASIC players experienced strong bookings in the past months, whereas standard microcomponent products (i.e., PC chip sets and graphics controllers) encountered a soft, lackluster market. The weakness in the standard product market can be attributed to two factors: an increase in competition and a shift in demand. Dataquest expects the strong bookings for ASIC devices to carry forth into the first half of 1991, primarily because of the long lead times of these products.

Dataquest anticipates that the memory device market will have extremely competitive pricing for 1Mb, 4Mb, and 256K DRAMs for the balance of 1990. The sluggish demand for 4Mb devices stems from the lack of design-ins, a package-standard shift from 350 mil to 300 mil, and the resulting mismatch in supply and demand. Competitive pricing also will continue for 256K and 1Mb, as well as 16K, fast SRAMs. Stability is emerging in the 64K fast SRAM market as a result of Japanese-based suppliers de-emphasizing this device and the departure of key SRAM manufacturers from this market. Pricing for 256K SRAMs will be competitive.

For 1991, Dataquest expects to see a definite shift to the 4Mb DRAM from the 1Mb DRAM. The market crossover to the 4Mb DRAM is expected to occur when a four to one (4:1) ratio is achieved between the 4Mb and 1Mb devices. This move could occur in the first quarter; however, it is entirely dependent on the rate of price decline for the 1Mb. There is a chance of a shortage of slow SRAMs in 1991, specifically the 64K (8Kx8). Users have concerns regarding the capacity of 256K slow SRAMs; however, we do not project a lack of this product.

The analog, discrete, and optoelectronics device market experienced weaker than historical performance in 1989. This downward trend has been due to a slowdown in consumer markets, with such items as camcorders and CD players reaching a level of saturation and softness. Dataquest believes that this soft booking and soft average selling price (ASP) environment will continue through the end of 1990. In 1991, Dataquest anticipates that pricing will stabilize and put an end to the slide experienced in 1990. Furthermore, bookings should return to 1987 levels.

SEMICONDUCTOR CONSUMPTION

In the midterm, Dataquest anticipates that semiconductor consumers will take a more conservative attitude toward buying. These customers should not experience difficulties in purchasing semiconductor devices. Memory is no longer in short supply. We expect to see relatively stable lead times and good availability of semiconductor devices throughout the first half of 1991 and, most likely, the remainder of that year. According to Dataquest's September procurement survey, systems sales outlook for the next six months is expected to remain positive at approximately 4.1 percent. (August's growth rate was 5.0 percent.)

The order rate for semiconductors is expected to grow in September by 14.0 percent over August levels. The six-month availability outlook for semiconductors remains very good, and this is expected to continue throughout the first half of 1991.

THE BUSINESS AND TECHNICAL COMPUTER SYSTEMS MARKETS

The business and technical computer systems markets will continue to see growth throughout 1990 and 1991, though at a lower rate than originally forecast because of the current tight economic situation. We have revised our worldwide factory revenue forecast, excluding personal computers, for 1990 downward from a growth rate of 14.2 percent to 7.9 percent. For 1991, we are forecasting a growth rate of 10.7 percent.

Mainframes offer the biggest profit margins in the industry, and this segment is very mature. IBM's recent announcement of the System/390 will effectively stall the market while users assess purchasing plans. The mainframe market may see some movement late in 1991 and in 1992, when the true Summit systems will be available.

Midrange computer systems (which include minicomputers, superminicomputers, and microcomputers) represent about 44 percent of the total market. This segment is experiencing the most difficulty; many midrange vendors reported flat sales through the middle of this year. Many new technologies that compete with older, existing, shared-logic minicomputer technology are being introduced in the midrange segment and especially in the workstation segment. Vendors of traditional minicomputers selling proprietary systems will be facing exceedingly tough competition. The workstation segment will continue to be the fastest-growing segment over the next several years, reflecting the strong movement toward distributed computing. With growth rates for 1990 and 1991 projected at approximately 40 percent each year, workstations account for most of the growth in the computer systems markets.

THE COMPUTER STORAGE MARKET

This last spring, Dataquest estimated a 10 percent growth in worldwide factory revenue for the computer storage market during 1990. Unit shipments were forecast to grow by 18 percent, and ASPs were projected to decline by 8 percent. Preliminary results of our midyear surveys indicate that unit shipments during the first half of 1990 were close to Dataquest's expectations. Unit shipments for the year still are anticipated to grow by 16 to 18 percent.

The revenue outlook is in jeopardy. Dataquest believes that there is excess production capacity in the 3.5-inch hard drive segment of the storage industry (representing 30 percent of factory revenue). This segment appears to be heading for the same problems that 5.25-inch drive producers experienced two years ago (the same manufacturers, in a few cases). At midyear, a price war began in the 3.5-inch, 40MB drive market in retail distribution. At the same time, OEM prices for 3.5-inch drives over 100MB were falling.

The rest of the computer storage market is progressing along the forecast. In both the rigid and flexible disk drive segments, 5.25-inch drives are being replaced rapidly by 3.5-inch products. Demand in the tape drive market is stable. New applications for optical disk drives are creating growth in this segment of the market.

Demand for more and better storage capabilities continues to expand, technological advances in magnetic storage seem to be inexhaustible, and the cost per megabyte of storage is declining rapidly in newly announced storage devices. The need for additional storage capacity is endless, as are the dynamics of the industry.

THE ELECTRONIC PRINTER MARKET

At the Electronic Printer Industry Service spring conference, Dataquest projected the 1990 US electronic printer market growth to be 12 percent in units and 17 percent in factory revenue. Shipments for the first half of 1990 were essentially on track. However, the jury is still out on consumer and business spending during the fourth quarter. A soft fourth quarter (typically 30 percent of annual sales) could reduce the 1990 growth rates by at least 2 or 3 percentage points. Dataquest believes that vendors should take a cautious stance on the market outlook for the next three quarters.

Revenue growth in the electronic printer industry is greater than unit growth because of the continuing printer market trend—from lower-cost dot-matrix impact printers to state-of-the-art nonimpact page printers, which have higher unit prices. During the past few months, demand for 1- to 6-page-per-minute (ppm) printers has been less than expected. At the same time, 7- to 10-ppm printers are shipping much better than expected.

Dataquest believes that this shift in demand is primarily attributable to pent-up demand from PC users. New products in the 7- to 10-ppm segment offer new features, such as scalable fonts, which the PC world has been wanting for a long time.

As market demand changes, so does the structure of the supplier side of the industry. So far this year, to mention a few, the following changes occurred:

- IBM is in the process of selling its Lexington, Kentucky, plant (which includes its personal printers production).
- Hitachi Koki bought DataProducts (which is an expansion by acquisition, rather than by building plants in the United States as other companies have done).
- Siemens divested part of its printer business (below 20 ppm).

Look for many more new and exciting product announcements this fall and next year. User demands for better printing capabilities are increasing, which is continuing to change the structure of the electronic printer industry.

THE DISPLAY TERMINAL MARKET

Dataquest has completed its midyear 1990 census. North American display terminal unit shipments decreased 3.7 percent from the like period in 1989 and were 3.1 percent below forecast. This market continues to grow in Western Europe, especially in preparation for Europe 1992. Higher sales are expected in Europe in 1991 and 1992.

IBM midrange terminals are on schedule, while the 3270 market has slowed in anticipation of IBM's Summit announcement. Processing terminals are the single largest growth segment, with first-half 1990 sales up 45.9 percent over first-half 1989 and 12.7 percent over forecast. Dataquest believes that shipments of processing terminals will increase 77.4 percent worldwide in 1991.

Overall, alphanumeric terminals suffer from a lack of standards—especially for windowing, application program interfaces, and user interfaces. Agreement on standards in these areas would foster further growth among independent alphanumeric terminal vendors.

THE CAD/CAM/CAE MARKET

The CAD/CAM/CAE market produced $12 billion in factory revenue in 1989 and is forecast to grow approximately $2 billion a year for the next few years. Some of the forecast growth for 1990 has not materialized yet, due primarily to product transitions in the electronic design market (EDA). The EDA market is predicted to have a strong fourth quarter as a result of updated products entering the market. If these products do not materialize, some of the projected revenue for 1990 for the CAD/CAM/CAE market will shift into 1991.

The Mideast crisis also is expected to cause slower capital spending for CAD/CAM/CAE equipment, as well as to have a slight dampening effect on the market. Design automation is dependent to some extent on US defense funding. The US federal government may curtail design of new defense execution requirements—which would result in fewer CAD-system buys by both the federal government and the aerospace industry.

The major issues facing vendors in 1991 will be distribution channels, open systems, and standards. Developing a successful distribution strategy is the most challenging of these issues, in that today's CAD dealer channel is inadequate for a robust distribution channel. Typical profit margins for CAD dealers are too low or uncertain to attract top-quality business people for sales, or even management, positions. There are far more good products than there are high-caliber people to sell and support them.

THE PERSONAL COMPUTER SOFTWARE MARKET

Dataquest estimates that personal computer software shipments reached $4.4 billion in worldwide factory revenue in 1989; these are projected to grow by an estimated 11 percent in 1990 and 13.5 percent in 1991. Growth in the 1990 to 1991 time frame will be driven largely by users buying software for new systems and upgrading older versions of their current software. These upgrades will increase as new technologies become more commercially viable. Dataquest expects Windows 3.0 to help drive PC software sales over the next few years because users want to move from character-based to graphical-based interfaces.

Sales of Macintosh software may exceed our previous 1991 projections. (Dataquest projected that Macintosh software would remain at about 12 percent of the total PC software market, based on factory revenue.) The lack of low-cost Macintosh products has restricted the growth of Macintosh systems. If the price of the new low-cost

Macintosh (to be introduced later this year) is in line with what has been reported in the trade press, Dataquest expects the new Macintosh products to compete successfully with low-end PCs.

Word processing, spreadsheet, accounting, and database management systems software will continue to be the major segments of the PC software market, based on factory revenue. Dataquest estimates that these four segments will account for over 50 percent of the total market in 1990 and 1991 and will continue to dominate the market through the mid-1990s.

THE TELECOMMUNICATIONS MARKET

In general, the worldwide telecommunications market is expected to increase by 6.7 percent in 1991 in terms of end-user revenue, with a 7.7 percent compound annual growth rate (CAGR) through 1994. This growth rate is driven primarily by the dominating influence of telecommunications services: local and long distance telephone calls. Excluding this revenue derived from network services, the growth in equipment-related revenue is expected to increase to a 10.1 percent CAGR through 1994. This equipment-related growth is expected to be fueled primarily by growth in the Asia/Pacific (including Japan), Eastern Europe, and rest of world (ROW) regions. Neither the US nor Western European forecasts match the robust growth rates of the other regions.

Overall, the US telecommunications market is expected to increase 4.9 percent in 1991, with a CAGR of 5.2 percent through 1994. Viewing the US telecommunications markets in aggregate, the fastest-growing markets are expected to be cellular mobile radio services, DSUs/CSUs, local area networks (LANs), and satellite earth stations. Network services, the dominating revenue producer, is expected to continue growing at a rather consistent 4.9 percent CAGR. On the downside, modems, statistical multiplexers, and data PBX systems continue to experience declining revenue in the United States, largely because of the advent of replacement technologies, market "commoditization," and market saturation.

The Western European telecommunications market still is expected to perform better than the US market—with a 5 percent increase expected in 1991 and a strong 8.4 percent CAGR forecast through 1994. Viewing all Western European markets across-the-board, the fastest-growing markets are expected to be voice messaging, video teleconferencing, LAN, private packet data switching, cellular telephone, and network management systems. As in the United States, statistical multiplexers and data PBXs are in the declining stages of their product life cycles.

Issues and trends in telecommunications for the 1990s include the following:

- Potential for further deregulation of RBOCs, such as easing of restrictions on manufacturing and information processing activities
- Telecommunications industry migration from being engineering-driven to being market-driven
- Increases in wireless portable communications equipment, such as cellular telephones
- Emerging social acceptance of the "home office" and the need for communications capabilities to make it possible
- Increasing connectivity between computers and telecommunications equipment.

Nancy Stewart
Gene Norrett

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Research Newsletter

TECHNOLOGY STOCKS FALL TO BARGAIN BASEMENT LEVELS—SO WHAT?

*Sic transit gloria mundi.**
—Thomas à Kempis, 1420

DATAQUEST PERSPECTIVE

Stocks are down. Way down. Not since 1974 have technology stocks reached such depressed levels. This decline has important implications for the entire technology community.

Table 1 provides revenue, profit, and stock data for an arbitrary selection of US technology companies for August 23, 1990. This table provides information on companies of various industries, large and small, old and new, and gives a representative sample of some better known technology stocks.

Clearly, stocks have taken a beating, with most falling dramatically from their 52-week highs. Most of these stocks peaked during the summer. For example, two months ago, on Friday June 22, the *Wall Street Journal's* "Heard on the Street" headline was: "Pros Put Chips on Extended Run-Up in Semiconductors." On this date, Motorola hit its high for the year. In the ensuing weeks, share prices have tumbled.

Why? A confluence of several factors has caused Wall Street to lose confidence in technology companies:

- Concern over the general business environment including competition, especially foreign, and the ability of companies to deal with rapidly changing markets and falling prices
- Disappointing profits and profit outlook for companies (Margins are skinny.)
- Unpleasant surprises in second-quarter reports including several major companies such as Businessland, Digital Equipment, and Texas Instruments
- Concerns over recession and its effect on cyclical stocks
- The Mideast crisis and the perceived certainty of negative economic effects

Although the Dow Jones average has fallen about 16 percent from its high, technology stocks have fallen 30 to 50 percent, more or less. Companies with problems have been hammered—N.E.T. from 34.375 to 6.0, Businessland from 11.0 to 2.5, Oracle from 28.374 to 12.75, Adaptec from 24.0 to 11.25, Conner Peripherals from 31.0 to 20.75.

Companies with good earnings now have low P/E ratios—Chips & Technologies at 6, for example. Companies with low earnings have low market capitalization—for example, Texas Instruments at 36 percent. Many companies, such as Seagate, are priced below book value. Across the board, these low values for high-tech stocks are unprecedented.

IMPLICATIONS

It is not likely that this debacle will be reversed rapidly. Once burned, investors will be twice shy. Technology companies must adjust to the long-term consequences:

- Liquidity difficulties
- Increased acquisition and licensing activity
- Opportunity

*How swiftly pass the glories of the world.

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TABLE 1
Technology Company
Financial Data and Stock Price

Company	Fiscal Year 1989 Revenue ($M)	Latest Revenue Second Quarter 1990 ($M)	Latest Profit Second Quarter 1990 ($M)	8/23/90 Stock Price ($)	Stock Price 12-Month High ($)	Number of Shares (Millions)	Market Capitalization ($M)	Market Capitalization as Percent of Revenue (Latest Quarter)	P/E Ratio (Latest Quarter)	Stock Price Percent Decline
Advanced Micro Devices Incorporated	1,105	268	(5.92)	5.500	11.375	82.10	452	42	-	52
Apple Computer Incorporated	5,284	1,365	119.76	33.750	45.625	129.00	4,354	80	9.09	26
Applied Materials Incorporated	502	144	10.46	26.750	40.500	16.80	449	78	10.74	34
American Telephone & Telegraph Company	35,210	9,025	657.00	31.500	47.000	1,075.00	33,863	94	12.89	33
Chips & Technologies, Incorporated	218	82	6.29	10.375	25.500	15.28	159	48	6.30	59
Compaq Computer Corporation	2,876	862	104.28	45.250	67.875	39.40	1,783	52	4.27	33
Conner Peripherals Incorporated	705	304	26.65	20.750	31.000	45.50	944	78	8.86	33
Cypress Semiconductor Corporation	199	54	8.51	9.750	15.625	38.30	373	173	10.97	38
Digital Equipment Corporation	12,742	3,365	74.39	63.000	103.375	122.00	7,686	57	25.83	39
Hewlett-Packard Company	11,899	3,242	178.00	32.750	53.125	238.00	7,795	60	10.95	38
International Business Machines	62,710	16,495	1,410.00	97.250	123.125	581.10	56,512	86	10.02	21

(Continued)

TABLE 1 (Continued)
Technology Company
Financial Data and Stock Price

Company	Fiscal Year 1989 Revenue ($M)	Latest Revenue Second Quarter 1990 ($M)	Latest Profit Second Quarter 1990 ($M)	8/23/90 Stock Price ($)	Stock Price 12-Month High ($)	Number of Shares (Millions)	Market Capitalization ($M)	Market Capitalization as Percent of Revenue (Latest Quarter)	P/E Ratio (Latest Quarter)	Stock Price Percent Decline
Integrated Device Technology Incorporated	181	49	0.26	4.125	10.875	25.50	105	54	101.14	62
Intergraph Corporation	860	254	16.55	14.000	23.500	53.90	755	74	11.40	40
Intel Corporation	3,127	968	170.69	32.500	52.000	188.80	6,136	158	8.99	38
Lotus Development Corporation	556	175	23.46	17.000	39.250	42.39	721	103	7.68	57
LSI Logic Corporation	547	160	6.20	8.375	13.000	41.10	344	54	13.88	36
Mentor Graphics Corporation	380	101	3.65	12.250	26.000	36.90	452	112	30.96	53
Micron Technology Incorporated	446	84	1.81	7.750	16.375	36.70	284	85	39.29	53
Motorola Incorporated	9,620	2,715	161.00	65.375	88.375	130.00	8,499	78	13.20	26
Octel Communications Corporation	87	36	4.94	17.250	27.750	15.20	262	181	13.27	38
Oracle Corporation	971	334	52.96	12.750	28.375	136.8	1,744	130	8.23	55
Quantum Corporation	446	163	17.34	14.500	25.750	27.59	400	61	5.77	44
Seagate Technology, Incorporated	2,413	668	29.69	9.125	19.750	51.78	472	18	3.98	54
Silicon Graphics Incorporated	264	120	11.20	24.000	40.875	17.20	413	86	9.21	41

