SAM-1988

Introduction to the Service

OVERVIEW AND PURPOSE

The Semiconductor Application Markets service (SAM) is one of seven semiconductor services provided by Dataquest.

As the range of semiconductor applications continues to become increasingly complex, so too does the task of examining and forecasting semiconductor consumption from an electronic equipment perspective. Dataquest's Semiconductor Application Markets service has developed a methodology and information base that provides a thorough analysis and forecast of semiconductor consumption by electronic equipment markets. The service provides comprehensive support to decision makers who need to focus on the industry in terms of semiconductor demand and future application markets. In companies of all sizes, SAM can facilitate and support decisions regarding:

- Strategic planning
- Tactical marketing
- Product planning
- Sales planning

SAM's position is unique in that it provides a third dimension with which to view the regional and product data that come from adjoining analysts and services. The six component division services listed below work in alignment with SAM:

- Semiconductor Equipment and Materials Service (SEMS)
- Semiconductor Industry Service (SIS)
- Japanese Semiconductor Industry Service (JSIS)
- European Semiconductor Industry Service (ESIS)
- Asian Semiconductor and Electronics Technology Service (ASETS)
- Semiconductor User Information Service (SUIS)

Figure 1 depicts the different perspectives on the semiconductor industry that these services provide.

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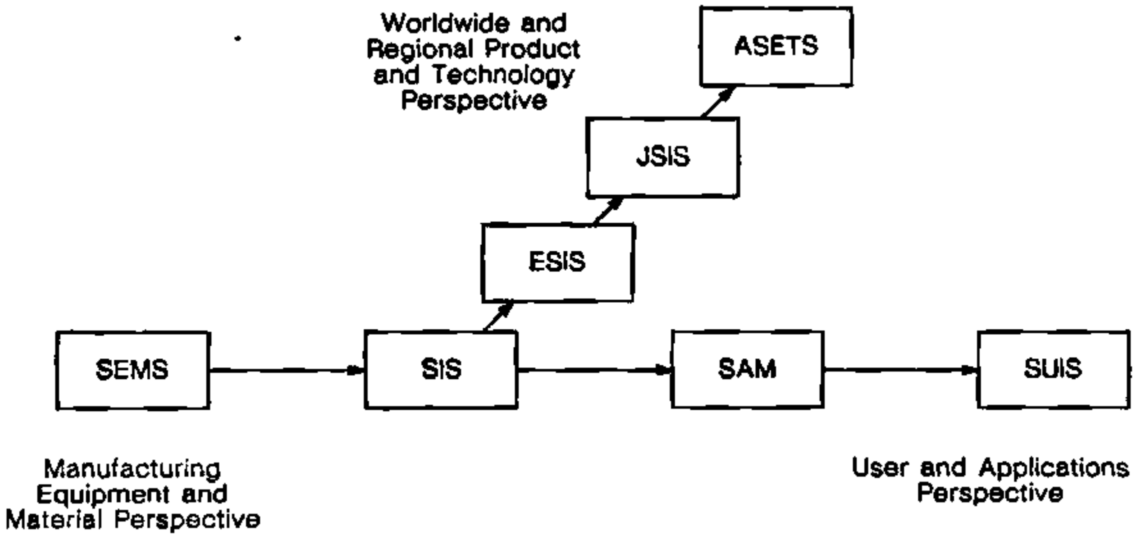
Figure 1

Dataquest Component Services Perspectives



Source: Dataquest April 1988

ELEMENTS OF THE SERVICE

The service has five basic elements:

- A loose-leaf binder contains the essential data that are at the core of the service's methodology

- Newsletters report and analyze electronic equipment system trends, electronic equipment markets, pricing and procurement activity, conferences, and related purchasing issues and trends as they pertain to application markets.

- An inquiry privilege allows the SAM client and a designated alternate access to the SAM staff for clarification or further information on the topics covered in the service.

- An annual two-day industry conference brings together semiconductor manufacturers, major semiconductor users, the financial community, and the Dataquest staff to discuss key issues affecting relationships between users and suppliers. Many of our clients have developed important business relationships at this conference.

- Clients may also have access to and use of Dataquest's Corporate Library. The extensive material in the library includes information by both subject and company, the semiconductor portion of which is electronically indexed. The library regularly receives numerous periodicals, including government data, annual reports, and foreign publications.

As a SAM notebook holder, you and your designee also have access to the Component Division's Inquiry Center. The Inquiry Center provides on-the-spot support and access to available data. If your inquiries extend beyond the need for additional data, and you need detailed analyses or opinions on topics that are relevant to the service, we suggest that you contact the SAM staff directly, as mentioned above.

Clients are often unaware of what they can seek via the inquiry privilege. The inquiry privilege gives the notebook holder access to unpublished information that is available within Dataquest and also to analyst expertise and opinion. It allows clients to "personalize" the information that they require in order to make decisions that are particular to their (or their company's) needs. We invite clients to make use of the inquiry privilege in order to seek this additional and available information. The inquiry is typically not a means for additional primary research, however.

Typical inquiries recently answered by the SAM staff are listed below. These provide an idea of how clients utilize the service on a regular basis. The inquiries revolve around several basic themes:

- The dynamics of a particular electronic equipment market, including:
  - A forecast in dollars
  - A forecast in units
  - Major manufacturers
  - Key trends
- Electronic equipment manufacturers' semiconductor procurement data
- The semiconductor content of a particular type of electronic equipment
- Semiconductor manufacturers' estimated sales by application market

Examples of specific inquiries are as follows:

- Smart card trends and outlooks; laser cards
- Long-term prospects for the U.S. computer industry
- Trends and purchasing surveys in electronic equipment markets
- Worldwide automotive semiconductor consumption by region

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- Laser printer forecast
- Historical I/O ratios
- Graphics terminals market size
- ASIC alliances in automotive industry
- January 1987 procurement survey results
- LAN forecast
- Home computer market
- Electronic equipment forecast
- Ten biggest buyers of PC chipsets
- Top PC chipset manufacturers and alliances
- Companies involved in ATE, cellular mobile radio, data communications, and consumer
- Size of talking toys and electronic game markets
- Markets for 32-bit MPUs
- Semiconductor graphics controller ICs
- Companies that manufacture flight management computer systems and electronic flight instrumentation
- Power supply and electronic dimmer switch manufacturers
- Size of military E^2 market
- IBM revenue by market; IBM organization
- Suppliers/users in automotive semiconductor market
- Footprint-and-performance-sensitive applications
- Graphics chip suppliers and markets
- Leading pay-telephone manufacturers

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BINDER CONTENTS

The binder containing the comprehensive data that are an integral part of SAM is given or sent to clients upon subscription. The layout of the remainder of the binder following this introduction is listed below. (A second binder is provided for convenient filing of SAM newsletters.)

Overview

This is a description of our research procedures and methodology. It also provides an explanation of our market segmentation by the six top-level application markets:

- Data processing
- Communications
- Industrial
- Consumer
- Military
- Transportation

This section also includes definitions of electronic equipment that is forecast by the service.

Company Electronic Equipment Revenue

This section consists of a historical (1980–1987) look at major electronic equipment revenue by company, year, and application market, preceded by an analysis of semiconductor consumption as it relates to the historical trends in this aggregate electronic equipment revenue.

Electronic Equipment Forecast

In this section, an electronic equipment forecast classifies and segments more than 200 types of electronic equipment within the six application market categories and projects a forecast for each line item.