(Continued)

TABLE 1 (Continued)
Technology Company
Financial Data and Stock Price

Company	Fiscal Year 1989 Revenue ($M)	Latest Revenue Second Quarter 1990 ($M)	Latest Profit Second Quarter 1990 ($M)	8/23/90 Stock Price ($)	Stock Price 12-Month High ($)	Number of Shares (Millions)	Market Capitalization ($M)	Market Capitalization as Percent of Revenue (Latest Quarter)	P/E Ratio (Latest Quarter)	Stock Price Percent Decline
Silicon Valley Group Incorporated	131	47	0.43	6.625	13.750	10.20	68	36	39.29	52
Sun Microsystems Incorporated	1,765	700	49.10	26.000	37.125	85.20	2,215	79	11.28	30
Tandem Computers Incorporated	1,633	472	32.44	13.875	30.125	101.40	1,407	75	10.84	54
Texas Instruments Incorporated	6,522	1,592	11.00	26.750	44.000	84.9	2,271	36	51.62	39
VLSI Technology Incorporated	289	85	2.40	5.625	12.250	23.80	134	40	13.95	54
Varian Associates, Incorporated	1,344	344	(34.10)	28.750	34.750	19.90	572	42	-	17
Western Digital Corporation	992	294	9.48	9.250	14.875	29.10	269	23	7.10	38
Xerox Corporation	16,441	4,255	(254.00)	39.000	68.500	101.70	3,966	23	-	43

Source: Dataquest (September 1990)

Lack of Liquidity

Already, the decline in public stocks has led to the cancellation of IPOs. Clearly, current prices are not prices that companies want to, or can, take back to the market; it is likely that Sun, for example, will cancel its intended offering. Exacerbating the problem, the newly conservative banking industry is steering clear of (perceived) risky high-tech companies. This movement is already in evidence in the Northeast.

Capital will be increasingly scarce and conservation of capital must become a priority for most companies. Reminiscent of Peter Drucker's advice, "Sell the mailroom!", more and more nonessential or noncritical activities will be farmed out, especially those that are capital intensive—such as wafer fabs and MIS departments. More nonstrategic business units will be sold.

Companies that are not public, and some that are, will look more actively at non-market-financing alternatives including selling part or all of the companies. Entrepreneurs will think twice about wanting to be a public company. On the other side of the coin, low share prices make LBOs increasingly attractive. Going private could be a trend of the 1990s. Cash will be king.

Acquisitions

Loss of liquidity reduces the options of companies, and low share prices definitely will induce salivation among corporate predators. A large percentage of companies are priced significantly below key takeover benchmarks—such as one times revenue. Both seller and buyer activity is sure to increase. For those companies that view this activity as unwholesome, defense mechanisms will be studied and installed.

In the United States, cultural reluctance toward acquisitions is nonexistent. Friendly and unfriendly acquisition by corporate and financial interests inevitably will rise.

Will low share prices create a fire sale to foreign interests? Because foreign stock markets were hit hard and because foreign companies generally are reticent to indulge in international cross-cultural acquisitions of a predatory (unfriendly) nature, a fire sale to Asian interests is unlikely. Buyouts of this nature will be the exception rather than the rule; nevertheless, some activity is bound to occur. On the other hand, lack of domestic liquidity historically has sent companies abroad for financing—such as Amdahl—and this will happen again: More technology and ownership will go abroad.

Lack of financing alternatives will encourage companies to sell parts or pieces of themselves, or to license or sell technology at more attractive prices. Participation in these activities may be more attractive to foreign establishments.

Opportunity

Established companies—i.e., those with cash or a high stock price—will see ample opportunity for acquisitions of technology or other beneficial strategic arrangements with other companies. Indeed, we think that an effect of the stock slide will be to bring, by necessity, the US high-tech community closer as interests, assets, and technology are traded for mutual advantage.

Companies that have the lowest (perceived) stock prices relative to value can take heart. Now is the time to move with alacrity and rewrite stock options—a onetime chance to secure and lock in exceptional talent.

Some companies will take advantage of low share prices and below book values to buy back their own stock. Intel already announced its intention to do this, and other companies are sure to follow.

Bernadette Cesena
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Research Newsletter

THE BUSINESS CYCLE: A THING OF THE PAST?

SUMMARY

Dataquest expects the US economy to grow at a compound average growth rate (CAGR) of 3 percent per year from 1990 through 1992. No recession is expected. This newsletter identifies and discusses some of the structural changes to the economy and other variables that contribute to this "no recession" outlook. Although the business cycle has not been eliminated, there is good reason to believe that, at least in the short term, the likelihood of recession—and its accompanying severity—has lessened. The economy's smooth expansion path minimizes the level of macroeconomic "background noise" or uncertainty and thus provides high-technology companies with a relatively hospitable environment to sharpen their company-specific competitive skills.

INTRODUCTION

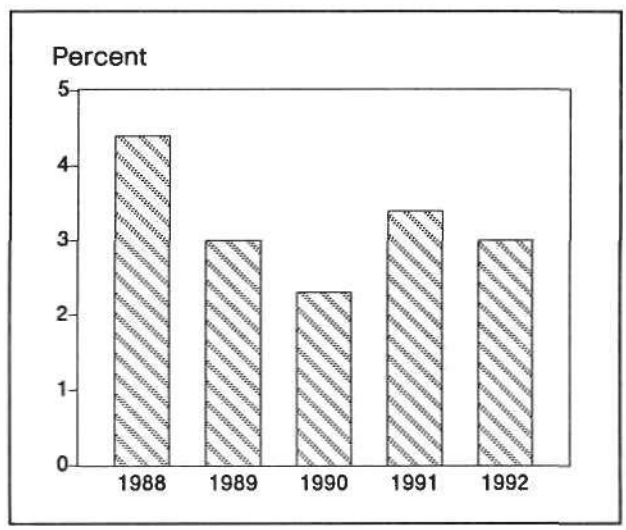
The US economy has been expanding for over seven years. Although it is still shy of the 106-month expansion of 1961 to 1969 during the Vietnam war, it is nonetheless *the longest peacetime expansion on record.* Indeed, excluding the Vietnam-war period, the average duration of the past six US economic expansions has been only 35 months before the economy began to contract. Pessimists fear that the next recession also will be longer and deeper; optimists argue that the business cycle is a thing of the past.

If the latest economic forecast by The Dun & Bradstreet Corporation (Dataquest's corporate parent) turns out to be correct, then the current US expansion has some way to go: D&B forecasts real US GNP growth to average 3.0 percent per year through 1992. As shown in Figure 1, real growth is expected to decelerate to 2.3 percent in 1990, down from 3.0 percent in 1989; to accelerate to 3.4 percent in 1991; and to stabilize at 3.0 percent in 1992. (Except for 0.2 percentage point reduction in 1990 growth, and the addition of the 1992 data point, this forecast is the same as published in last quarter's newsletter entitled *Economic Outlook: In Like a Lamb, Out Like a Lion.* Nothing about the outlook has changed sufficiently to justify further revision at this time.)

But just because the economy avoids outright recession (defined as two or more quarters of negative real growth), it does not mean that the concept of the business cycle is dead. These days, however, a downturn does not have to be a full-blown recession with a contraction in the *level of output;* it might instead take the form of a period of deceleration in the rate of output *growth.*

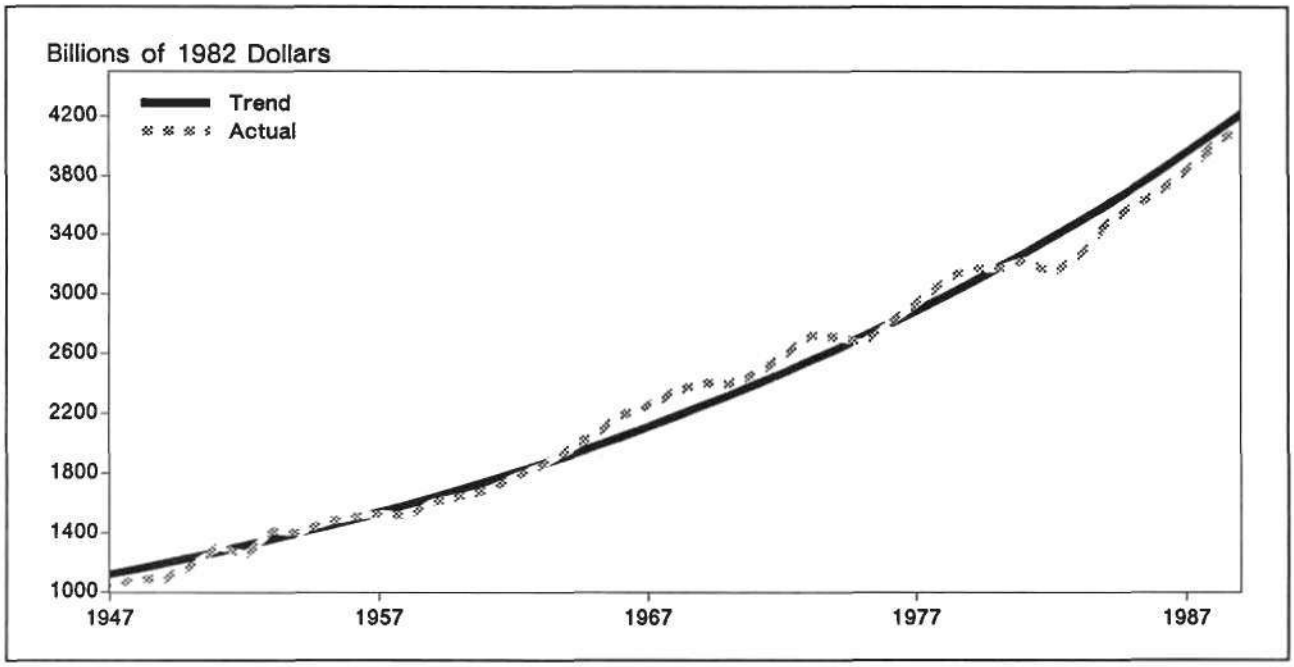
It turns out that the post-World War II period exhibits milder business fluctuations than the pre-World War II period. Figures 2, 3, and 4 show the

FIGURE 1
US Real GNP Growth
Annual Percent Change



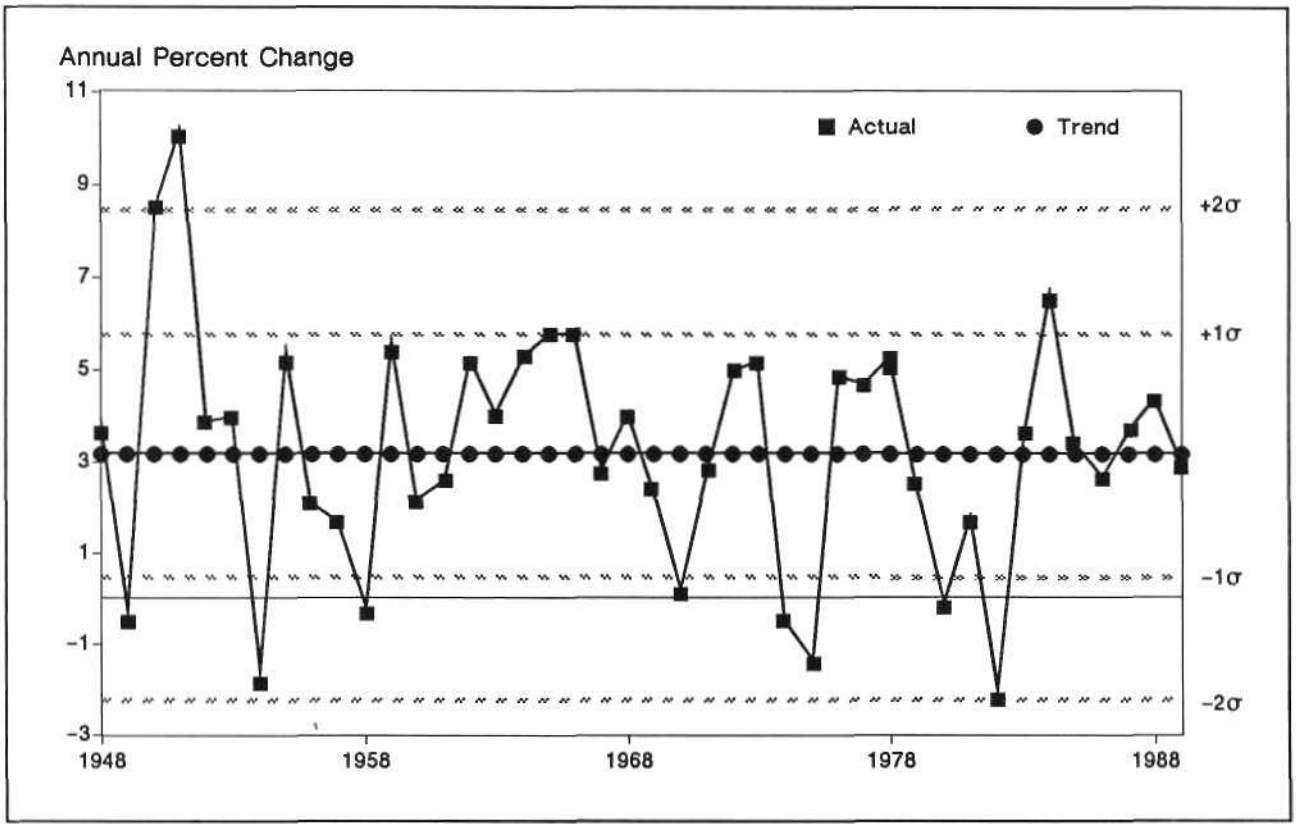
Source: US Department of Commerce, The Dun & Bradstreet Corporation

FIGURE 2
US Real Gross National Product



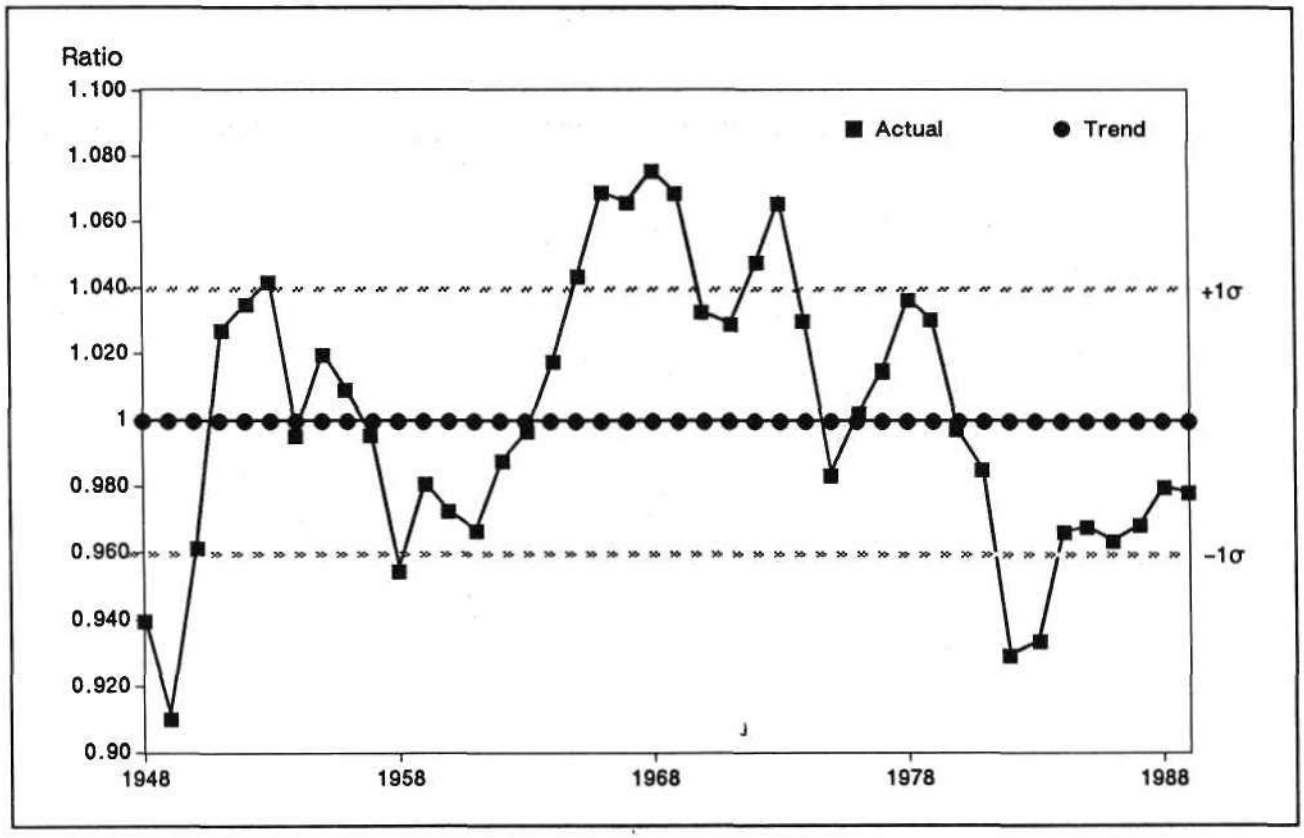
Source: US Department of Commerce, Dataquest (July 1990)

FIGURE 3
US Real Gross National Product—Annual Percent Change



Source: US Department of Commerce, Dataquest (July 1990)

FIGURE 4
US Real Gross National Product—Ratio of Actual to Trend



Source: US Department of Commerce, Dataquest (July 1990)

actual and trend growth paths of US real GNP; the actual and trend *growth rates*, including the ±1, ±2 standard-deviation bands; and the ratio of the actual level of real GNP to its trend level, including the ±1 standard-deviation bands, respectively, through 1989. Current research suggests that the *length* or period of the business cycle has not changed, but that expansions have become longer, contractions shorter, and the amplitude dampened.