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Semiconductor Consumption Analysis

Total semiconductor consumption analyses are included by:

- Application market segment (particular equipment type)
- Product by application market segment
- Technology by application market segment

The semiconductor consumption analysis is followed by six subsections (which are separated by tabs), one for each of the six application markets. Behind tabs are trends and market overviews for the segments, or "bottom up" detailed analyses for specific equipment within segments. For example, behind the transportation tab is a detailed discussion of the automobile semiconductor market that includes information such as the number of cars produced, technology trends, and semiconductor content per average car. In addition, behind each subtab, is semiconductor consumption data by product and technology that pertains to each subtab's market.

As staff members report on additional equipment types or trends that are industry- or equipment-specific, the material will be filed and located behind these tabs.

SUPPORT

Dataquest's position and strength in providing this product is unprecedented. The service is structured so that the SAM staff is supported by an integral information base with sources second to none. Our staff maintains ongoing dialog with:

- Semiconductor users from all industries that both make and buy devices
- Dataquest's other technology services, providing an ongoing view of their quickly changing industries from both regional and equipment market product viewpoints

SAM draws upon the expertise of more than 25 electronic equipment services at Dataquest for information. However, detailed market share information and competitive analyses are considered an element of the appropriate industry service's standard subscription; clients may be required to subscribe to that service for an additional fee if they wish ongoing access to this level of information.

Figure 2 illustrates the Dataquest infrastructure that supports this service.

Figure 2

Dataquest Infrastructure

Other Dataquest Technology Services

\+ Primary Research and Analysis by SAM Analysts = SAM Provides

Information on electronic equipment manufacturers'

- Revenue and market share
- Semiconductor consumption
- Procurement locations

Electronic equipment forecasts

- By equipment type
- By year
- By application market

Semiconductor consumption forecasts by application market

- By product and technology
- By equipment type

Plus detailed service sections covering market trends and semiconductor analyses within each of the major application markets, which are:

- Data processing
- Communications
- Industrial
- Consumer
- Military
- Transportation

Source: Dataquest
April 1988

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Definitions

One of SAM's strengths comes from its ability to glean information from Dataquest's in-house experts who analyze fast-growing electronic equipment markets. Several of the Dataquest industry services have devised definitions that are particular to the equipment that they forecast. For clients who are unfamiliar with Dataquest's definitions, we have provided each service's definitions for the equipment markets whose names may not clearly or accurately describe the equipment. In this way, users of the forecast information can understand the data in relation to the appropriate market segment and equipment type.

For your convenience, we have also defined some of the equipment types whose data comes from non-Dataquest sources (for example, the U.S. Department of Commerce). These definitions appear after the Dataquest definitions and are listed by application market in the order that they appear in the data tables. Here again we have only defined equipment whose category title (in the table) may not be clear.

Lists of all electronic equipment types and their forecasts are located behind the tab entitled Electronic Equipment Forecast.

Definitions

COMPUTERS

Dataquest's Computer Industry Services define the following:

Computer Systems are combinations of programmable hardware and software that minimally include a central processing unit (CPU), input/output (I/O) capability, internal memory, system peripherals, system software, a power supply, and some form of cabinetry.

- Corporate Resource Computer Systems are large-scale computer systems capable of supporting more than 150 concurrent users, and capable of supporting the central data processing needs of a large organization or the needs of a smaller number of users performing computationally intensive applications. Corporate resource computers require the support of dedicated personnel. This segment includes systems commonly called mainframe computers and supercomputers. Current pricing typically exceeds $1.5 million.

- Business Unit Computer Systems are medium- to large-scale computer systems that typically support from 65 to 150 concurrent users, and serve the data processing needs of a large business unit of a large organization or the central data processing needs of a smaller organization with equivalent requirements. These systems also may support a smaller number of users engaged in computationally intensive applications. Business unit computer systems require limited support personnel. This segment includes systems commonly called superminicomputers. Current pricing typically ranges from $250,000 to $1.5 million.

- Large Department Computer Systems are medium-scale computer systems that typically support from 21 to 64 concurrent users, and serve the data processing needs of a large department in a large organization or the central data processing needs of a smaller organization with equivalent requirements. These systems also may support a smaller number of users performing computationally intensive applications. Large department computer systems require limited support personnel. This segment includes systems commonly called minicomputers and superminicomputers. Current pricing typically ranges from $75,000 to $250,000.

- Small Department Computer Systems are small- to medium-scale computer systems that typically support from 11 to 20 concurrent users, and serve the data processing needs of a department in a large organization or the central data processing needs of a small organization with equivalent requirements. These systems also may support a smaller number of users performing computationally intensive applications. Small department computer systems usually require no dedicated support personnel. This segment includes systems commonly called supermicrocomputers and minicomputers. Current pricing typically ranges from $25,000 to $75,000.

Definitions

- Work Group Computer Systems are small-scale computer systems that typically support from 2 to 10 concurrent users. These systems have resident multiuser capability and are commonly referred to as multiuser microcomputers. They require no dedicated support personnel. Work group computer systems are typically priced at less than $25,000.

- Single-User Enhanced Computer Systems are computer systems that support no more than one user and typically are intended for dedicated use in a particular technical application. The dedicated purpose of a system is usually evident in the packaging, hardware and software configuration, selling channels, and other characteristics of the product and in the ways it is marketed. Single-user enhanced computer systems include technical workstations, instrument controllers, and automation devices. They are typically priced at less than $75,000.

- Personal Computers (PCs) are computer systems that have the following characteristics:

  - They are human oriented, meaning they are intended to meet individual business, professional, educational, and personal data processing needs, and do not generally act as instrument controllers or automation devices.

  - They are single-user oriented, meaning that although communications may be involved, systems are intended for the data processing needs of individuals, and involve only one interactive device. PCs can generally be purchased, operated, and used by an individual rather than an organization.

  - They have full alphanumeric keyboards, which distinguishes personal computers from programmable calculators, video games, and dedicated special-function computers.

  - They have local programming capabilities using high-level programming languages, and most support BASIC, or a derivative of it. Other languages such as Pascal, FORTRAN, and COBOL are also available on personal computers.

  - They have a resident operating system in ROM or magnetic media. This distinguishes PCs from terminals.

  - They are able to run general-purpose applications. This distinguishes PCs from systems that are dedicated through permanent hardware or firmware adaptation to functions such as word processing and financial analysis.

  - Their retail price is $10,000 or less.

Definitions

In the data base, market forecasts are presented for three price segments of personal computers. These are:

- Personal computers less than $1,000
- Personal computers priced from $1,000 to $5,000
- Personal computers priced from $5,001 to $10,000

TERMINALS

Dataquest's Display Terminal Industry Service and Graphics Terminal Industry Service define their industries accordingly:

Display Terminals

Display terminals are desktop electronic devices that are dependent upon a data communications link to a computer system, and that:

- Provide an interface between a human operator and a computer system or a communications network
- Deliver a visual presentation of incoming data to the operator
- Allow the operator to enter or modify information in the computer system via a keyboard, media reader, or other local device

Alphanumeric Display Terminals

Alphanumeric terminals are display terminals that provide character information to the human operator.

Dataquest distinguishes four segments of alphanumeric display terminals. These are:

- Segment 1 (Minicomputer-Based)—Includes display terminals provided by minicomputer manufacturers or display terminals that are protocol specific to IBM System/34, /36, and /38 computers. These terminals may operate in either character or block mode. This new segment does not include terminals that are compatible with those of the minicomputer manufacturers but are supplied by independent manufacturers.
- Segment 2 (Non-IBM, Protocol-Specific)—Includes terminals which are protocol specific to Burroughs, Honeywell, or Sperry mainframes. It also includes terminals of this type that connect to other computers by means of protocol emulation.

- Segment 3 (IBM 3270)—Includes terminals that are protocol specific to IBM's 3270 Information Display System. Segment 3 includes all of the IBM 3270-type terminals and 3270-compatible terminals produced by other manufacturers; these terminals may be directly plug compatible or may incorporate software emulation of the 3270 protocol. Terminals that can provide the appearance of a 3270 device when used with a protocol converter are not included.

- Segment 4 (Host/Vendor Independent)—Includes all host-independent display terminals produced by the "independent" manufacturers. These terminals may operate in either character or block modes. The independent manufacturers do not supply mainframes or minicomputers to which their display terminals may attach. This segment does not include those terminals that are from the independent manufacturers and that are protocol specific to either Segment 2 or Segment 3. Such terminals are included in those segments, as appropriate.

Graphics Terminals

Graphics terminals are display terminals that provide graphical presentation of information to the human operator.

Dataquest distinguishes three segments of graphics terminals by applications use. These are:

- Data Conversion Graphics Terminals support the use of graphics to summarize or otherwise relate discrete data that were not originally graphics data.

- Concept Design Graphics Terminals support graphics displays that help realize accurate images of ideas conceived in the human mind.

- Imaging Graphics Terminals display a real image, visible or nonvisible, that was digitized to allow enhancements or data extraction.

COPIERS AND DUPLICATORS

Dataquest's Copying and Duplicating Industry Service classifies plain paper copiers into the following industry segments, listed with features that are characteristically found in them:

- Personal Copiers (PCs)
  - Tabletop
  - Moving platen
  - Single cassette

Definitions

- Minimally featured
- Easy to install and service
- Superior reliability
- Compact, lightweight
- Monthly copy volume of up to 1,000, with average copy volume of 400
- Multiple copy speed of up to 12 copies per minute
- Purchase price less than $1,600, with typical price of $1,000

• <u>Segment 1</u>

- Tabletop
- Moving platen (generally)
- Single cassette
- Minimally featured, but may include reduction, enlargement, interrupt function, optional feeder and sorter
- Average copy volume of 5,000
- Multiple copy speed of 15 to 20 copies per minute
- Typical purchase price from $1,295 to $3,595

• <u>Segment 2</u>

- Tabletop
- Stationary platen
- Generally dual cassettes/trays
- A3 maximum copy size
- Possible enhancements may include reduction, enlargement, optional on-line feeder, sorter, and large-capacity paper cassette
- Multiple copy speed from 21 to 30 copies per minute

Definitions

- Typical monthly copy volumes ranging from 5,000 to 20,000, with average volume of 10,000
- Typical purchase price from $3,800 to $5,000

- Segment 3
  - Tabletop or console (more recent introductions are usually tabletop)
  - Stationary platen
  - Units generally offered as "systems," with standard features including reduction, enlargement, automatic duplexing, feeder, sorter, and 1,000-sheet tray (These features are sometimes offered on a modular basis.)
  - Multiple copy speed from 31 to 45 copies per minute; also includes console units with speeds greater than 25 cpm
  - Typical monthly copy volumes ranging from 5,000 to 30,000, with average volume of 18,000
  - Purchase price from $4,445 to $8,795

- Segment 4
  - Console or tabletop
  - Stationary platen
  - Highly featured
  - Multiple copy speed from 40 to 75 copies per minute
  - Typical monthly copy volume range from 10,000 to 75,000, with average volume of 32,000
  - Purchase price from $5,695 to $26,500

- Segment 5
  - Console
  - Stationary platen
  - Highly featured; increasing emphasis on modularity of features (input/output devices, reduction, finishing)

- Typical monthly copy volume range from 25,000 to 125,000, with average volume of 65,000
- Multiple copy speed from 70 to 90 copies per minute
- Purchase prices between $15,000 and $75,000, depending on configuration

- Segment 6
  - Large equipment with numerous peripherals and special features, primarily for use in Central Reproduction Department (CRD) environments
  - Possible specialized features include image shift, slip-sheet insertion, variable reduction
  - Intended for copy volumes of 100,000 per month and above; typical volume 170,000 per month
  - Multiple copy speed 91 copies per minute and above
  - Purchase prices between $43,000 and $130,000, depending on configuration

OFFICE AUTOMATION

Dataquest's office automation services market coverage is wide-ranging, including electronic typewriters. This is defined on the following pages.

Electronic Typewriter Industry

- Segment 1 (Portable ETs)—Segment 1 electronic typewriters typically are considered portable typewriters. Calculation functions, as in a pocket calculator, are usually available. Print mechanisms currently utilize thermal or daisywheel technology.
- Segment 2 (Compact ETs)—Segment 2 electronic typewriters typically are considered compact in size as they usually are physically between the size of a portable and a full-size unit. Print mechanisms typically are daisywheel technology.

- Segment 3 (Low-End, Full-Size)—Electronic typewriters in Segment 3 mark the low price level of full-size ETs. Print mechanisms typically are golfball or daisywheel technology for all full-size ETs. Editing capability and memory capacity are minimal. These typewriters may or may not have a partial line display.

- Segment 4 (Midrange, Full-Size)—Segment 4 electronic typewriters represent the midprice level of full-size ETs. Editing capability is between Segments 3 and 5 and memory is limited to a few thousand characters. Line display is common.

- Segment 5 (High-End, Full-Size)—Electronic typewriters in Segment 5 represent the high price level of full-size ETs. This segment includes ETs with functionality that considerably overlaps that of products described as word processors, personal computers, etc. Editing capability is substantial and memory capability is many pages (10–100). Removable memory is available. Displays of many sizes may become standard.

- Segment 6 (Display)—Typewriters that fit the Segment 6 definition are positioned by the vendor as a typewriter and fit a typewriter footprint. These products have fixed or detachable keyboards, lift-off ribbons, and a screen size 12 lines by 80 characters as a minimum. Removable memory is common.

- Segment 7 (Modular Displays)—Typewriters that fit the Segment 7 definition are sold into the typewriter-based market and have a modular orientation (rather than having a typewriter footprint). These models also have lift-off ribbon capacity and a screen size 12 lines by 80 characters as a minimum.

Word Processors

Word processors are workstations that are designed for entering, manipulating, filing, and printing text documents. Workstations are defined as computer-based products that perform specifically defined functions as an aid to a user in completing a specifically defined task or series of tasks.

- Standalone word processors are capable of functioning independently from a central controller or storage device, although they may communicate with each other. These products generally have removable magnetic media. Products that have evolved from electronic typewriters generally are not included in this category. The ability to share a printer among workstations does not disqualify a product from being a standalone word processor.

- Shared-system word processors are connected to an external file server or controller.

- Word processor file servers are centralized data storage devices that are accessible and dedicated to shared word processing units.

Definitions

Smart Cards

Smart cards are typically credit card or credit card size devices that contain one or more integrated circuits. These devices are usually carried by an individual. Common applications include financial transactions, record keeping, and user identification.