THE ECONOMY'S EVOLUTION TOWARD INCREASED STABILITY

Economists and others have come up with numerous and sometimes humorous theories to explain business fluctuations. They range from the mundane (e.g., the interaction of consumption and investment) to the insane (e.g., the sunspot cycle) to the prevailing (i.e., incomplete information regarding money-supply growth, and supply- and demand-side shocks to the economy). Does the dampening of business fluctuations have something to do with the depletion of the ozone layer, harmonic convergence, and the clear-cutting of old-growth stands of redwood trees? Perhaps, but Dataquest looks at some of the more likely reasons that economic activity is now less volatile.

The Shift in Output to Services

The demand for most services is significantly less sensitive to changes in output than the demand for consumer durables and investment goods. The reason is partly because services, unlike goods, cannot be stored as easily. Also, most services are less capital-intensive, and business' capital spending on marginal investment projects tend to be the first item cut when the outlook changes for the worse. As shown in Figure 5, US services' (broadly defined as wholesale and retail trade; fire, insurance, and real estate; and other services) share of output has jumped from 36.1 percent in 1947 to 47.9 percent in 1987. Services' share of total employment has similarly increased. Interestingly, and contrary to popular belief, manufacturing's

share of output actually has increased 0.8 percentage points during the past 40 years, from 21.2 percent in 1947 to 22.0 percent in 1987. During the same interval, the primary (i.e., agriculture, forestry, and fisheries; mining; and construction) sector's share of output has declined 8.5 percentage points, from 18.7 percent in 1947 to 10.2 percent in 1987.

Increased Government Spending

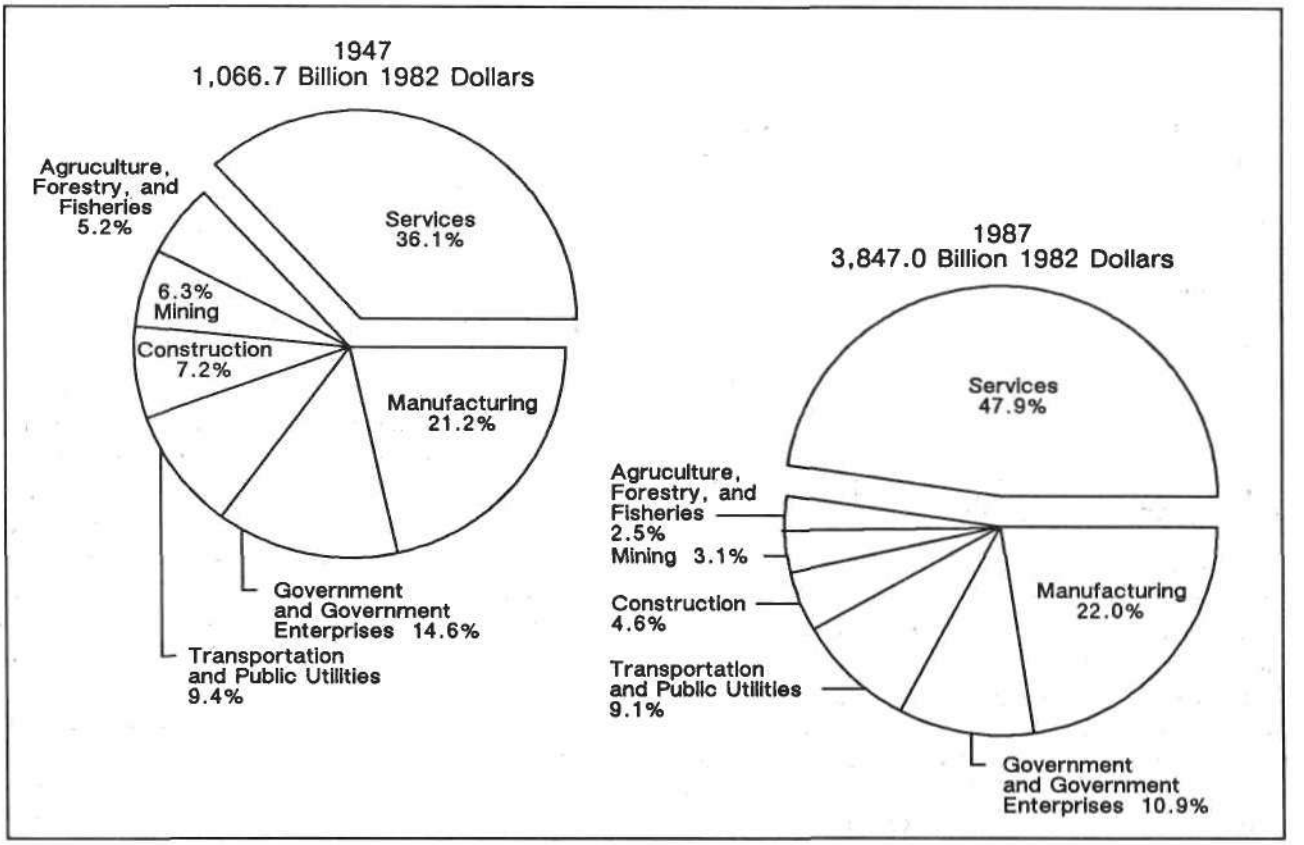
Figure 6 shows that federal, state, and local government spending on goods and services as a share of total domestic expenditure on goods and services has increased from 13.4 percent in 1929 to 17.6 percent in 1947 and to 19.2 percent in 1989. The surge in government spending has had a dampening effect because the public sector does not shrink during contractions. (In fact, the ratio of government expenditure to total expenditure tends to be countercyclical with respect to the business cycle.) "Automatic stabilizers" also have played a bigger role. Taxes automatically shrink and unemployment benefits rise as the economy goes into recession, which helps buoy household income.

Incidentally, if we compare the increasing trend in government spending with the decreasing trend in government's share of total output (see Figure 5), does this confirm our suspicions that *the US taxpayer is paying more and getting less?*

Improved Inventory Control

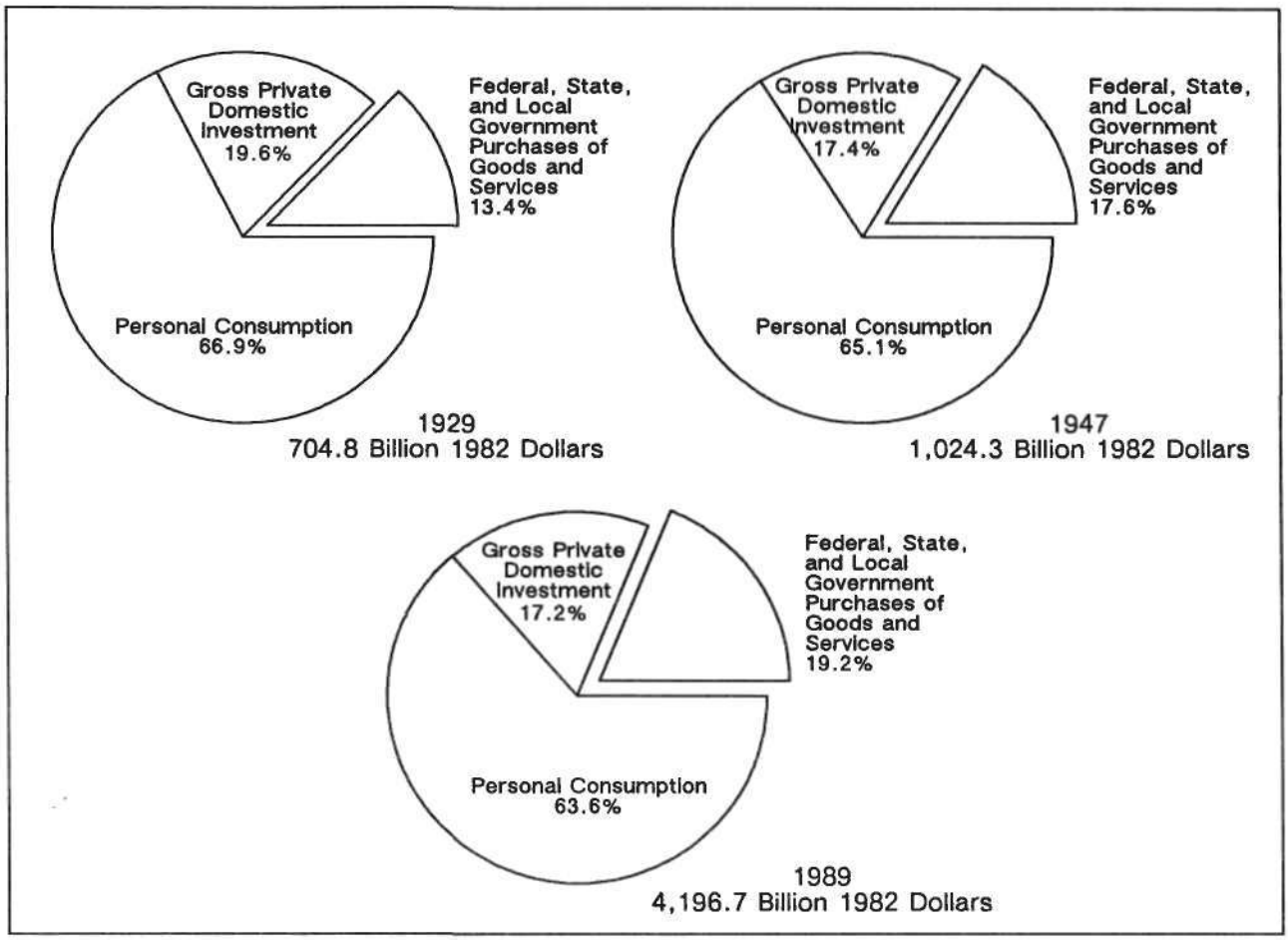
Computers and point-of-sale terminals now give manufacturers and retailers real-time information, allowing them to match production more closely to orders and therefore avoid an undesired accumulation of inventory. In the past, undesired inventory would accumulate rapidly as demand slowed unexpectedly, forcing companies to close factories and lay off employees, thus working actual inventories down to desired levels. Such inventory management often turned a relatively innocuous soft landing into a dramatic recession. For example, the decline in business inventories in

FIGURE 5
US Real GNP by Industry



Source: US Department of Commerce

FIGURE 6
US Expenditure, Goods and Services



Source: US Department of Commerce

1982 accounted for 41.0 percent of the decrease in total US domestic purchases, while personal consumption expenditure continued to expand at a 1.3 percent rate.

Financial Reform and Innovation

Some of the worst prewar recessions were exacerbated by financial collapses and consequent shrinkages in the money supply. Today, prompt intervention and cooperation by central banks can (sometimes) avert such panics. For example, the collapse of the New York Stock Exchange in October 1987 barely sent a discernible ripple through the real economy.

MORE FACTORS PROLONGING THE EXPANSION

These four changes in the economy's structure are likely to continue to dampen the business cycle in the future, warding off a "coming crash" that some members of the financial press are prognosticating. But other variables, which could yet be reversed, also have contributed to the prolongation of the current expansion.

Lower Inflation

Previous expansions typically were extinguished by accelerating inflation, which forced the Federal Reserve Bank (Fed) to cut money-supply growth. The unexpected change in monetary policy caught producers, consumers, lenders, and borrowers by surprise, with the result that the economy slipped into recession. That is why eternal vigilance on inflation is the best way to prolong expansion.

In Washington, D.C., for instance, the White House is leaning on the Fed to ease up on its fight against inflation by relaxing money-supply growth. Moreover, the Fed is concerned about the extent of

corporate debt, the savings and loan collapse, and the (supposed) fragility of the domestic financial system. The result is a reluctance to restrain money growth and raise short-term interest rates. Gradual acceleration in the inflation rate, with the customary crunch to follow, is not wholly implausible, although it is improbable at this time.

Soft Oil Prices

The collapse in world oil prices in 1986 could not have been better timed: It helped give a much-needed boost to growth just as the US and Japanese economies had begun to slow. Doomsayers still fret about a renewed surge in oil and other commodity prices. Indeed, with the recent escalation of Middle East tensions, such a scenario, while perhaps improbable, is, again, by no means implausible.

ASYNCHRONOUS ECONOMIES

Perhaps the most important reason why a worldwide recession can be avoided in the near term is that the United States', Japan's, and West Germany's economies currently are less synchronized with one another than during the past 20 years. In the 1970s, these countries' business cycles were closely aligned; they expanded and contracted in unison. Today, the lack of synchronization is reflected in the relatively large external imbalances between these big three economies. During the expansion of the 1980s, the United States was the world economy's engine, driving Japan's and West Germany's export-led growth. Today, domestic demand is sluggish in the United States and the United Kingdom, but it remains buoyant in Japan and West Germany. Indeed, West Germany's—and the rest of the developed world's—expected investment in East Germany could enhance the current worldwide expansion beyond the bounds that otherwise would be realized in the absence of Germany's reunification.

The rising trend in foreign demand for American exports should help forestall a recession in the United States. At the same time, the shrinking trade surpluses of Japan and West Germany as they meet more of the rise in domestic demand with imports should help keep US inflation at bay.

IT'S NOT PARTY TIME YET

It's not time to roll out the barrel just yet; clear heads are still needed. Although some important characteristics of the business cycle appear to have changed for the better recently, it would be erroneous to conclude that the business cycle is a thing of the past. However, based on the evidence presented, it is fair to conclude that the world has entered a period in which the *probability* of a recession in the near term, and its attendant severity, has diminished.

Perhaps the biggest risk to the expansion (and the most difficult to quantify) is an unexpected external shock—a sudden trade war, an unexpected and growth-diminishing change in fiscal policy, oil price rise, debt default, some far-reaching political event, a natural disaster in a major international trade center, etc. Prior to the trebling and doubling of world oil prices in 1973 and 1979, respectively, most forecasters looked forward to continued uninterrupted growth. However, what really happened was that the US economy proceeded to slide into two of its severest and protracted recessions of the postwar period.

IMPLICATIONS FOR HIGH-TECHNOLOGY

In view of the fact that the macroeconomic forecast remains unchanged from the previous quarter—and furthermore, does not call for a recession through 1992—the implications of the outlook for high-technology business also remain unchanged. In fact, the implications, listed as follows, bear repeating from last quarter's *Economic Outlook*:

- In the current and expected near-term future economic environment, Dataquest maintains that company- and/or industry-specific variables such as technology and factor-input prices will play a more important role in influencing high-technology company performance than economic aggregates such as national income, employment, inflation, and interest rates.
- This should not be interpreted to mean that company and industry performance is completely invariant with respect to overall economic activity. High-tech business is a capital-intensive business in the business of selling capital goods. Obviously, there is a direct relationship between aggregate investment spending and high-tech business conditions. The short-run relationship between the aggregate economy and high-tech company and industry performance is, however, relatively "loose" and more variable when compared with other industries. In the long run, these aggregate variables—and others such as the quality of the labor force, fiscal policy, regulatory environment, and tax incentives (or disincentives)—contribute greatly to a high-tech company's or industry's international competitiveness.

- The economy's relatively smooth near-term expansion path should minimize the background noise or uncertainty usually associated with doing business.

Dataquest is the last to deny that competing in the electronics business these days is easy. We admit that the going is tough, either because of a heightened level of *honest* international competition, or a (sometimes correctly) perceived presence of unfair trade practices. But it is a new era and this is the way the world *is*. In this context, subjective value judgments about how the world *ought to be* are irrelevant.

Executives and managers face a myriad of variables that influence their company's performance, ranging from those that management controls directly to those that must be taken as given. Trying to change things that are beyond a company's control is misguided management and wastes effort and resources.