TELECOMMUNICATIONS

Dataquest's Telecommunications Industry Service (TCIS) defines the equipment in its industry accordingly.

Telecommunications includes products and services that provide or manage the flow of information from person to person, person to machine, or machine to machine. Telecommunications equipment is hardware and software products that facilitate telecommunications. In the forecast, the telecommunications equipment market analysis is a combination of customer premises telecommunications equipment and public telecommunications equipment. (These categories combine with radio, broadcast and studio, and other to become the entire communications sector. Within radio, TCIS monitors the cellular mobile radio market as well. Those definitions are also included.)

Customer Premises Telecommunications

Premises telecommunications equipment comprises the transmission and switching equipment used by end users in implementing premises voice and data networks. The premises telecommunications market analysis is a combination of the following segments: terminal equipment, data communications equipment, local area network connections, business communications systems, data PBX, automatic call distributors, and attached network functions.

Terminal Equipment

Terminal equipment, in the data base, includes the following segments: single-line telephone sets and integrated voice/data workstation products.

Single-Line Telephone Sets. Single-line telephone sets are nonelectronic terminals or handsets used for voice communications. A single-line telephone is used as an interface between a user and a telephone switching system.

- Business single-line telephone sets are used in business establishments, including government and education establishments. They include standalone telephones and single-line telephones or stations behind a Centrex, PBX, or key telephone system.

- Residential single-line telephone sets are used in residences and include cordless, standard, feature, and other varieties of residential telephones.

Definitions

Integrated Voice/Data Workstation Products. Integrated voice/data workstation products are desktop or board-level devices that integrate the functionality of a telephone and a terminal, or a telephone and a personal computer. This integrated functionality includes, at a minimum, simultaneous voice and data transmission.

- Asynchronous integrated voice/data workstations are desktop devices with integrated telephone and terminal functionalities that transmit data asynchronously, are compatible with telex and TWX, and have either limited or full editing capabilities. These devices have terminal capabilities frequently referred to as "conversational" or "dumb," and correspond to basic alphanumeric display terminals.

- Synchronous integrated voice/data workstations are desktop devices with integrated telephone and terminal functionalities that have full editing capabilities, operate in either character or block mode, and provide IBM 3270 emulation by direct plug-compatibility or by incorporation of software emulation of 3270 protocol. These devices may offer additional, non-3270 features.

- Personal computer integrated voice/data workstations are desktop devices with integrated telephone and personal computer functionalities. They have local programmability, local mass storage, and resident operating systems.

- Integrated voice/data add-ons are telephones that attach to a terminal or personal computer, or circuit boards designed to be plugged into terminals or personal computers, to provide integrated voice/data functionalities.

Data Communications Equipment

Data communications equipment includes the following segments: modems, statistical multiplexers, T-1 multiplexers, and front-end processors.

Modems. Modems are electronic devices that provide modulation and demodulation functions of transmitted data signals over telephone lines, and convert digital data signals to analog for transmission over leased lines or the analog public switched telephone network. A number of other features are available on modems. Dataquest segments modems on the basis of type (data terminal or personal computer) and transmission speed, expressed in bits per second (bps).

Data terminal modems are intended primarily for use with data terminals. All modems were data terminal modems prior to 1982, when some modems first started to be marketed expressly for personal computers.

- 300-bps data terminal modems

- 1,200-bps data terminal modems

- 2,400-bps data terminal modems

- 4,800-bps data terminal modems
- 9,600+-bps data terminal modems

Personal computer modems are intended primarily for use with personal computers, though functionally they may be identical or nearly identical to data terminal modems.

- 300-bps personal computer modems
- 1,200-bps personal computer modems
- 2,400-bps personal computer modems
- 4,800+-bps personal computer modems
- High-speed modems include modems that fall into the following transmission speeds:
  - 14.4 Kbps
  - 16.0/16.8 Kbps
  - 19.2 Kbps

Statistical Multiplexers. Statistical multiplexers are electronic devices that consolidate several data streams onto a single high-speed telephone line.

T-1 Multiplexers. T-1 multiplexers are electronic devices that consolidate or pool multiple data streams onto a single high-speed T-1 data line. A T-1 line operates at 1.544 Mbits/sec and allows multiplexing 24 64-Kbit/sec channels on a single line. T-1 multiplexers are synonymous with the telephone company term "DSD-1 Facility."

Front-End Processors. Front-end processors are computer-based products expressly designed to relieve host computers of processing tasks such as line control, message handling, code conversion, error control, and application functions. They may also serve the functions of network management and routing, thus off-loading these duties from the host computer. Included are remote concentrators that are not attached directly to a host computer but are connected via a communications link to another front-end processor. Not included in this definition are general-purpose computer systems functioning as front-end processors.

Definitions

Local Area Network (LAN) Connections

Local area network (LAN) connections are combinations of hardware and software that enable connection of a device to a cable-based network system that serves a building or a campus environment. The network must be capable of connecting three or more devices in a peer-peer relationship for the purpose of sharing information and resources. Excluded are connections that are point-to-point, through PBXs or through data PBXs. Dataquest segments LAN connections on the basis of the type of device connected—multiuser computer systems, terminals, personal computers, office workstations, computer-aided engineering workstations, and special-purpose devices.

Local Area Network Computer System Connections. Local area network computer system connections are the hardware and software that directly connect a multiuser computer system to a network, allowing the system to communicate with other devices on the network.

Local Area Network Terminal Connections. Local area network terminal connections are the hardware and software that connect any type of device to a network via an industry standard interface, such as RS-232-C or IBM 3270. This definition includes connections of devices, such as personal computers that access a network via terminal emulation.

Local Area Network Personal Computer Connections. Local area network personal computer connections are the hardware and software that directly connect a personal computer to a network, excluding network connections via terminal emulation.

DSU/CSU

Data service units (DSUs) and channel service units (CSUs) provide an interface to digital services such as the Bell Dataphone Service (BDS).

Data Network Control Systems

Data network control systems are products or devices that diagnose, isolate, reinstate, or accumulate information for network components or provide reports and analyses of network performance.

Local Area Network Office Workstation Connections. Local area network office workstation connections are the hardware and software that directly connect a word processor or other dedicated office automation workstation to a network, excluding network connections via terminal emulation.

Local Area Network CAE Connections. Local area network CAE connections are the hardware and software that directly connect a computer-aided engineering workstation to a network, excluding network connections via terminal emulation.

Definitions

Local Area Network Special Connections. Local area network special connections are the hardware and software that directly connect a network server (such as a gateway, print server, or file server) or a special factory device (such as a numerical control computer or a robot) to a network, excluding network connections via terminal emulation.

Business Communications Systems

Business communications systems includes the following key segments: key telephone systems and PBX. Market analyses for business communications systems are presented for the number of lines connected to these systems by line-size segment. For PBX, line size refers to the number of lines with which a system is equipped.

Key Telephone Systems. Key telephone systems are customer premises telephone switching systems that allow telephones to interface to the public telephone central exchange or office without using an access code. Typically, these systems also require proprietary multibutton telephones, a centralized key service unit (KSU), and "skinny wire" cable consisting of 2- or 3-pair conductors. If the system requires dialing an access code, Dataquest classifies it as a PBX.

The key telephone systems market is segmented by technology (electromechanical 1A2 or electronic).

- Electromechanical 1A2 key telephone systems utilize mechanical switching technology for call processing. In other words, these systems use a metallic connection in the call processing circuitry.

- Electronic key telephone systems utilize electronic switching technology for call processing. In other words, these systems use an electronic switching matrix in the call processing circuitry.

PBXs (Private Branch Exchanges). PBXs (private branch exchanges) are customer premises telephone switching systems that, through the dialing of an access code, permit telephones to interface to the public telephone central exchange or office. A PBX includes desktop end-user terminals, attendant consoles, building wiring, switching cabinets, and interconnections between switching cabinets.

Dataquest segments the PBX market by system line size. Lines are the number of telephones attached to a system.

- 1- to 40-line-size PBXs
- 41- to 100-line-size PBXs
- 101- to 400-line-size PBXs
- 401- to 1,000-line-size PBXs
- More than 1,000-line-size PBXs

Definitions

Data PBXs (Private Branch Exchanges)

Data PBXs (private branch exchanges) are digital PBXs that allow terminals to switch and contend for computer ports by providing RS-232-C connections, but that do not provide voice switching. The market analysis includes revenues for both data PBX base units and add-on channels.

Automatic Call Distributors

Automatic call distributors are customer premises, computer-based systems that provide real-time monitoring of the telephone system work load; distribute calls to the agent who is idle the longest; use a queuing or waiting list assignment that (1) holds the callers in queue until agents are available, (2) averages out the random flow of traffic, and (3) decreases peak traffic load. These systems also contain features known as gates or agent split groups that provide functional divisions within the routing scheme and allow calls to be directed to specific groups or agents.

Attached Network Functions

Attached network functions includes the following segments: protocol converters, voice messaging systems, station message detail recording/call accounting, and video teleconferencing.

Protocol Converters. Protocol converters are electronic devices that create compatibility between peer protocols at the data link level. These devices are also known as terminal controllers, protocol emulators, communications control units, access controllers, and network access systems. Not covered in this definition are software emulation packages, including host or front-end processor packages; personal computer emulator boards or software; word processing document converters; X.25 gateways, including packet assemblers/disassemblers (PADs); or devices that provide for terminal connection to the host via PBXs, such as computer-PBX interface (CPI) or digital multiplex interface (DMI).

Voice Messaging Systems. Voice messaging systems are computer-based systems that enable flexible, nonsimultaneous voice communications. The principal feature of voice messaging is time shifting of both messages sent and messages received, which is accomplished by message storage on magnetic media. Flexibility is accomplished through software and can include message broadcasting to multiple recipients, controlled access to messages, and other features. Voice messaging functions are available through dedicated, in-house systems; subsystems on PBXs; service bureaus; and specialized software and terminal products. This definition does not include personal computer board-level products.

- Standalone voice messaging systems attach to telephone systems but are not integrated subsystems of the telephone systems. Standalone systems provide basic telephone answering functions and limited access to PBX software features such as call forwarding, return to operator, or message waiting indication. A standalone system requires that the call be manually transferred between the PBX and the voice messaging system.

- PBX-integrated voice messaging systems are integrated subsystems of private branch exchanges (PBXs). PBX-integrated systems provide automatic call routing to the voice messaging system from the PBX and provide users many of the features and functionalities provided by the PBX.

Call Accounting. Station message detail recording (SMDR)/call accounting includes equipment and services that record the calling activity of a Centrex, PBX, or key telephone system. The recorded information can be manipulated to generate reports and support telephone cost allocation and other telephone management information needs. SMDR equipment includes standalone devices, PBX- and key system-integrated systems, and call accounting software for computer systems.

Video Teleconferencing. Video teleconferencing includes equipment and services related to one-way and two-way video communications that use specialized video equipment and/or transmission networks. These communications are for the purpose of conferencing between locations.

Public Telecommunications

Public telecommunications comprises public network services and equipment. Public network equipment comprises the transmission switching equipment used by carriers in implementing public voice and data networks. In the data base, the public telecommunications market analysis is a combination of the transmission equipment and switching equipment segments.

Transmission Equipment

Transmission equipment includes the following segments: multiplex equipment, carrier systems, microwave radio equipment, and satellite earth station equipment.

Multiplex Equipment. Multiplex equipment is equipment used to combine a number of voice-frequency message channels for transmission over a common medium, such as satellite, microwave radio, cable carrier, or fiber-optic cable. Excluded from this definition are data-only customer premises multiplex equipment and multiplex equipment that is integral to carrier or microwave radio systems.

Carrier Systems. Carrier systems provide transmission of a number of voice frequency signals over a common cable. This segment includes subscriber carrier systems and trunk carrier systems.

Microwave Radio Equipment. Microwave radio equipment includes microwave antennae (dishes), transmitter/receiver systems, power supplies, waveguides, channel banks, repeaters, and other equipment used in microwave radio systems. This definition includes both analog and digital equipment and both public common carrier and private industrial equipment.

Satellite Earth Station Equipment. Satellite earth station equipment is the earth-based equipment used in connection with orbiting, geostationary satellites used for voice and data communications and television program distribution. It includes antennae and electronic transmitting/receiving terminals. This definition excludes satellite earth station equipment used for direct broadcasting satellite (DBS) reception.

Switching Equipment

Switching equipment includes the following segments: central office switching equipment, other common carrier switching equipment/tandem switches, private packet data network nodes, and private packet data network packet assemblers/disassemblers (PADs).

Central Office Switching Equipment. Central office switching equipment includes electronic or electromechanical systems that interconnect local telephone lines (loops) and connect local telephone lines to long-distance trunk lines. This definition includes analog and digital equipment (mentioned below) and equipment used by both the Bell operating companies and the independent telephone companies.

- Central office analog switching equipment
- Central office digital switching equipment

Other Common Carrier Switching Equipment/Tandem Switches. Other common carrier switching equipment/tandem switches includes switching equipment used by the other common carriers in providing long-distance communications services.

Private Packet Data Network Nodes. Private packet data network nodes are electronic devices that manage packet transmission around the entire network, automatically rerouting packets over the network when overcrowding of nodes occurs.

Private Packet Data Network Packet Assemblers/Disassemblers (PADs). Private packet data network packet assemblers/disassemblers (PADs) are electronic devices that connect terminals directly to the network and provide the protocol conversion from native mode to CCITT X.25.

RADIO

Under the communications category "radio," the Telecommunications Industry Service monitors the cellular mobile radio market.

Definitions

Cellular Mobile Radio

Cellular mobile radio is a form of telephone system in which the service area is divided into a grid of cells, each served by a low-power transmitter. Each cell is assigned operating frequencies for communications with mobile telephones within the cell. The cell site equipment connects over land lines to a mobile telephone switching office that switches lines between individual mobile units and connects mobile units to the telephone network. Cellular mobile radio equipment is the equipment used in cellular mobile radio systems. This segment includes mobile telephones and base station equipment.

Mobile Telephones

Mobile telephones include mobile units for automobiles and portable units for hand-held operation.

Base Station Equipment

Base station equipment includes all site equipment and switching equipment used in cellular radio systems.

MANUFACTURING SYSTEMS

Manufacturing Systems include programmable equipment used for the production of goods.

Process Control Systems

Process control systems monitor and maintain the operation of plants that manufacture homogeneous materials such as oil, chemicals, and paper. Process control systems are capable of detecting adverse circumstances and taking corrective action. They may also send an alarm to an operator who can then decide on the appropriate response.