Dataquest advises its clients to take this opportunity during the lull between the inevitable macroeconomic storms to be diligent in sharpening their competitive edge. Companies need (sic, must) focus on the specific variables *they control*, which will contribute most to future competitiveness, profitability, and growth. As tough as it is to compete these days, it is easier to run a business in an expanding economy than in one that is declining.

Terrance A. Birkholz

Dataquest
a company of
The Dun & Bradstreet Corporation

Research Newsletter

DATAQUEST'S 1990 ELECTRONICS INDUSTRY FORECAST

INTRODUCTION

Every year, Dataquest surveys both vendors and users in most major high-technology industries to collect market share and market-sizing data. This newsletter presents a summary of our industry forecasts and is designed to provide an overview of the sizing, trends, and events shaping each industry. Unless otherwise noted, all data are given in terms of factory revenue. Japan is included in the Asia/Pacific region, and totals may not add correctly because of rounding.

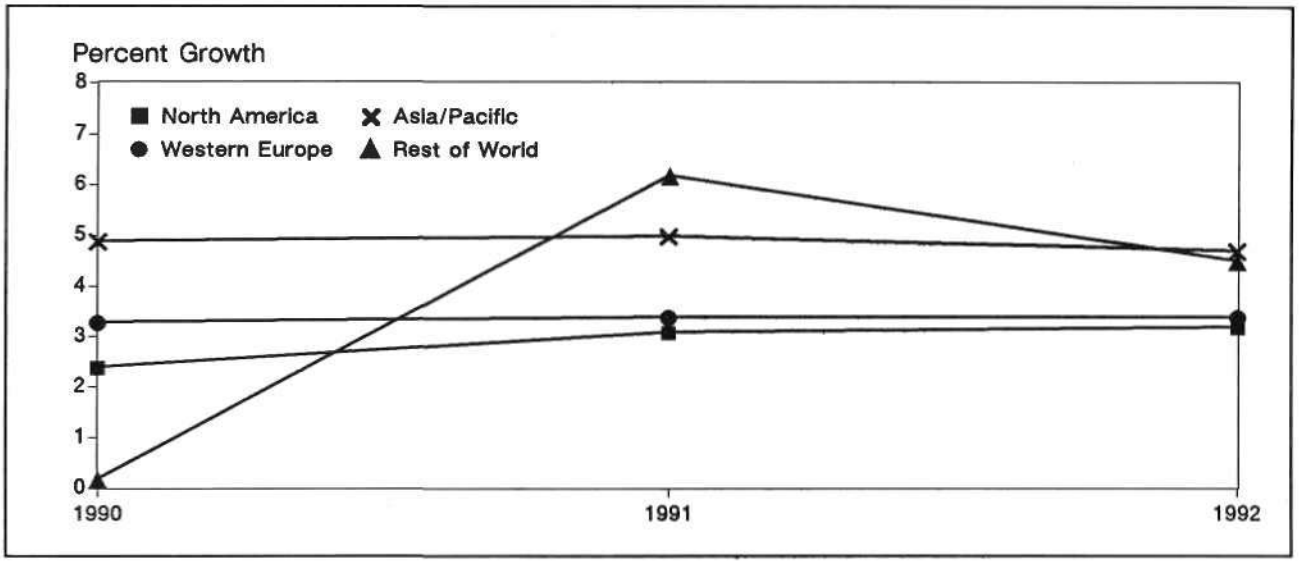
ECONOMIC OVERVIEW

During the late 1980s and throughout the first quarter of 1990, many structural changes took place in the international economy that guarantees that this decade will be as difficult to forecast as the last one. Nevertheless, we believe that the global economy, as compared with that of any one domestic sector, will be the economic catalyst for growth of high-technology markets in the 1990s. Figure 1 shows our economic projections for the four major regions of the world.

Highlights that will fuel future growth include the following:

- North America—The US-Canadian Free Trade agreement will reduce tariffs on most goods, while the Brady plan will assist the development of Latin American countries, thereby creating demand for products and services.
- Asia/Pacific—In the 1980s, Japan's growth propelled its economy to third place worldwide (behind the United States and the Soviet Union). We expect the "Four Tigers" (Taiwan, South Korea, Singapore, and Hong Kong) to enjoy similar rapid growth in the 1990s.

FIGURE 1
Real Gross Domestic Product



Source: The Dun & Bradstreet Corporation, Dataquest (July 1990)

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- Europe—The majority of the 1992 initiatives will become reality, thereby creating a unified market. Furthermore, the most significant of recent events is the raising of the Iron Curtain in Eastern Europe, which in itself opens up a potential market of more than 400 million people.

TELECOMMUNICATIONS

Table 1 shows our current five-year forecast. As is typical in this industry, the vast majority (over 80 percent) of revenue is attributed to network services such as local, long-distance, and international telephone calls. For this analysis, we also have included revenue related to the cable television industry (CATV), which is increasingly becoming a competitive factor in this industry.

Factors influencing our forecast include the following:

- The continuing globalization of the industry, including consistent standards
- Europe—Increasing demand for data/data networking equipment, unification effects of 1992, and the opening of Eastern Europe
- Asia/Pacific—For Japan, we see increasing demand for equipment (both voice and data) due to the opening of trade, along with increasing demand for private networks and competitive network service offerings. The Four Tigers of Asia/Pacific also are expected to consume an increasing amount of telecommunications equipment and services.

Communications—Whether it be voice, the written word, or data, communication is key to business as we know it; therefore, by association, so is the telecommunications industry. Irrespective of international boundaries, the companies positioned to fulfill both the continuing and newly emerging demand for telecommunications will prosper.

TABLE 1
Telecommunications Forecast (Billions of Dollars)

	1989	1990	1994	CAGR 1989-1994
North America	$196.6	$207.1	$266.0	6.5%
Western Europe	100.2	102.1	142.1	8.6%
Asia/Pacific	66.8	72.0	102.5	9.2%
Rest of World	40.2	43.0	60.2	8.8%
Worldwide	$403.7	$424.3	$570.9	7.7%

Source: Dataquest (July 1990)

BUSINESS AND TECHNICAL COMPUTER SYSTEMS

Table 2 shows our current worldwide five-year forecast for business and technical computers, excluding personal computers. Dataquest expects the current trend of flat growth in North America to continue. Europe and Asia/Pacific will exhibit increasing revenue as vendors expand their international sales activity. New market opportunities are expected as European unification and the opening of the Eastern Bloc moves forward.

Additional factors influencing our forecast include the following:

- Mainframes—"Downsizing" will become more prevalent; not necessarily all the way down to networked PCs but more often to less expensive platforms that perform the same functions.
- Midrange systems—Lower margins and the importance of indirect channels are forcing vendors to rethink their distribution strategies.
- Workstations—Product life cycles will continue to be very short, and vendors will continue to challenge each other in the price/performance arena. Workstations will be the fastest-growing segment for both the technical and commercial sides of the market.
- All systems—The demand for open systems and standards will continue as proprietary systems decline. Emerging new technologies such as multimedia and the use of strategic processing styles (OLTP, distributed processing/applications, etc.) will stimulate growth. Increasingly, vendors will derive revenue from the "S factor": services, support, software, and systems integration.

TABLE 2
Business and Technical Computer Systems Forecast (Billions of Dollars)

	1989	1990	1994	CAGR 1989-1994
Worldwide	$67.2	$76.8	$107.8	9.9%

Source: Dataquest (July 1990)

PERSONAL COMPUTER SYSTEMS

Hardware

Table 3 shows Dataquest's actual and short-term projections for PCs. The variance in the forecast is caused by an unexpected rise in the number of 386- and 386SX-based PCs sold. Also, more portable and hand-held PCs were introduced and sold in 1989 and 1990 than expected. These PCs typically are priced higher than desktop PC systems sold in 1988. In addition, there was more of an increase than previously expected in sales of PCs with higher-capacity disk drives and greater memory; these factors also increased the average selling price (ASP) per unit. Each of these factors contributed to the higher 1989 revenue sales and 1990 sales projections.

Table 4 shows our current five-year forecast for PCs. Dataquest anticipates that rapid growth of notebook and hand-held PCs will be one of the primary factors driving this forecast. The trend is for smaller, portable, and faster systems to displace larger, bulky desktop systems. Dataquest also expects the emergence of fast, portable notebook and hand-held PCs to create a secondary PC market—PCs that are primarily used for travel.

TABLE 3
Personal Computer Forecast Comparison
(Billions of Dollars)

	1989	1990	CAGR 1989-1994
Last Year's Forecast	$32.8	$38.6	17.7%
Current Forecast	$34.6	$42.4	22.5%
Percent Difference	5.5%	9.8%	

Source: Dataquest (July 1990)

TABLE 4
Personal Computer Forecast (Billions of Dollars)

	1989	1990	1994	CAGR 1989-1994
North America	$18.9	$23.0	$34.2	12.6%
Western Europe	11.1	13.7	17.5	9.5%
Japan	2.5	3.3	6.2	19.9%
Rest of World	2.1	2.4	4.8	18.0%
Worldwide	$34.6	$42.4	$62.7	12.6%

Source: Dataquest (July 1990)

Notebook PCs are expected to experience a very rapid compound annual growth rate (CAGR) of 76.5 percent based on unit shipments through 1994. The hand-held category is expected to experience explosive growth of 126.4 percent CAGR, based on unit shipments through 1994, while the price per unit should decline to about $600. Dataquest also expects a proliferation of PCs into Eastern Europe, the Far East, Middle East, and parts of Southeast Asia.

Software

Table 5 shows our current five-year forecast for PC software. Factors driving this forecast include our expectations that international sales of software will grow rapidly. Dataquest expects an increase in the export of PCs to Eastern Europe, the Far East, and parts of Southeast Asia to provide a commensurate increase in PC software sales. Dataquest also expects an increase in sales of PC software to Japan as Japan continues to open up its market to exports. Operating environments and telecommunications software will be key growth areas in the PC software market through 1994.

Growing sales of new PCs will continue to drive sales of PC software. PC software sales will grow at a slightly higher rate than PC hardware sales over the next five years because PC software is sold to the installed base as well as with new systems. The replacement rate of PC software is also higher than for PC hardware because the cost per unit of PC software is significantly lower than the cost per hardware unit. Overall, the growth rates of both PC software and hardware have slowed as these markets mature.

TABLE 5
Personal Computer Software Forecast
(Billions of Dollars)

	1989	1990	1994	CAGR 1989-1994
North America	$2.7	$2.8	$4.8	12.2%
Western Europe	1.3	1.5	2.4	13.0%
Asia/Pacific	0.3	0.3	0.9	24.6%
Rest of World	0.1	0.2	0.6	43.1%
Worldwide	$4.4	$4.8	$8.7	14.6%

Source: Dataquest (July 1990)

SEMICONDUCTORS

Table 6 shows our actual and short-term projections for worldwide semiconductor revenue, comparing this year's forecast with last year's forecast and actuals. In the second half of 1989, DRAM prices fell much more dramatically than we had anticipated—although we had predicted a decline—thus causing two negative quarters. In addition, commodity analog IC prices also suffered severe price attrition in the last half of 1989. These factors, combined with a general softening of the PC market, are the major causes of our variance with 1989 actuals. We have not changed our basic outlook for 1990; and we believe that the market will be down very slightly from 1989.

Table 7 shows our current five-year forecast by region. After three quarters of negative growth, the worldwide semiconductor industry resumed positive growth in the second quarter of 1990. PC business, in the dumps during the second half of 1989, has begun to turn around dramatically, particularly in Europe. Semiconductor industry sources indicate that their orders began to rebound in the first quarter of this year.

Dataquest expects semiconductor demand to continue to strengthen over the coming months. We believe that growth will continue through 1993, which will be the peak year of this cycle, and begin to taper off during 1994. Although we expect semiconductor penetration in electronic equipment to continue to increase, the overall electronic equipment market is maturing and experiencing slower growth, and relationships between semiconductor suppliers and semiconductor users are smoothing out the traditional volatility in the semiconductor demand curve.

From 1989 through 1994, we believe that Asia/Pacific and Europe will represent the fastest-growing regional markets for semiconductors. In the case of Asia/Pacific, this anticipated growth is due to the low initial revenue attributed to the region (including Japan) and fast-growing economies which still can absorb considerable electronic equipment production growth through domestic demand. In Europe, this fact is due mainly to the 1992 Effect, which is driving trends to produce semiconductors locally in Europe for consumption there and also driving trends toward standardization across Europe for such applications as cellular phone technology.

TABLE 6
Semiconductor Forecast Comparison
(Billions of Dollars)

	1989	1990	CAGR 1989-1994
Last Year's Forecast	$58.2	$57.9	(0.5%)
Current Forecast	$56.4	$56.0	(0.7%)
Percent Difference	(3.1%)	(3.3%)	

Source: Dataquest (July 1990)

TABLE 7
Semiconductor Forecast (Billions of Dollars)

	1989	1990	1994	CAGR 1989-1994
North America	$17.7	$17.2	$33.5	13.6%
Western Europe	9.5	9.7	19.2	15.1%
Asia/Pacific	28.8	28.7	58.2	15.1%
Rest of World	0.4	0.4	0.7	11.8%
Worldwide	$56.4	$56.0	$111.6	14.6%

Source: Dataquest (April 1990)

SEMICONDUCTOR APPLICATION MARKETS

Major application segment trends that provide an impetus for semiconductor consumption growth include data processing and communications. Data processing's movement toward decentralized computing and concurrent processing will play a prominent role in consumption shifts. This movement toward desktop computing coupled with the use of smart peripherals will drive higher consumption of MOS function as well as analog devices. Such devices require dedicated controller or logic functions coupled with additional memory. Dataquest expects the consumption of MOS digital devices in data processing to show significant growth from 1989 through 1994. Dataquest forecasts data processing semiconductor consumption revenue to grow at a CAGR of 16.5 percent from 1989 through 1994.

In addition, Dataquest forecasts a 14.1 percent CAGR from 1989 through 1994 for semiconductor consumption revenue in the communications application segment. Brisk growth will be experienced due to expansion in premise telecom applications and a marked improvement in performance within the Japanese and Western European communications industries. Western Europe will experience

benefits from standardization and the movement toward a pan-European market. Strong growth in the areas of cellular, networking, and facsimiles constitute key factors in the positive aggregate consumption trends.

Dataquest forecasts particularly high performance from Asia/Pacific-ROW for consumer electronics semiconductor consumption. As in the past, audio and video equipment will provide the base for the majority of consumer electronics semiconductor consumption. The expected high levels of consumption in this region can be attributed primarily to the substantial quantity of goods being manufactured for export.

DISPLAY TERMINALS

Table 8 shows Dataquest's actual and short-term projections for display terminals. The variance in the forecast is caused by our segment 1 (IBM System 3X and compatibles) experiencing a greater demand than previously anticipated.

IBM also is selling more AS/400 multiuser systems in the international market, which creates a strong international demand for twin-ax terminals.

Table 9 shows our current five-year forecast. The primary factors driving this forecast are the general-purpose text and processing terminal (PT) segments. Dataquest's recent report on the 3270 market shows that the PTs will be used increasingly to displace display terminals attached to IBM mainframes, thereby increasing computational power for multiuser systems.

We also expect the Western Europe and Rest of World (ROW) regions to outperform the world market due to the expansion of proprietary and UNIX-based multiuser systems to support the computing needs of a unified Europe.

TABLE 8
Display Terminal Forecast Comparison
(Billions of Dollars)

	1989	1990	CAGR 1989-1994
Last Year's Forecast	$5.2	$5.1	(2.8%)
Current Forecast	$5.4	$5.3	(2.1%)
Percent Difference	3.6%	4.4%	

Source: Dataquest (July 1990)

TABLE 9
Display Terminal Forecast (Billions of Dollars)

	1989	1990	1994	CAGR 1989-1994
North America	$2.3	$2.1	$2.3	(0.2%)
Western Europe	2.3	2.3	2.9	4.2%
Asia/Pacific	0.6	0.5	0.5	(4.0%)
Rest of World	0.2	0.3	0.9	32.6%
Worldwide	$5.4	$5.3	$6.5	3.8%

Source: Dataquest (July 1990)

The demand for IBM 3270-compatible display terminal products also is stronger in international markets, thereby fueling growth in this area.

GRAPHICS AND IMAGE PROCESSING

Imaging Subsystems

Table 10 shows our actual and short-term projections for image processing subsystems. The variance in the forecast is caused by the unexpected strong growth in medical ultrasound devices.

Table 11 shows our current five-year forecast. The primary factors driving this forecast are medical and machine-vision applications. Within these applications, the dominant factor in adoption of embedded subsystems for machine vision is the cost-effectiveness of the digital approach.

While the North American region continues to dominate the market, we expect the most growth to occur in Europe. Immediate opportunities can be expected from the raising of the Iron Curtain, but the greatest growth will be fueled by a unified Europe after 1992.