Programmable Machine Tools

Programmable machine tools include numerical control (NC) computer numerical control (CNC), direct numerical control (DNC), and flexible machining centers used for metal cutting and metal forming.

Definitions

Mechanical Assembly Equipment

Mechanical assembly equipment includes:

- Dial or rotary assembly machines
- In-line transfer machines
- Flexible assembly equipment (except robots)

Plastic Processing Machinery

Plastic processing machinery includes numerically controlled machinery used for:

- Injection
- Structural foam
- Extrusion
- Blow molding
- Thermoforming
- Reaction injection

Robotic Systems

Robotic systems are automation systems that include a robot, computer hardware and software, and integrated tooling. A robot is defined as a reprogrammable multifunctional manipulator designed to move material.

MATERIAL HANDLING

Material handling equipment and systems encompass a number of technologies covered by the Manufacturing Automation Service. They include equipment classified as follows:

- Movement—Automated guided vehicle systems, conveyors, and monorails are covered in this chapter; cranes and lift trucks are included only when they are computer-controlled; material handling robots are included in the Robotics in Manufacturing chapter.

- Storage—Automated storage and retrieval systems, miniload, microload, and carousels are covered in this chapter.

- Identification—Bar codes, radio frequency, machine vision, and other sensors used for identification are covered in the Sensors in Manufacturing chapter.

- Controls—The computers, programmable controllers, and software used in material handling are included in the MAS volumes Computers in Manufacturing and Software in Manufacturing.

Automated Guided Vehicle Systems (AGVSs)

AGVSs include unmanned mobile transporters under programmable control that are used to move materials and tooling throughout the factory and warehouse. These transporters include towing vehicles, pallet trucks, unit-load transporters, light-load transporters, automated forklifts, and self-loading and self-unloading vehicles.

Automated Storage and Retrieval Systems (AS/RSs)

AS/RSs include all hardware, software, and systems that are used for mechanical hoists and carriages, and that interface with racks and bins for automatic storage and retrieval of unit loads, pallets, and individual parts. These systems move materials from inventory to operations and back to inventory, frequently for work-in-process inventory.

Automated Warehouse Systems (AWSs)

An AWS refers (broadly) to dedicated AS/RSs that are used not on the factory floor, but in warehouses that may or may not be located with the manufacturing facility. The value of an AWS includes the control system and the associated material handling equipment and structures, but excludes the building unless it is a structural part of the automated system. AWS refers to computerized warehouse inventory control systems, which includes the computers and software that monitor and control the materials in warehouses, whether or not the materials are part of an automated storage device or system.

Conveyors

Conveyors are transporting devices for moving materials along a pathway that are driven by a chain, sliding belt, moving slats, or powered rollers. In addition to providing transportation, conveyors can also sort and accumulate. Conveyors are used in nearly every manufacturing and nonmanufacturing industry. Dataquest's MAS focuses primarily on the unit load conveyors that are used in manufacturing, and excludes the bulk handling conveyors that are used to transport coal, ore, oil, grain, etc., in mining, agriculture, and other nonmanufacturing industries.

Monorails

A monorail system transports loads in a suspended carrier, or trolley, that runs on wheels along a fixed overhead rail. Automated monorails offer flexibility through multiple routes and elevations, and provide transportation, accumulation, and storage of goods. Dataquest's MAS looks at both patented steel and aluminum track monorail systems.

MILITARY

Space Systems

Space systems include satellites, various space platforms, launch vehicles, and ground control equipment.

Avionics

Avionics systems include airborne navigation systems, computer systems, flight and engine controls, and instrumentation.

Command and Control

Command and control equipment includes ground and shipboard computer-based information processing systems.

Radar/Sonar

Radar/sonar equipment includes airborne, shipboard, and ground-based search, acquisition, detection, tracking, fire control, and sonabuoy systems.

Electronic Warfare

Electronic warfare equipment includes warning receivers, jammers, assorted electronic countermeasure systems, signal intelligence systems, and reconnaissance systems.

Missiles/Weapons

Missiles and weapons include guidance, control, fusing, and launcher equipment.

Definitions

Communication

Military communications equipment includes voice, data, and cryptographic equipment.

Simulation and Training

Simulation and training equipment includes flight and situation simulators, equipment operation, and maintenance systems.

Miscellaneous Equipment

Miscellaneous equipment includes classified systems, test equipment that are not elsewhere classified (N.E.C.), vehicle control, medical equipment, assorted development and office equipment, and unassigned research and development equipment.

Civil Aerospace

Aeronautical, Nautical, and Navigational Instruments

Aeronautical, nautical, and navigational instruments include flight and navigation sensors, transmitters and displays, gyroscopes, and airframe equipment instruments.

Aircraft Engine Instruments

Aircraft engine instruments include sensors, transmitters, and displays specific to engine functions and do not include flight equipment.

NON-DATAQUEST DEFINITIONS

The following information provides brief descriptions of the equipment that is not defined by Dataquest services but comes from such sources as the U.S. Department of Commerce. We have listed the equipment and definitions by application market segment (as it appears in the respective segments detailed forecast—behind the Electronic Equipment Forecast tab). We have listed only equipment types whose names do not clearly define the equipment.

Definitions

Data Processing

Input/Output

Key Entry Equipment. Key entry equipment includes data entry equipment like key disk, key tape, or keypunch equipment.

Media-to-Media Data Conversion. Media-to-media data conversion equipment includes computer output-to-microfilm recording units, tape print units, card-to-tape conversion units, as well as document entry devices.

Communications

Radio

Mobile Radio Systems. Mobile radio systems include airborne, marine, and ground systems sold as complete packages that include transceivers, power amplifiers, antennae, repeaters, transmitters, etc. It does not include amateur and CB radio equipment.

Mobile Base Stations. Mobile base stations include air, marine, and ground stations (transmit/receive package) and does not include amateur and CB radio equipment (Mobile Vehicular is similar).

Checkout, Monitoring, Evaluation, and Other. Checkout, monitoring, evaluation, and other is classified as electronic support equipment for communication systems.

Broadcast and Studio

Audio Equipment. Audio equipment includes amplifiers, preamplifiers, control consoles, and other equipment, including terminal and broadcast equipment.

Video Equipment. Video equipment includes amplifiers and television cameras and other equipment such as synchronization equipment, live cameras, and control consoles.

Cable Television Equipment

Cable television equipment includes all equipment for both the head and subscriber ends.

Other

Transmitters, receivers, and RF power amplifiers include point-to-point equipment (except amateur and CB radio) and include all components whether shipped complete or separately. Radio communications equipment is also included. These systems are communications equipment and exclude broadcast. (A similar title is listed in Broadcast. That equipment is transmitters, translators, and RF power amplifiers including AM, FM, and television. Broadcast transmission live and phasing equipment is also in this category.)

Definitions

Industrial

Security/Energy Management

Discrete Devices. Discrete devices include automatic controls that are principally used as components for air conditioning, refrigeration, and heating.

Manufacturing Systems/Instrumentation

Test Equipment. Test equipment consists of automated test systems and equipment such as IC testers and PC-board testers, as well as general test equipment (e.g., oscilloscopes, spectrum analyzers, digital multimeters, etc.)

Integrating and Totalizing Meters for Gas and Liquids. Integrating and totalizing meters for gas and liquids include those that register consumption and positive displacement, including meters, fuel dispenser meters, and gas meters.