TABLE 10
Imaging Subsystems Forecast Comparison
(Billions of Dollars)

	1989	1990	CAGR 1989-1994
Last Year's Forecast	$1.1	$1.0	(3.1%)
Current Forecast	$1.3	$1.4	0.2%
Percent Difference	25.8%	30.1%	

Source: Dataquest (July 1990)

TABLE 11
Imaging Subsystems Forecast (Billions of Dollars)

	1989	1990	1994	CAGR 1989-1994
North America	$1.0	$0.9	$1.2	5.0%
Western Europe	0.2	0.2	0.4	12.4%
Asia/Pacific	0.1	0.1	0.1	0
Rest of World	0.1	0.1	0.1	(14.5%)
Worldwide	$1.3	$1.3	$1.8	5.5%

Source: Dataquest (July 1990)

Graphics Terminals

Table 12 shows 1989 revenue actuals and short-term projections for graphics terminals. We have updated our forecast based on increasing competition from PCs and workstations for a share of the desktop market.

Table 13 shows our current five-year forecast. The primary factors driving our forecast are the continuing demand for workstations, PCs, and X terminals.

A shift is taking place in the graphics terminal market away from the long-standing domination by the United States. The North American market will continue to grow, but at a slower rate compared with other geographical segments due in part to the large installed base. This occurrence will allow European markets to benefit from the heavy investments made by Western companies and the newly emerging Eastern European markets. The Asia/Pacific region is expected to grow the fastest in terms of percentage increases, but from a small base.

The influence of X Window System graphics terminals will have the strongest positive effect on total graphics terminal performance in the 1990 to 1994 timeframe.

TABLE 12
Graphic Terminal Forecast Comparison (Billions of Dollars)

	1989	1990	CAGR 1989-1994
Last Year's Forecast	$1.0	$0.9	(4.8%)
Current Forecast	$0.8	$0.8	0.4%
Percent Difference	(18.3%)	(13.8%)	

Source: Dataquest (July 1990)

TABLE 13
Graphic Terminal Forecast (Billions of Dollars)

	1989	1990	1994	CAGR 1989-1994
North America	$0.6	$0.5	$0.6	1.7%
Europe	0.2	0.2	0.4	24.6%
Asia/Pacific	0.1	0.1	0.1	29.9%
Rest of World	0.1	0.1	0.1	13.6%
Worldwide	$0.8	$0.8	$1.3	9.7%

Source: Dataquest (July 1990)

ELECTRONIC PRINTERS

North American 1989 electronic printer market revenue grew less than Dataquest had anticipated a year ago. We believe that this slowed growth was because many users were integrating more of the capabilities of their existing systems rather than spending money on new equipment. This severely impacted the serial printer market, which accounted for nearly all of the forecast shortfall (see Table 14).

The electronic printer market has had major changes during the past two years, which will continue through the rest of the 1990s. The serial printer market is leveling off—demand for dot matrix printers is on the decline (they are being partially replaced by ink jet printers). Serial printers—which have dominated the market for years—are also being replaced by page printers. During 1990, Dataquest believes that worldwide page printer revenue will exceed that of serial printers for the first time.

For the next few years, the key growth areas are expected to be in the page printer (1 to 6 ppm) and in the ink jet segments, with CAGR in the 30 to 40 percent range. Also, many new and exciting advances in printer/printing technologies are anticipated for the 1990s, leading the user to higher

TABLE 14
North American Electronic Printer Forecast Comparison (Billions of Dollars)

	1989	1990	CAGR 1989-1994
Last Year's Forecast	$6.6	$7.2	9.4%
Current Forecast	$6.2	$7.2	15.7%
Percent Difference	(6.4%)	0	

Source: Dataquest (July 1990)

TABLE 15
Electronic Printer Forecast (Billions of Dollars)

	1989	1990	1994	CAGR 1989-1994
North America	$6.2	$7.2	$8.7	7.0%
Western Europe	6.5	7.3	9.3	7.4%
Asia/Pacific	1.4	1.7	2.2	8.8%
Rest of World	0.7	0.8	1.2	10.4%
Worldwide	$14.8	$16.9	$21.3	7.5%

Source: Dataquest (July 1990)

expectations of printing quality and creating new markets for electronic printers. Dataquest's worldwide outlook through 1994 is shown in Table 15.

DOCUMENT IMAGE MANAGEMENT SYSTEMS

Table 16 shows our actual and short-term projections for document image management systems (DIMS). The variance in the forecast was due to the following two factors:

- In last year's database, we counted business and technical DIMS together, whereas 1989 actuals reflect only business DIMS units shipped.
- Low-volume DIMS shipments were lower than expected.

Table 17 shows our current five-year forecast for this market. The primary factors driving this forecast are as follows:

- Major computer vendors—The entry of all of the major computer systems vendors into this market means that they take it seriously as a way to sell hardware and preserve the customer base.

TABLE 16
Document Image Management Systems Forecast Comparison (Billions of Dollars)

	1989	1990	CAGR 1989-1994
Last Year's Forecast	$1.3	$1.6	24.0%
Current Forecast	$1.4	$1.8	26.0%
Percent Difference	10.0%	12.0%	

Source: Dataquest (July 1990)

TABLE 17
Document Image Management Systems Forecast (Billions of Dollars)

	1989	1990	1994	CAGR 1989-1994
North America	$0.8	$1.0	$2.8	28.7%
Western Europe	0.3	0.4	0.9	22.9%
Asia/Pacific	0.2	0.3	0.4	18.3%
Rest of World	0.2	0.2	0.3	16.0%
Worldwide	$1.4	$1.8	$4.4	25.1%

Source: Dataquest (July 1990)

- Distributed computing—Networked computing is the newest computing wave; and distributed document imaging systems already are coming on strong.
- Cost-per-seat decline—The average DIMS cost per seat, although still high, is expected to decline.

INTEGRATED OFFICE SYSTEMS

Table 18 shows our current five-year forecast for integrated office systems (IOS). In 1989, the IOS market grew at its lowest rate, 10.7 percent, since its beginning in the early 1980s. Europe continued to bolster the overall market. IOS revenue is forecast to grow at a CAGR of 13.4 percent from 1990 through 1994. The manufacturer segment remains by far the largest IOS segment. Several factors indicate that this growth trend will continue over the next five years. These factors include the following:

- Within the manufacturer segment, the third-generation office systems form vendors will inject new vitality into shipments.

TABLE 18
Integrated Office Systems Forecast (Billions of Dollars)

	1989	1990	1994	CAGR 1989-1994
North America	$0.8	$0.9	$1.3	10.3%
Western Europe	0.5	0.6	1.1	18.5%
Rest of World	0.1	0.1	0.1	4.8%
Worldwide	$1.4	$1.5	$2.5	13.4%

Source: Dataquest (July 1990)

- UNIX-based IOS should benefit from the continuing popularity of technical workstations, whose vendors are increasingly attempting to penetrate the commercial sectors of their markets.
- Currently the dark horse of the group, PC LAN-based IOS, which has the potential to benefit many more users than either of the other two segments at a price that is much more affordable, is poised to grow explosively.

ELECTRONIC PUBLISHING

Table 19 shows our actual and short-term projections for the electronic publishing market. The variance in the forecast is caused by the unexpected flattening of desktop publishing software unit shipments and a significant decrease in page printer prices.

Table 20 shows our current five-year forecast for PC- and workstation-based publishing. Many growth areas that help drive this forecast exist in the electronic publishing market. Some of these areas are as follows:

- Illustration and image editing software—Graphics software for creating illustrations from scratch and providing ready-to-use illustrative material have great sales potential, not only to new desktop publishers, but also to the installed base of DTP users. Image editing software for scanned images also is a growth area due to the increase in the use of desktop scanners.

TABLE 19
North American Electronic Publishing Forecast Comparison (Billions of Dollars)

	1989	1990	CAGR 1989-1994
Last Year's Forecast	$3.9	$5.1	31.0%
Current Forecast	$3.6	$4.8	34.0%
Percent Difference	(6.9%)	(4.8%)	

Source: Dataquest (July 1990)

TABLE 20
Workstation-Based Publishing Forecast (Billions of Dollars)

	1989	1990	1994	CAGR 1989-1994
North America	$4.6	$5.9	$9.8	16.36%

Source: Dataquest (July 1990)

- Hardware opportunities—Laser printer prices are dropping rapidly, thus increasing the ratio of laser printers to CPUs. Scanners are becoming a more common desktop appliance. The high-resolution full-page monitor market also shows very significant growth.

CAD/CAM/CAE

Table 21 shows our actual and short-term projections for the CAD/CAM/CAE industry. The variance in the forecast is caused by stronger growth than expected in some application areas, as well as higher growth in key international markets.

Table 22 shows our current five-year forecast. The primary factors driving this forecast are as follows:

- A strong demand exists for all applications in established international markets. The year 1992 is having an impact on investments made in computer-aided design and manufacturing technology.
- Opportunities are emerging slowly in Eastern Europe and China.
- A reduction of CAD buys in traditional applications is occurring due to the shrinking US defense budget.

TABLE 21
CAD/CAM/CAE Forecast Comparison (Billions of Dollars)

	1989	1990	CAGR 1989-1994
Last Year's Forecast	$11.8	$13.2	10.6%
Current Forecast	$12.4	$14.3	13.3%
Percent Difference	5.0%	8.0%	

Source: Dataquest (July 1990)

TABLE 22
CAD/CAM/CAE Forecast (Billions of Dollars)

	1989	1990	1994	CAGR 1989-1994
North America	$4.7	$5.1	$8.2	11.8%
Western Europe	4.3	5.1	8.0	13.2%
Asia/Pacific	3.1	3.7	5.9	13.8%
Rest of World	0.3	0.3	0.7	21.0%
Worldwide	$12.3	$14.3	$22.9	13.0%

Source: Dataquest (July 1990)

- The price/performance ratio of computers continues to improve, giving incentive to buy new hardware and improving the performance of major application software.
- Both vendors and end users are shifting from host-based systems to technical workstations.

PLAIN PAPER COPIERS

Revenue in the plain paper copier market comes from three main sources: sales to the end user, service revenue, and rental income, which represent about 35, 40, and 25 percent of the market, respectively. During 1989, unit sales to end users were unexpectedly flat, causing a 2 percent reduction in our revenue projections from a year ago (see Table 23 for total revenue comparisons). Service revenue in 1989 was 2 percent below our previous forecast, and rental income projections were right on target.

Dataquest anticipates continued growth in most segments of the US plain paper copier market; however, growth rates are expected to be less than in previous years. Many new opportunities exist, particularly in the midvolume segments. Dataquest anticipates that the midvolume segments of the copier market (which account for about one-half of total revenue) will experience healthy growth rates through the forecast period. Table 24 shows our 1990 to 1994 forecast.

We expect two major changes to take place in the copier market. The first is increased productivity. We expect copier manufacturers to continue their improvements in paper handling. We also anticipate that other new features will be added, which will allow the user to prepare a completed report or booklet in one step, thus minimizing the amount of time required at the copier.

The second area of change is more product differentiation. One approach will be improved product guarantees or warranties. Another method will be augmenting these warranties with more sophisticated diagnostic equipment. The diagnostic tools that we expect will be most useful are the ones that are transparent to the user, which will give the user the perception of improved service and reliability. The successful vendors will increase the productivity of their copiers and also will provide prompt, complete service of their products.

TABLE 23
United States Copier Forecast Comparison
(Billions of Dollars)

	1989	1990	CAGR 1989-1994
Last Year's Forecast	$14.1	$14.6	3.9%
Current Forecast	$13.6	$14.2	4.1%
Percent Difference	(3.2%)	(3.0%)	

Source: Dataquest (July 1990)

TABLE 24
Plain Paper Copier Forecast (Billions of Dollars)

	1989	1990	1994	CAGR 1989-1994
United States	$13.6	$14.2	$14.9	1.8%

Source: Dataquest (July 1990)

COMPUTER STORAGE DEVICES

During 1989, the market performed better than expected primarily because of increased demand for 3.5-inch rigid disk drives. Table 25 compares the final computer storage market results.

Dataquest's forecast for worldwide computer storage factory revenue calls for 9.7 percent growth during 1990. Table 26 shows our forecast through 1994.

TABLE 25
Computer Storage Forecast Comparison
(Billions of Dollars)

	1989	1990	CAGR 1989-1994
Last Year's Forecast	$17.4	$18.7	8.1%
Current Forecast	$17.6	$19.3	9.7%
Percent Difference	1.3%	3.2%	

Source: Dataquest (July 1990)

TABLE 26
Computer Storage Forecast (Billions of Dollars)

	1989	1990	1994	CAGR 1989-1994
North America	$9.8	$10.6	$11.4	3.1%
Western Europe	4.3	4.6	5.4	4.8%
Asia/Pacific	2.2	2.5	2.8	5.4%
Rest of World	1.3	1.7	2.6	15.1%
Worldwide	$17.6	$19.3	$22.3	5.0%

Source: Dataquest (July 1990)

The 3.5-inch rigid disk drive is now king. It will be the largest contributor to computer storage revenue this year with 20 percent of the worldwide market. By 1994, Dataquest expects the 3.5-inch drive market to make up nearly 50 percent of the total computer storage market's revenue. But watch out for the sub-3.5-inch rigid drives. The 1.8- and 2.5-inch drives are bursting onto the scene much more quickly than we anticipated a year ago. The current market they are addressing, notebook computers, are just starting up the demand curve. If that market—and others that demand smaller-diameter disk drives—take off by more than 50 percent per year, our current 3.5-inch rigid drive forecast could be too high.

Storage densities are increasing, as are the cost/performance ratios of products that incorporate new/advanced storage devices. The demand for more and better storage capabilities/capacities will continue to increase, which sets the stage for a dynamic computer storage market in the 1990s.

Note: This newsletter was compiled from material supplied by the following Dataquest groups: Applications Information Group, Central Research Group, Components Group, Information Systems Group, and the Peripherals Group.

Ken Newbury

Dataquest
a company of
The Dun & Bradstreet Corporation

Research Newsletter

DATAQUEST'S 1989 ELECTRONICS INDUSTRY MARKET SHARES

INTRODUCTION

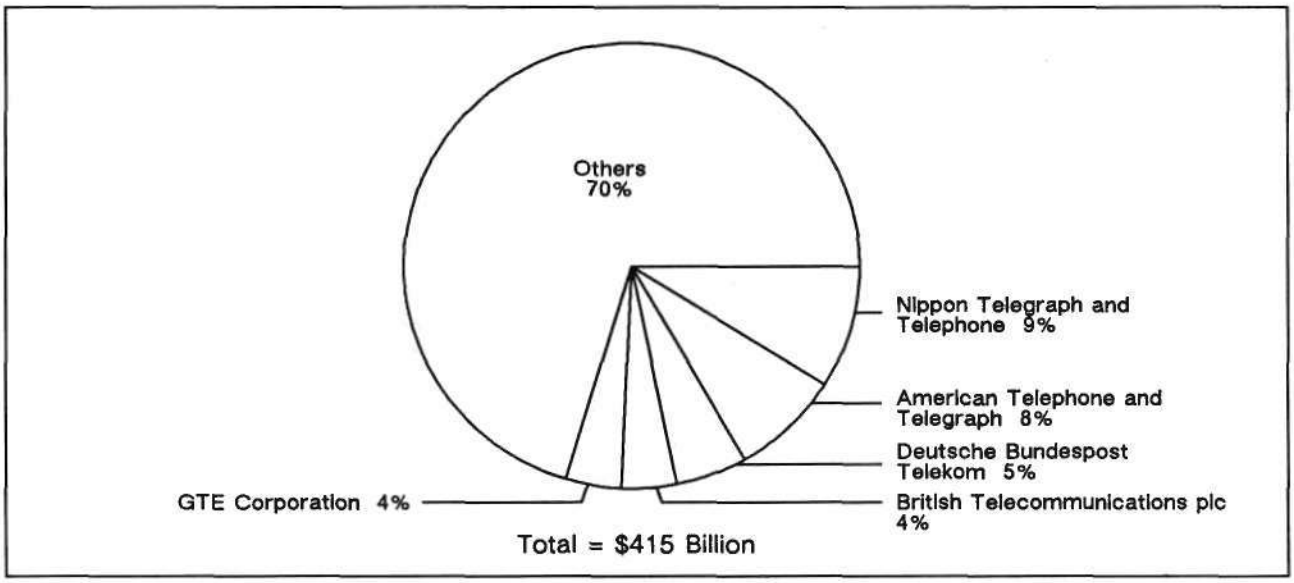
Every year, Dataquest surveys both vendors and users in most major high-technology industries to collect market share and market-sizing data. This newsletter presents a summary of the 1989 market share results and is designed to provide an overview of the major players and major events of 1989 in the high-technology markets of telecommunications, business and technical computer systems, personal computer systems, semiconductors, display terminals, graphics and imaging systems, electronic printers, document image management systems, integrated office systems, electronic publishing, CAD/CAM/CAE, plain paper copiers, and computer storage devices.

Unless otherwise noted, all data are given in terms of factory revenue.

TELECOMMUNICATIONS

The revenue market shares shown in Figure 1 reflect the total telecommunications market, including network services and equipment sales. As is typical in this industry, the vast majority (over 85 percent) of revenue is attributed to network services such as local, long distance, and international telephone calls. Because of this revenue imbalance, the market share leaders shown below are representative of network providers—postal, telegraph, and telephone organizations (PTTs) and regional Bell operating companies (RBOCs)—and not equipment manufacturers. As a point of comparison, the top five equipment providers, in alphabetical order, (Alcatel, AT&T, NEC, Northern Telecom, and Siemens) have a combined

FIGURE 1
Telecommunications
Estimated 1989 Worldwide Revenue Market Shares
(Billions of Dollars)



Source: Dataquest (June 1990)

Dataquest Incorporated, 1290 Ridder Park Drive, San Jose, CA 95131-2398 / (408) 437-8000 / Telex 171973 / Fax (408) 437-0292

equipment-related revenue of slightly over $36 billion—which is almost exactly the total telecommunications-related revenue of NTT, the number-one telecommunications supplier.

The staggering size of the telecommunications market, combined with the necessity of communications standards and network compatibility, highlights the international character of this industry, which, therefore, demands a global perspective. (Of the 5 companies shown in Figure 1, 4 countries are represented as worldwide market share leaders.) Expanding the list to the top 10, the RBOCs start appearing along with Alcatel and Bell Canada Enterprises (includes Northern Telecom). Then, 6 different countries are represented in the top 10 market leaders.

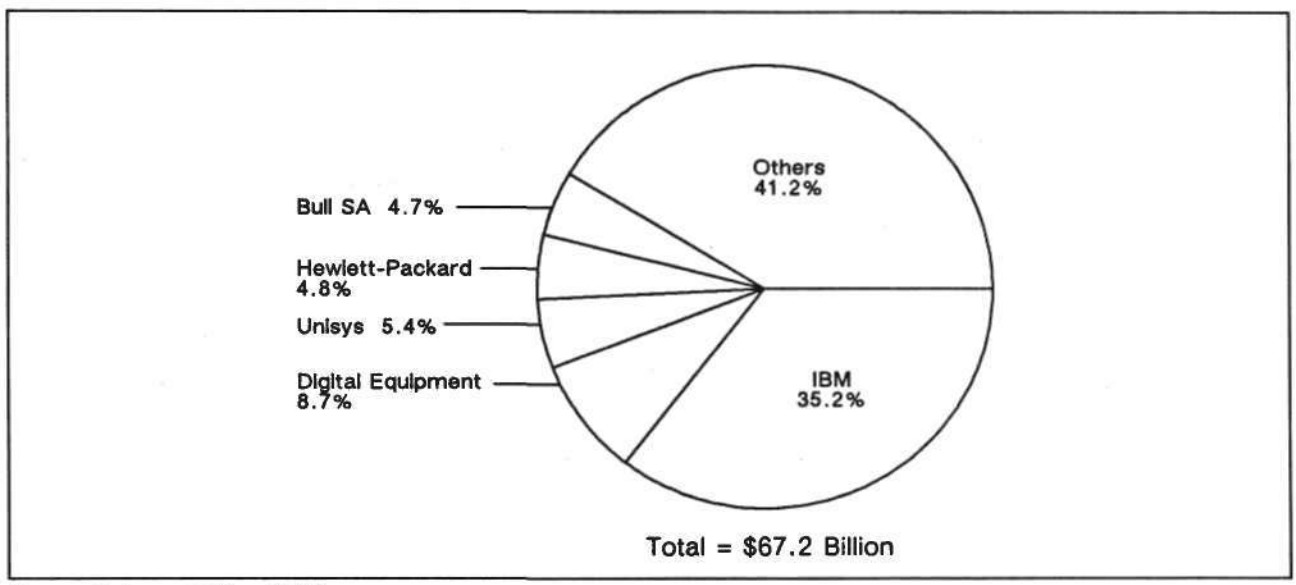
The 1990s portend to be an exciting time for the telecommunications industry. The continuing globalization of the industry, utilization of communications standards such as ISDN, ongoing mergers and acquisitions, and the opening of the Eastern bloc nations set the stage for a tumultuous business environment for the next several years.

BUSINESS AND TECHNICAL COMPUTER SYSTEMS

The business and technical computer systems industry showed only moderate growth in 1989. Totalling $67.2 billion (excluding personal computers) in worldwide factory revenue, the market grew only 9 percent over 1988. The only segment of the market showing any real spark was the workstation segment. There was significant growth in this segment, not only on the technical side, but also on the commercial side of the market where workstations made a strong debut. The mainframe and midrange (superminicomputers, minicomputers, and microcomputers) segments of the market have stagnated. The supercomputer segment showed a small amount of growth but remains a relatively small niche.

Figure 2 shows the total market and the market shares of the top vendors in 1989. Remaining in the lead with a market share of 35.2 percent, IBM continues to grow at a very moderate rate. IBM's saving grace in 1989 was the AS/400. In 1989, this product line completed its first full calendar year of general availability. Even though shipments of these superminicomputers systems fell short of many independent predictions, the AS/400 accounted for the bulk of revenue growth in the commercial side of the market last year. Digital Equipment holds on to second place in the market, with 8.7 percent share of the market. As a major vendor of minicomputers, Digital has seen its fortunes fall with the declining popularity of the traditional minicomputer. Digital has been able to recoup some lost ground through its workstation line.

FIGURE 2
Business And Technical Computer Systems
Estimated 1989 Worldwide Revenue Market Shares
(Billions of Dollars)



Source: Dataquest (June 1990)

Unisys placed third in the market in 1989, with 5.4 percent of the market. Though not a particularly good year overall for Unisys, the company did make gains in the mainframe segment with the 2200 line. Hewlett-Packard ranks at number four in 1989, with a market share of 4.8 percent. Hewlett-Packard was able to augment its market share slightly this year with the purchase of workstation vendor Apollo.

Coming in at fifth place is France's Bull S.A. With a market share of 4.7 percent, Bull (including Bull HN) came in right on the heels of Hewlett-Packard. Bull struggled in the first half of 1989, but was able to regain momentum in the second half, even against increased non-Europe-based competition.

Other vendors that are likely to make headway into the top vendors' domain over the next several years are Fujitsu, Hitachi, NEC, Siemens (with Nixdorf), and Sun Microsystems, all with market shares in the 4.3 to 2.5 percent range in 1989.

PERSONAL COMPUTER SYSTEMS

Hardware

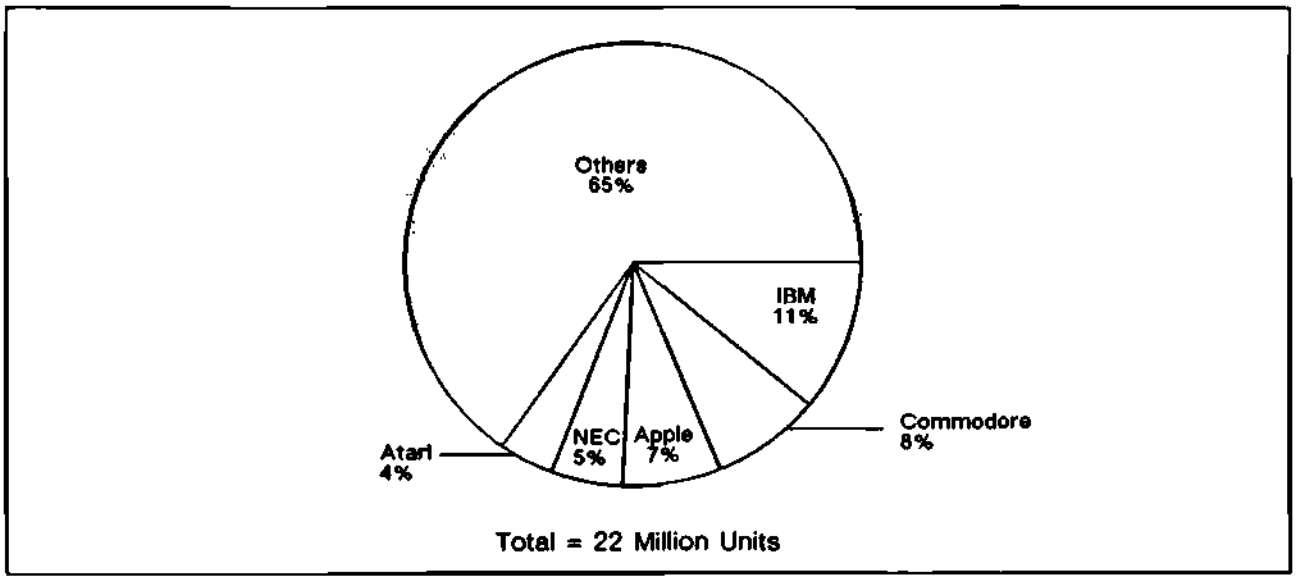
The year 1989 was a year of little relative change in the personal computer industry; previous industry leaders held their positions, and second-tier vendors continued to compete ferociously in all distribution channels. This state of affairs was maintained through the implementation of advanced technologies.

Computers that use Extended Industry Standard Architecture (EISA) finally appeared in 1989. So far, EISA has been implemented only on high-end 80386 and 80486 systems.

Despite facing an onslaught from PC-compatible makers, IBM is still at the top of the heap in terms of units shipped and revenue. IBM's share of compatible shipments is double that of its nearest competitors, NEC and Compaq.

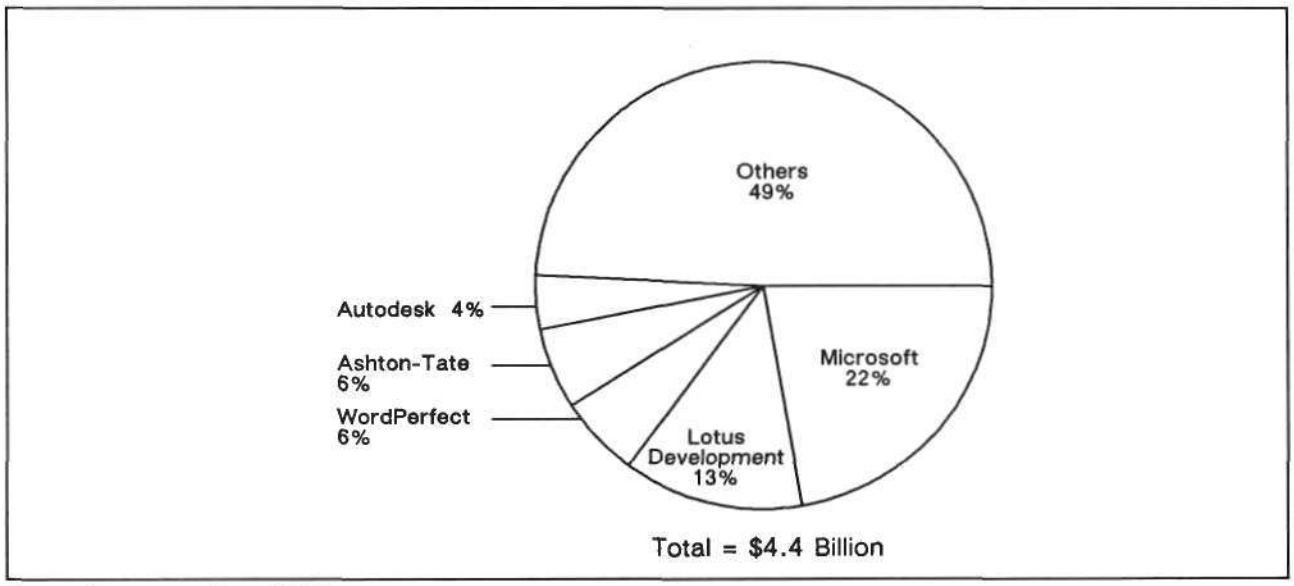
Commodore and Apple remain in second and third place, respectively, and the top five personal computer vendors hold 35 percent of the overall unit marketplace (see Figure 3). While NEC's aggressive marketing, strong channel push, and fleshed-out product line helped to give it 5 percent of the total market, the fact that the company sells a special Japanese-language machine only to Japanese customers dramatically skews its market share. Other major competitors in the top 10 unit PC suppliers are Compaq, Epson, Olivetti, Tandy, and Toshiba.

FIGURE 3
Personal Computers
Estimated 1989 Worldwide Unit Market Shares
(Millions of Units)



Source: Dataquest (June 1990)

FIGURE 4
Personal Computer Software
Estimated 1989 Worldwide Revenue Market Shares
(Billions of Dollars)



Source: Dataquest (June 1990)

Software

The year 1989 was a mixed year for PC software vendors. The top five vendors continue to control the lion's share of the market, with 51 percent of the personal computer software market. The leading personal computer software markets—spreadsheets, word processing, and database management systems—continue to be dominated by single vendors: Lotus, WordPerfect, and Ashton-Tate. Competition is heating up in each of these markets, as competitors introduce successful products such as Borland's Quattro Pro and Paradox and Microsoft's Word for Windows.

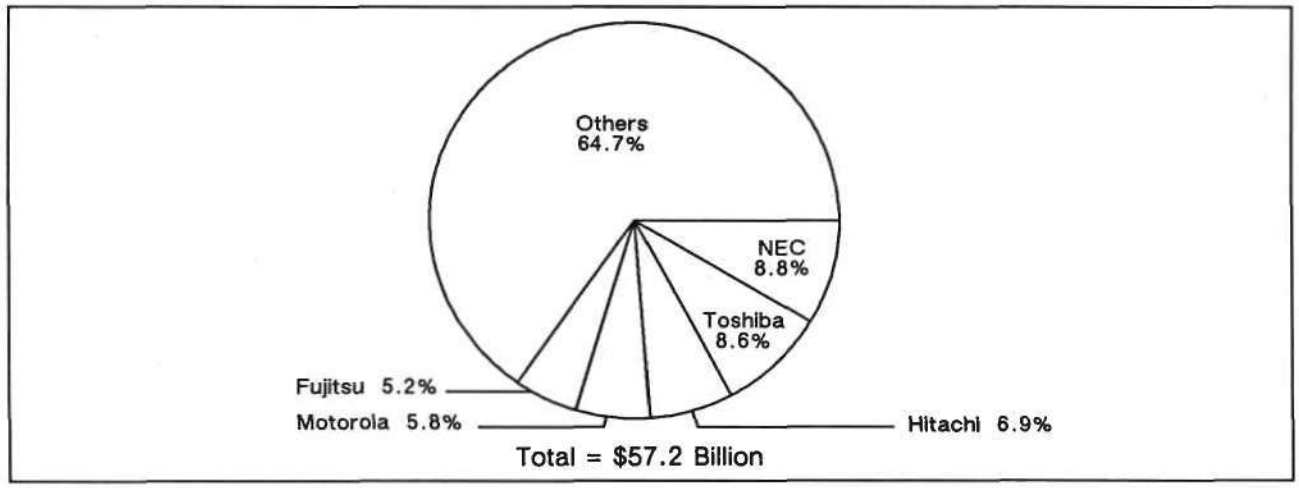
The top five vendors remain the same as in 1988. Ashton-Tate dropped from number three in 1988 to number four in 1989 (see Figure 4). Ashton-Tate's decline in revenue was largely due to its unsuccessful introduction of dBase IV. These dBase products accounted for an estimated 74 percent of Ashton-Tate's revenue in 1989. Microsoft continues to dominate the market with 22 percent market share. As in the past, Microsoft will maintain its lead position with its broad range of successful products. WordPerfect, with its flagship product, WordPerfect, stayed firmly on top. The company continued to hold a substantial lead in the word processing market.

SEMICONDUCTORS

The worldwide semiconductor market revenue grew 12 percent in 1989, slowing from a 33 percent growth rate the previous year. Significant events of 1989 in the industry include the following:

- Japanese companies continued to gain share of the worldwide semiconductor market and now hold 52 percent of it, up from 51 percent in 1988.
- Asia/Pacific (excluding Japan) companies' market share grew to 3.5 percent.
- Japanese companies' share of the North American chip market grew to 26 percent, while North American companies' share of the Japanese chip market remained constant at 9 percent.
- NEC remains the number-one semiconductor supplier in the world, followed by Toshiba, Hitachi, Motorola, and Fujitsu.
- MOS memory was clearly the market leader, growing 40 percent.
- Companies that are strong in MOS memory continued to dominate the market because of their heavy reliance on MOS memory sales.