Panel Meters, Elapsed Time Meters, Portable Measuring Instruments, and Electrical Recording Instruments. All panel meters, elapsed time meters, portable measuring instruments, and electrical recording instruments are electrical indicating instruments used to measure electricity.

Other

Lab and Scientific Apparatus. Lab and scientific apparatus include balances and scales, furnaces and ovens, evaporation, distillation, sterilizers, burners, dryers, and associated and similar equipment used within the scientific and lab environment.

Consumer

Audio

Radio. Home radio receivers include AM, AM-FM, and FM radios that are classified as table models, clock models, and portable radios. It does not include high-fidelity receivers, radio-phonograph combinations, and television receivers, nor does it include automobile radios, stereos, or tape players.

Stereo Sets and High-Fidelity Equipment. Stereo sets and high-fidelity equipment includes phonographs and high-fidelity components including receivers, tuners, power amplifiers, turntables, and audio tape recorders and players. Audio amplifiers are included in this segment as well.

Video

Video Cassette Recorders and Players (VCRs or VTRs). Video recorders and players include complete systems that have a tape format such as beta, VHS, or 8mm.

Video Disk Players. Video disk players include complete systems that have a disk format.

Color Television and Black and White Television Receivers. Household television receiver equipment includes table and portable models of less than 10 inches to more than 17 inches that are both monochrome and color. It also includes console and television–radio–phonograph–type recorder combinations.

Personal Electronics

Electronic Games. Electronic games include those that are for arcades or amusement centers and home games that are typically attached to television receivers.

Input/Output Ratios

As mentioned in the Methodology section, the input/output (I/O) ratio rests at the core of Dataquest's research on semiconductor application markets. The following section defines and discusses the I/O ratio historically, with respect to its applicability to research on semiconductor consumption from an electronic equipment perspective.

THE POWER OF INPUT/OUTPUT RATIOS

I/O ratio analysis offers a number of benefits to the market researcher, which include the following:

- It allows one market variable to be simply derived from another.
- Carefully constructed ratios can be relatively independent of time.
- The ratio can provide a means of "top down" analysis.
- Insight into important trends can sometimes be gained from ratio changes over time.

An example of I/O ratio analysis allowing one market variable to be easily derived from another can be seen by considering the amount of steel used per automobile. If this ratio is known to be relatively constant, steel use by the auto industry can be derived from a forecast of automobile sales rather than by extrapolating steel use.

Carefully constructed ratios tend to be relatively independent of time. For instance, steel use per auto will not be directly changed by variations in steel or auto prices. However, it might vary slowly as the size mix of automobiles is changed, since compact vehicles use less steel than full-size cars.

Input/output ratios tend to provide a type of "top down" analysis. For instance, steel use per car does not specify the type of steel or the supplier that the auto companies will prefer. It simply gives the total available market for steel in autos. Suppliers and products must compete within this available market. Some might gain share by lowering prices or by improving the performance of their material, but total use will remain unchanged.

Because I/O ratios tend to stay constant over the long run, any ratio changes over time provide important trend information. In the foregoing example, if aluminum and plastic were included with steel as the primary materials used in cars, a decline in steel with time might be explained as being due to substitution of another material.

Similarly, with respect to semiconductors, the I/O ratio reflects the relationship between the dollar value of semiconductors in a type of electronic equipment and the revenue generated by that equipment. The ratio is typically expressed as a percentage.

For example, in a "bottom-up" analysis, if a piece of electronic equipment (such as a personal computer) sells for $1,000 and has $100 worth of semiconductors in it, the I/O ratio is expressed as:

$$\frac{\text{Semiconductor Value--(Dollars In)}}{\text{Equipment Revenue--(Dollars Out)}}$$

$$\frac{\$\ 100}{\$1{,}000} = 0.10 \text{ (multiplied by 100) equals 10 percent}$$

On a macro, or "top's-down" level, understanding a company's equipment revenue and its total semiconductor use allows an I/O ratio to be developed for use on the aggregate. For example, instead of examining an individual PC (as above), we can look at the manufacturer's PC revenue and also its semiconductor consumption (both merchant procurement and captive production, if necessary) for the equipment. Here, a company's PC revenue could be $1 billion and its semiconductor consumption for these PCs could be $100 million. Again, we would derive the I/O ratio by dividing dollars in by dollars out and seeing that the aggregate I/O is still 10 percent.

Dataquest derives I/O ratios using both methods--closely examining the semiconductor content of individual pieces of electronic equipment, or looking at aggregate revenue and total semiconductor consumption of companies involved in particular electronic lines of business.

As described in the Methodology section, once an I/O ratio is derived for a given type of equipment, we apply it to the history and forecast of that equipment. In our PC example, if the market in the U.S. in 1984 were $15.9 billion, the semiconductor consumption for that equipment would be approximately $1.59 billion.

ECONOMIC THEORY OF INPUT/OUTPUT RATIOS

Wassily Leontief won the Nobel prize in Economic Science in 1973 for his pioneering work in input/output analysis. He originally did this work to predict the impact of government policy changes on the economy. For instance, input/output analysis might be used at the end of a war to predict the impact of a decline in tank production on steel consumption if the steel use per tank were known.

The basic assumption of early work with input/output analysis was that ratios tend to be unchanging with time. It turns out that this assumption is quite accurate, and that input/output ratios give significant insight into the workings of the economy. Later work has shown that technology and other factors may tend to cause ratios to change with time, and it takes these changes into account (for example, if integration or substitution of one input for another becomes commonplace within the equipment). In the short term, especially with respect to the price-driven semiconductor industry, year-to-year ratios can change dramatically. For example, I/O ratios in 1984 compared with 1985 were vastly different because, on the average, prices in the semiconductor industry changed much more dramatically than in its electronics equipment counterparts. So, depending on year-to-year dynamics, the ratios may change. However, over the long run, from industry cycle to industry cycle, they tend to remain fairly constant.

In its complete form, the Leontief method of analysis divides the economy into segments or industries. Some studies have used as many as 200 segments. Each industry appears in both a row and a column of a two-dimensional matrix. The number at the intersection of two industry segments represents the output of the row industry utilized by the industry heading the column. The sum of the numbers in the row is then the total output of the row industry. The sum of the numbers in a column is the total input to the column industry. The input is not necessarily equal to that industry's output unless other factors such as labor, capital, and profit are included in the analysis.

A Semiconductor Example

The calculator industry was an important consumer of semiconductors in the early 1970s. More importantly, this industry was exposed to extremely rapid technological change during this period: retail selling prices of comparable calculators fell by a factor of 10 or more in four years. Thus, the calculator industry should serve as a severe test of the stability of input/output ratios in high-technology markets and of the effectiveness of this approach.

Input/output analysis offers much insight into the use of semiconductors in calculators. In addition, the calculator products of the early 1970s are similar to the personal computers of today, so some of the insights are still useful.

Table 1 shows an input/output analysis for two calculators: a printing calculator introduced in 1972 and a small pocket calculator introduced in 1976. It is interesting to note the manner in which the costs of items with no semiconductor content fell in such a way as to keep the ratio of semiconductor use to selling price relatively constant. (This ratio rose from 7.7 percent in the 1972 product to 12.3 percent in the 1976 product.)

For instance, the keyboard cost fell from $13.00 to $0.56. This transition was achieved only through a complete change in the technological approach to keyboards. The first keyboard had a separate switch for every key, and each keytop, plunger, and switch had to be assembled from individual components. (In this example, the assembly labor for the keyboard is included in the keyboard price because the keyboard is purchased as a separate item.)