FIGURE 5
Semiconductors
Estimated 1989 Worldwide Revenue Market Shares
(Billions of Dollars)



Source: Dataquest (June 1990)

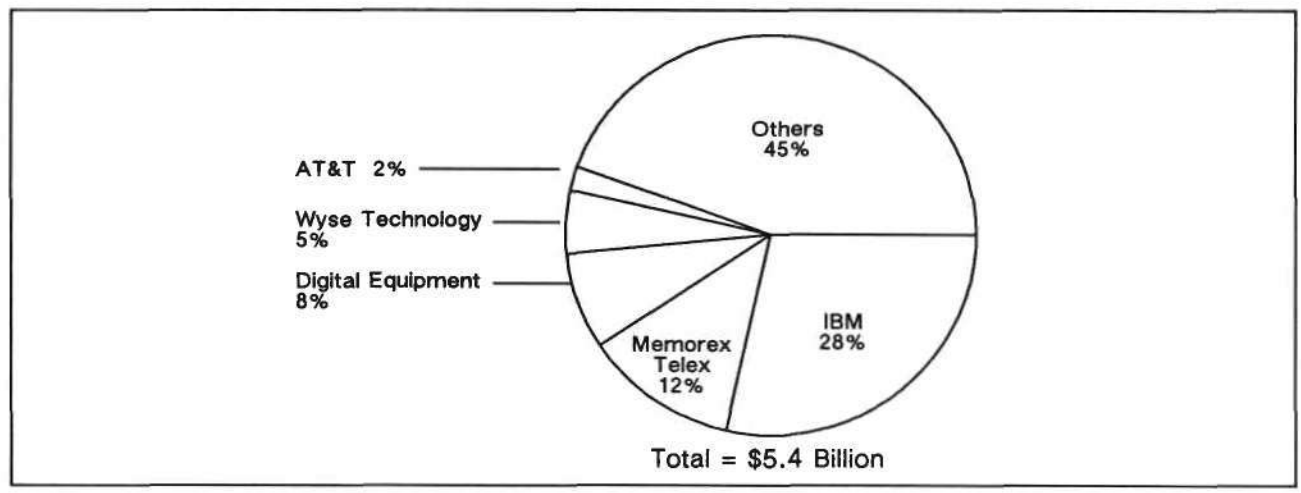
Figure 5 shows the top five semiconductor vendors' shares of the worldwide semiconductor market. Companies that participate in the volatile DRAM market continue to gain market share over the long term, although severe market downturns and questionable profitability of this market in the past caused many US firms to leave it.

Our data also clearly show that the US semiconductor industry's goal of achieving 20 percent market share in Japan is far from realization. However, in light of the plans that many Japanese purchasers have announced to increase their purchases of foreign semiconductors, this 1991 goal might conceivably be reached.

DISPLAY TERMINALS

The display terminal market decreased slightly during 1989, by 0.6 percent, compared with 1988 revenue. Figure 6 shows worldwide

FIGURE 6
Display Terminals
Estimated 1989 Worldwide Revenue Market Shares
North America-Based Vendors
(Billions of Dollars)



Source: Dataquest (June 1990)

display terminal market shares for the top North America-based vendors. IBM led with 28 percent of the market. Memorex Telex, Digital Equipment, Wyse Technology, and AT&T also turned in good performances.

During 1989, there were declines in the minicomputer, protocol-specific, and IBM 3270 segments of the display terminal market. The IBM 5250 market remained strong because of the continued addition of terminals to AS/400 installations.

The ASCII terminal market grew about 9 percent over 1988. Wyse is the market leader in this segment. Ampex exited the market and C. Itoh repositioned itself as an OEM manufacturer.

In the processing terminal market, revenue grew by 38 percent during 1989. Dataquest believes that the primary growth areas remain in the ASCII and processing terminal segments of the display terminal market.

GRAPHICS AND IMAGING SYSTEMS

Graphics Terminals

Figure 7 shows the 1989 worldwide revenue of $795 million and the top five vendors in the graphics terminal market.

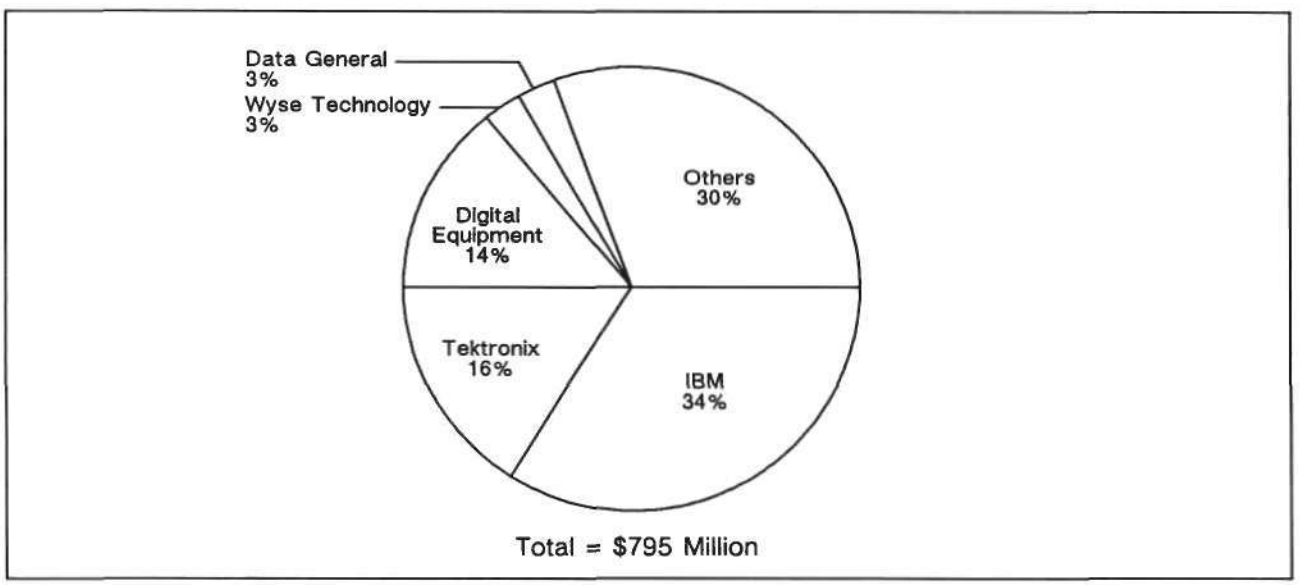
IBM's introduction of the 6090, a 5080 replacement, during 1989 helped it to maintain market share. Most other companies had lower revenue because of increased competition from personal computers and workstations. Dataquest expects the real growth opportunities for graphics terminals to be in the X Window protocol segment.

Imaging Subsystems

The 1989 worldwide revenue for the image-processing subsystems was $1.34 billion, a revenue increase of 26 percent compared with 1988. Figure 8 shows the top five vendors in the image-processing subsystems market.

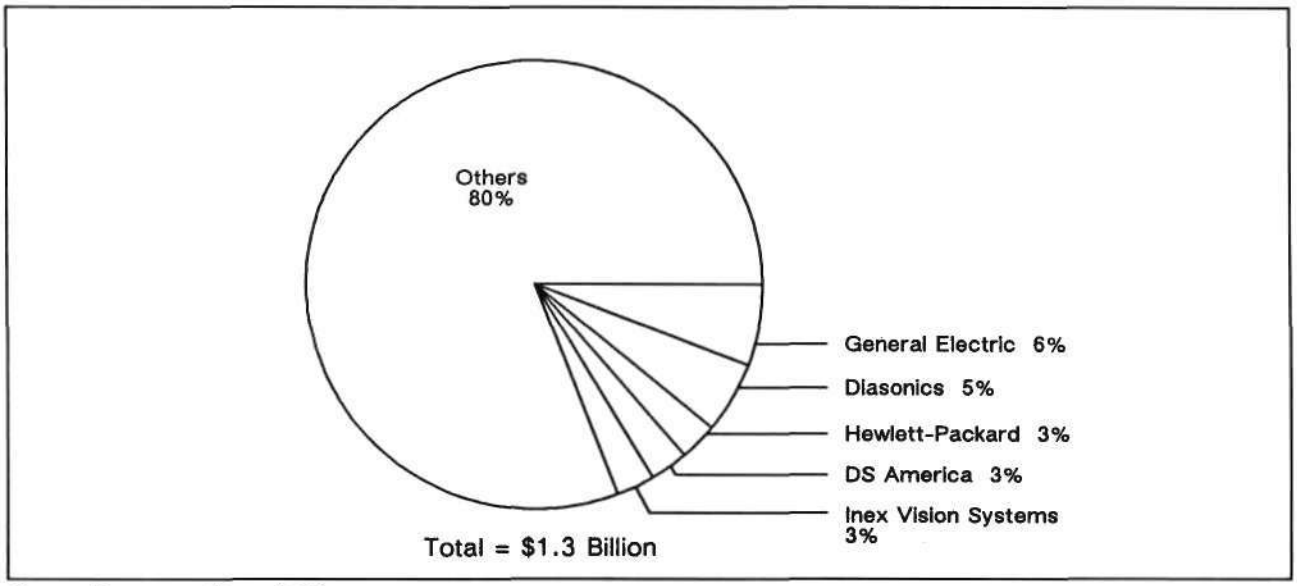
The top three vendors are all in the medical-imaging application segment, which grew by 50 percent during 1989. Revenue in the machine vision application increased 24 percent compared with 1988—Inex Vision Systems is the leading vendor in this segment. Electronic prepress application revenue grew by 16 percent last year—DS America is the market leader in this segment of the imaging subsystems market.

FIGURE 7
Graphics Terminals
Estimated 1989 Worldwide Revenue Market Shares
(Millions of Dollars)



Source: Dataquest (June 1990)

FIGURE 8
Imaging Subsystems
Estimated 1989 Worldwide Revenue Market Shares
North American-Based Vendors
(Billions of Dollars)



Source: Dataquest (June 1990)

ELECTRONIC PRINTERS

Worldwide electronic printer factory revenue grew to $14.8 billion in 1989, up 13 percent over 1988. The year 1989 was a good year, but a year of many changes. Worldwide serial and line printer revenues were essentially flat, while the page printer market grew by nearly 38 percent. The soft market for personal computers in North America during the last half of 1989 resulted in only 3 percent growth in the North American printer market. The Western European electronic printer market grew by an estimated 25 percent—continuing its 20 to 30 percent growth pattern.

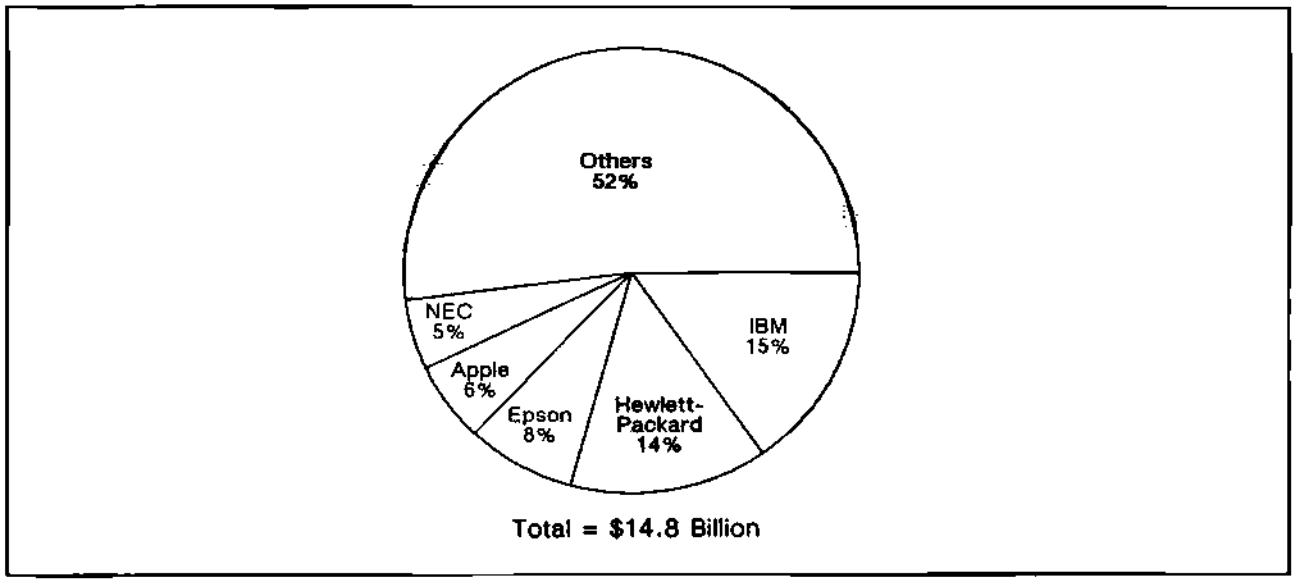
The introduction and acceptance of many 4-ppm to 6-ppm printers during 1989 added to the many changes taking place in the printer market. The availability of faster processors, more on-board memory, and improved software have all contributed to the advances in the printer/printing technology. Printing quality is improving and printing speeds are increasing. It is now easy to reprint pages that were too time-consuming and/or too costly to reprint with previous technologies.

The user is moving to a higher level of quality expectations. Dataquest expects these trends to continue and many new and exciting advances in printing technology and user acceptance to occur during the 1990s.

Figure 9 shows the major vendors of electronic printers. North American companies have about 50 percent of the worldwide market; Japanese and Western European companies have approximately 40 percent and 10 percent market shares, respectively.

The top five vendors have about 50 percent of the worldwide market. Individual company market shares drop off rapidly below the 5 percent range. There are 10 companies with a 2 to 4 percent market share and over 40 companies in the 1 percent and under range.

FIGURE 9
Electronic Printers
Estimated 1989 Worldwide Revenue Market Shares
(Billions of Dollars)



Source: Dataquest (June 1990)

DOCUMENT IMAGE MANAGEMENT SYSTEMS

The document image management systems (DIMS) market experienced very steady and healthy growth in 1989. Traditionally a market dominated by systems integrators and turnkey image systems vendors, the balance of power shifted as the major computer systems vendors entered the market. Figure 10 depicts the major vendors selling DIMS.

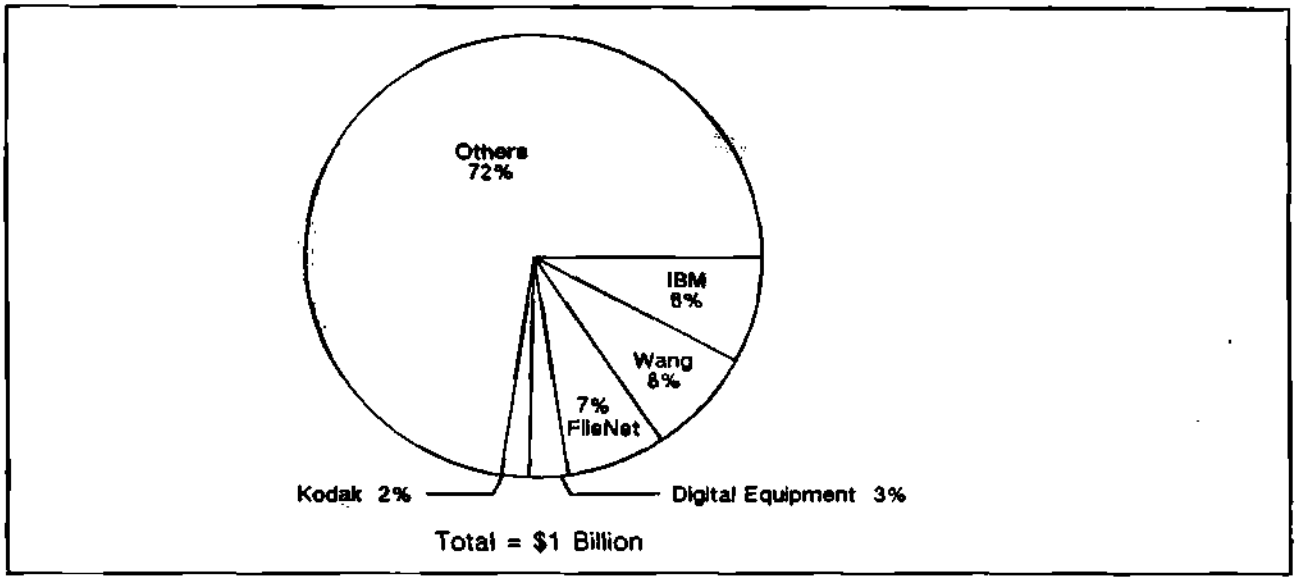
The DIMS market consists of low-, mid- and high-volume systems. While the low-volume segment continued to grow in 1989, this segment began to grow at a slower rate. This slowdown indicates a trend where users are moving document imaging into a more dynamic, networked, work-group environment rather than using it for standalone filing and retrieval.

The midrange segment grew at the fastest rate by far. This growth reflects a maturing of document image system's use. Following are some reasons for this strong growth:

- Current users are upgrading single-user systems to multiuser versions.
- The introduction of lower-priced, work-group systems by high-end vendors.
- More attractive "starter" prices make it easier for the next wave of image systems users to cost-justify installing a first system.

High-volume systems also showed strong growth, but at a slower rate than the other two segments. Key factors that have influenced this segment are the high degree of customization required for a system—in many cases over $1 million per system—and the entry of several major computer systems vendors into the document imaging market. The high degree of customization may limit the total available market. The entry of computer systems vendors into the market will provide more market coverage; this is expected to drive high-volume systems up over the next five years.

FIGURE 10
Document Image Management Systems
Estimated 1989 Worldwide Revenue Market Shares
North America-Based Vendors
(Billions of Dollars)



Source: Dataquest (June 1990)

INTEGRATED OFFICE SYSTEMS

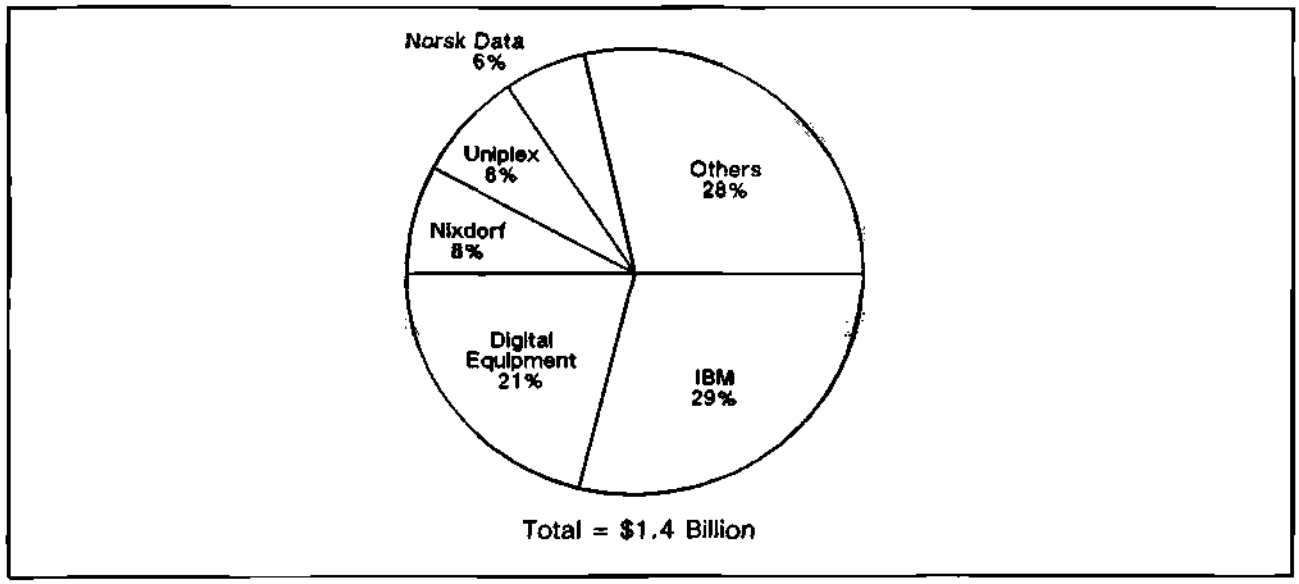
Increasingly being positioned as a strategic platform rather than a mere set of productivity tools, integrated office systems (IOS) have the potential to become the primary mechanism whereby vendors maintain control of their accounts, in a world where they are increasingly less able to differentiate themselves on the basis of their hardware offerings alone. IOS are becoming very sophisticated and challenging for those vendors with the determination to capture that potential.

There are three main segments in the IOS market: manufacturer-based systems, UNIX-based systems, and PC LAN-based systems. Manufacturer-based systems account for over 80 percent of the revenue. Figure 11 depicts the major vendors in the IOS market.

Several factors are currently influencing or will influence the IOS market in the future:

- The impact of third-generation systems
- The move toward the client/server model of computing, to which office systems are so well suited
- The emergence of new and exciting technologies—including multimedia, user agents, and document management systems
- The potential integrating capabilities of office systems, through both software and connecting disparate hardware systems
- The attraction of more users by unbundled IOS and unbundled pricing

FIGURE 11
Integrated Office Systems
Estimated 1989 Worldwide Revenue Market Shares
(Billions of Dollars)



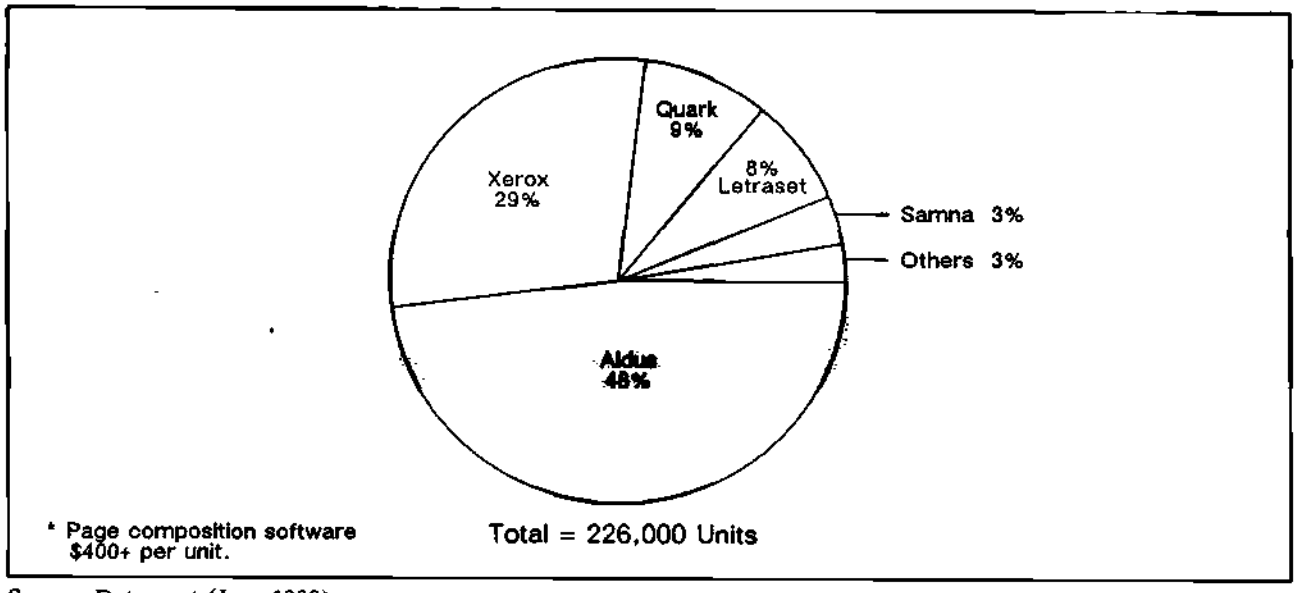
Source: Dataquest (June 1990)

ELECTRONIC PUBLISHING

The PC and PC-compatible publishing market exhibited strong growth from 1988 to 1989 despite lackluster performance from the traditional market contenders. Figure 12 depicts the leading vendors in the PC-based publishing market for page composition software used by Apple and IBM personal computers. The enormous installed base of PCs and PC-compatibles continues to provide a largely untapped market for electronic publishing, especially for inexpensive products tuned to operate within the limitations of 640K memory and 80286 processors. This untapped market potential should contribute to promote strong market growth in the future.

The year 1989 marked the first decline in previously breakneck US growth rates for the traditional suppliers of page composition software, the product category that spawned the desktop publishing (DTP) phenomenon. Dataquest does not believe that this Macintosh (Apple Computer) publishing market deceleration is indicative of a gloomy decade ahead for DTP. Significant, relatively untapped Macintosh publishing product opportunities still exist in the United States and Europe including technical publishing, illustration and intelligent character recognition (ICR) software, fonts, clip art, personal laser printing, and desktop scanning.

FIGURE 12
Page Composition Software, PC-Based Publishing*
Estimated 1989 Worldwide Market Shares
North America-Based Vendors



Source: Dataquest (June 1990)

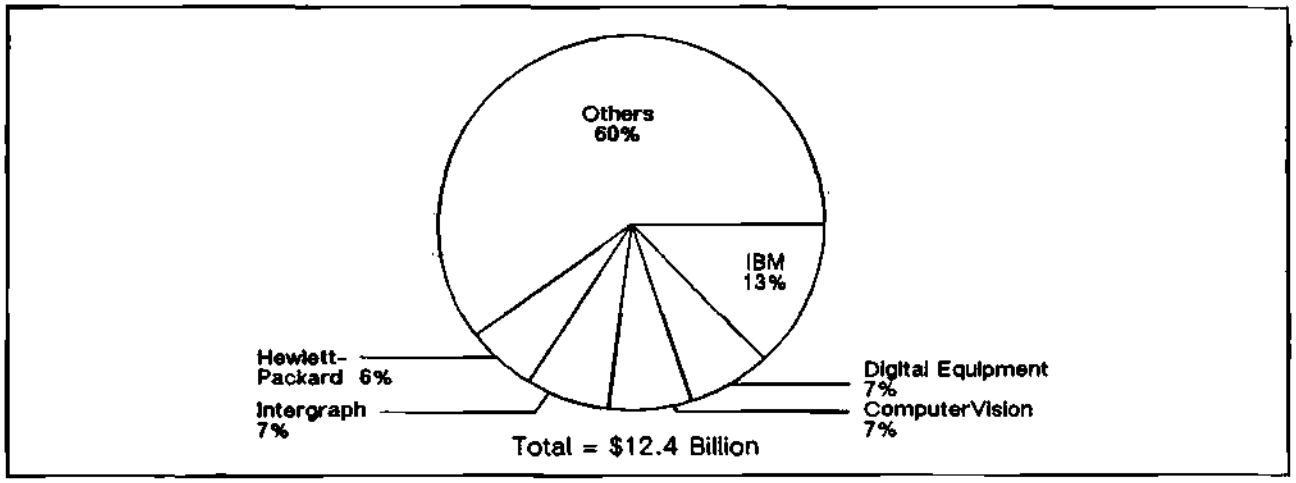
CAD/CAM/CAE INDUSTRY

The CAD/CAM/CAE market experienced robust growth, expanding 14 percent in 1989. Such strong growth in the face of industry instability is clear evidence of this market's vitality as well as its insatiable demand for leading-edge CAD/CAM/CAE products. Advances in core technologies added fuel to the growth by creating new applications and adding value to proven applications. Figure 13 depicts the leading vendors in the CAD/CAM/CAE market.

During 1989, a number of important underlying trends affected the performance of the worldwide CAD/CAM/CAE industry including the following:

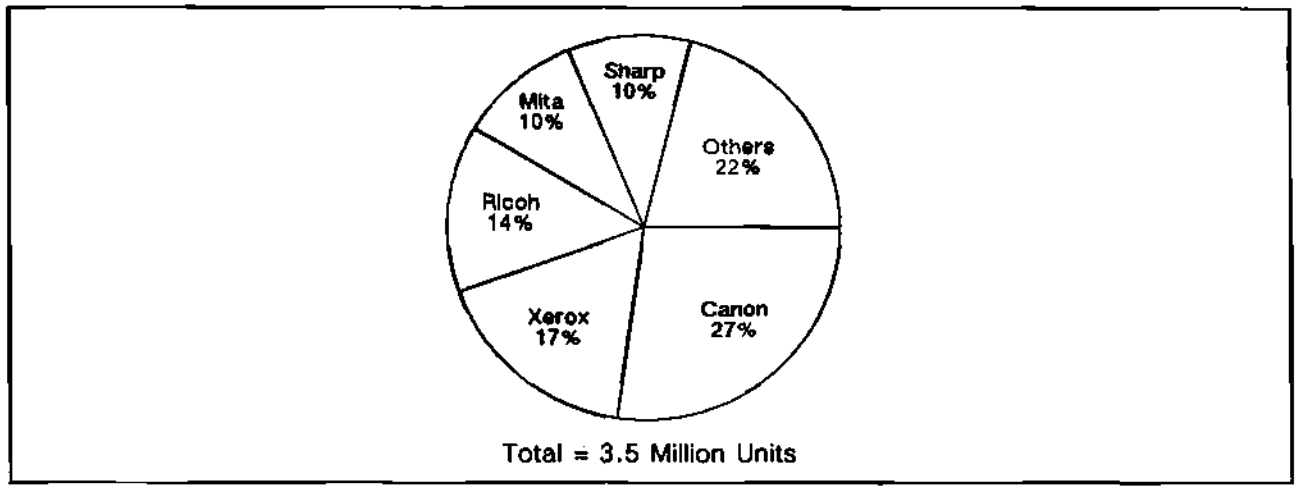
- Intense competition in end-user markets—Strong demand for CAD/CAM/CAE products reflects the fierce competition in the markets that rely on this technology.
- Market globalization—Japan continues to be a hotbed of activity for CAD/CAM/CAE vendors; the European market surpassed all forecasts in gaining even more ground as the largest regional consumer of CAD/CAM/CAE tools.
- Pushing the price/performance envelope—Increasing workstation performance and fierce price competition among computer vendors continued to be a driving force behind the CAD/CAM/CAE market's strong growth.
- Growing overlap between PCs and workstations—In 1989, the overlap in price/performance between PCs and workstations grew even larger.

FIGURE 13
CAD/CAM/CAE
Estimated 1989 Worldwide Revenue Market Shares
(Billions of Dollars)



Source: Dataquest (June 1990)

FIGURE 14
Plain Paper Copiers
Estimated 1989 Worldwide Market Shares



Source: Dataquest (June 1990)

PLAIN PAPER COPIERS

Plain paper copier unit shipments grew by 4 percent during 1989. Although the copier market is leveling out, opportunities remain in particular segments of the market—specifically in the midvolume segments. Dataquest anticipates that the midvolume copier segments will continue to grow at healthy rates through 1994.

Demand for products in the midvolume segments will be met primarily through the dealer distribution channel, with the units manufactured in Japan. We expect growth in Asia/Pacific and Eastern Europe to be higher than that of the more mature US, Western European, and Japanese markets for the next few years.

Figure 14 shows the top five vendors' unit shares of the worldwide plain paper copier market. The market is dominated by Canon, Xerox, and Ricoh, with a combined market share of nearly 60 percent. Sharp and Mita have a combined share of 20 percent; Konica, Minolta, and Toshiba each participate with 4 to 6 percent of the market.

COMPUTER STORAGE

The worldwide computer storage revenue grew by 8 percent during 1989 to $17.6 billion. Figure 15 shows the market leaders in computer storage devices. Mergers and consolidations continued, with many companies being bought out by larger companies or filing for bankruptcy under Chapter 11.

The computer storage market is dominated by North American and Japanese companies. European and Rest of World companies have less than 5 percent of the worldwide market. At the segment level, the geographic breakdowns are as follows:

- The 3.5- and 5.25-inch rigid drive market is dominated by North American companies, with over 90 percent of the respective markets.
- The flexible drive market is served almost entirely by Japanese companies (over 95 percent).
- The tape drive market is served mostly by North American companies (over 70 percent).

The computer storage market is undergoing many changes. The following are just a few highlights of the 1989 computer storage market:

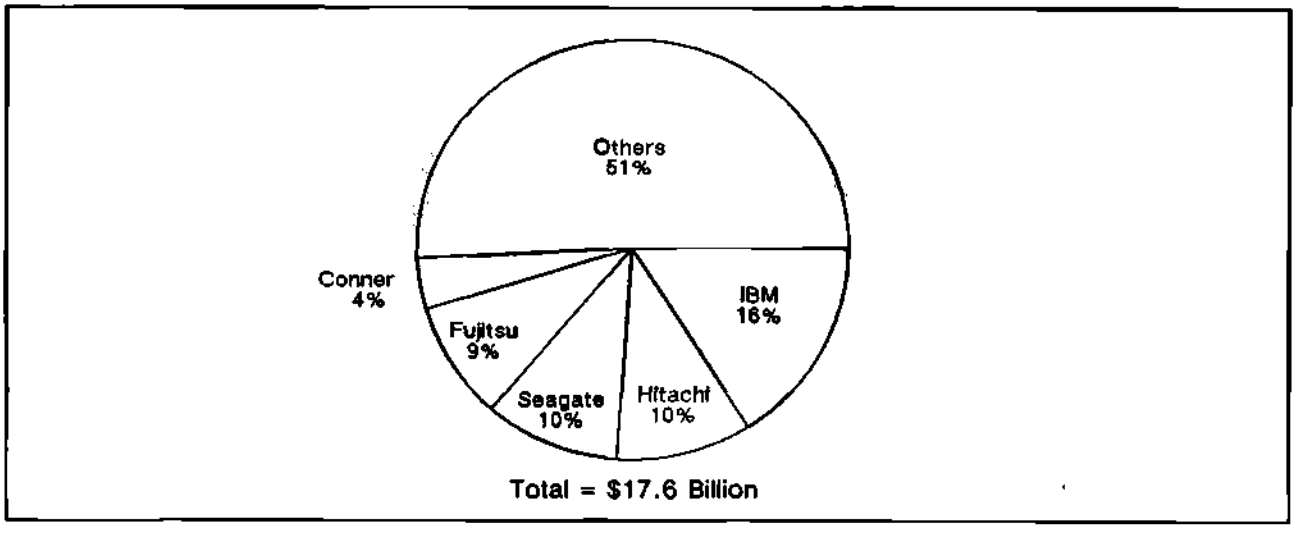
- Seagate's acquisition of Imprimis made Seagate a 70 percent market share leader in unit shipments in the rigid 5.25-inch segment.
- Conner Peripherals became the fastest-growing company in disk drive history, selling principally to OEM buyers.
- Hewlett-Packard began a quality war by announcing 5-year warranties and 150,000-hour mean time between failure (MTBF) rates on its 5.25-inch hard disk products.
- The worldwide tape drive market crossed the $2.5 billion mark during 1989, an increase of 17 percent from 1988.

More people are using more storage devices, which is expanding the market potential. Magnetic-recording densities are increasing, along with the cost/performance of the products that incorporate these new higher-density storage devices.

Paul Wittrock
Patricia S. Cox

Note: This newsletter was compiled from material supplied by the following Dataquest groups: Applications Information Group, Central Research Group, Components Group, Information Systems

FIGURE 15
Computer Storage Devices
Estimated 1989 Worldwide Revenue Market Shares
(Billions of Dollars)



Source: Dataquest (June 1990)