By contrast, the keyboard for the pocket calculator consists of only four items for all keys: a bottom conductor, a spacer, a top conductor, and a molded single-piece keypad. The bottom conductor is arranged in columns, the top conductor in rows. When a key is depressed it makes a connection between the row and the column. The LSI chip processes that information to figure out which key has been depressed. All keys are molded of a single piece of plastic in such a way that they can flex individually.

Input/Output Ratios

Table 1

Input/Output Ratio Analysis for Two Electronic Calculators

	Printing Calculator Circa 1972		Pocket Calculator Circa 1976	
	Dollars	Percent	Dollars	Percent
Selling Price	$595.00	100.0%	$19.95	100.0%
Factory Cost	$195.00	32.8%	$10.01	49.9%
Printer	$ 49.00	8.2%	-	0
Display	-	0	$ 2.40	12.0%
LSI Chip(s)	$ 35.00	5.9%	$ 1.50	7.5%
Other Semiconductors	11.00	1.8%	0.96	4.8%
Total Semiconductor	$ 46.00	7.7%	$ 2.46	12.3%
Keyboard	$ 13.00	2.2%	$ 0.56	2.5%
Case	15.00	2.5%	0.55	2.8%
Power Supply	9.00	1.5%	-	0.0%
PC Board	12.00	2.0%	0.97	4.9%
Other Components	9.00	1.5%	0.21	1.1%
Miscellaneous	3.00	0.5%	0.87	4.4%
Total Other	$ 61.00	10.3%	$ 3.16	15.8%
Labor	$ 39.00	6.6%	$ 1.99	10.0%

Source: Dataquest
April 1988

Fundamentally, the 1976 keyboard achieved its low cost by reducing the number of parts required. Some of this simplicity was achieved by complicating the LSI chip somewhat. Since more complex chips can be purchased every year for the same price, complicating the chip tends to be "free."

Similar changes occurred in other parts of the calculator design. The pocket calculator uses a low-power LSI chip and display. For this reason, the power supply could be completely eliminated by substitution of a battery. The cost of the battery is not included because it is supplied by the purchaser as a separate item.

Substitution of a display instead of a printer for the readout function reduces costs from $49.00 to $2.40. The display might consist either of LEDs or a liquid crystal.

Other components are also less expensive because of the simplicity of the design. The case is less expensive because it is much smaller, and the printed circuit board is less expensive because it holds only 10 or 15 components instead of 600. Most of the additional components are eliminated by including their function on the LSI chip. Several connectors are also eliminated because the chip, display, and keyboard can all be part of the main printed circuit board, whereas in the printing calculator they are mounted separately.

Although the input/output ratios in Table 1 are relatively stable between the two calculator products, they do change somewhat. Some of this change is due to a change in the channel of distribution rather than a change in technology. Note that factory cost for the printing calculator is 32.8 percent of the selling price, whereas for the pocket calculator it is 49.9 percent of the selling price. This difference is due to the fact that the printing calculator has a higher sales expense. It is sold with a direct sales force that calls on customers individually, while the pocket calculator is sold on a wholesale basis through normal consumer channels.

Table 2 recomputes the input/output ratios using the factory cost as a basis. Note here how stable the ratios become: the output device consumes about one-fourth of the cost whether it is a display or a printer. The semiconductor content is about one-fourth of the cost in both instances. Labor is constant at 20 percent. Finally, other costs are about 31 percent in both models.

The relative constancy of these ratios tends to justify the use of input/output analysis in high-technology markets, even during periods of rapid technological change.

Dataquest, in its analysis of end markets, prefers to use a ratio of semiconductor content in dollars to the company's sales in dollars. This ratio tends to be relatively constant with time for a given company, especially when the markup appropriate to the channel of distribution is taken into account. As a cross-check, however, we regularly analyze key types of electronic equipment and the semiconductors that they contain. These analyses are typically performed on equipment, that sells in high volume or otherwise impacts the semiconductor market. They include:

- Personal computers
- Disk drives
- Printers
- Cellular mobile radios

Total semiconductor I/O ratios can also be further subdivided into major categories, such as memory, microdevices, standard logic, ASICs, and linear. They are derived in the same manner as the aggregate semiconductor I/O ratio. This allows an understanding of each opportunity within specific electronic equipment market for example, memory in personal computers, or microdevices in printers.

Table 2

Cost Ratio Analysis for Two Electronic Calculators

	Printing Calculator Circa 1972		Pocket Calculator Circa 1976	
	Dollars	Percent	Dollars	Percent
Factory Cost	$195.00	100.0%	$10.01	100.0%
Printer	$ 49.00	25.1%	-	0
Display	$ -	0	$ 2.40	23.9%
LSI Chips(s)	$ 35.00	17.9%	$ 1.50	14.9%
Other Semiconductors	11.00	5.6%	0.96	9.6%
Total Semiconductor	$ 46.00	23.6%	$ 2.46	24.6%
Keyboard	$ 13.00	6.7%	$ 0.56	5.6%
Case	15.00	7.7%	0.55	5.5%
Power Supply	9.00	4.6%	-	0
PC Board	12.00	6.2%	0.97	9.7%
Other Components	9.00	4.6%	0.21	2.1%
Miscellaneous	3.00	1.5%	0.87	8.7%
Total Other	$ 61.00	31.3%	$ 3.16	31.6%
Labor	$ 39.00	20.0%	$ 1.99	20.0%

Source: Dataquest
April 1988

Methodology

INTRODUCTION

The information behind this Overview tab is presented in three parts. The first, "Methodology," describes Dataquest's segmentation of electronic equipment into six application markets, and introduces the major data bases contained in the notebook. The second section, "Input/Output Ratios," describes the economic research that establishes the basis for using input/output ratios to generate a forecast of semiconductor consumption by application or end-equipment markets. The third section, "Definitions," presents definitions of many of the specific equipment types included in the equipment forecast, which is located behind the tab entitled "Electronic Equipment Forecast."

ELECTRONIC EQUIPMENT MARKET SEGMENTATION

Dataquest segments electronic equipment according to the most widely recognized application areas that form the six major semiconductor application market segments:

- Data Processing
- Communications
- Industrial
- Consumer
- Military
- Transportation

Placement of equipment types within each segment is a matter open to a variety of interpretations. Dataquest spent more than a year and a half compiling and defining this segmentation, utilizing for input:

- Other Dataquest technology services
- Industry analysts in the semiconductor manufacturing community
- Trade association and government statistics

In this way, our segmentation both complemented and enhanced the way electronic markets have historically been analyzed. The assumptions by which Dataquest determined its placement of some of the more controversial equipment types in each segment are described in the following paragraphs.

Methodology

Data Processing

The Data Processing segment is structured to include any equipment whose primary purpose is information processing. This includes add-on and peripheral devices that are used to reproduce computer data for such things as storage and hard-copy output.

The Data Processing segment is further subdivided into Computer, Data Storage Subsystems, Terminals, Input/Output, and Dedicated Systems. The last subsegment includes equipment with a more or less specifically defined operation, such as electronic typewriters, word processors, and automated banking/teller machines.

All personal computers (PCs) are placed within the Data Processing segment rather than in the Consumer segment because they are products whose primary function is flexible data processing. The majority of products listed in the Consumer segment are electrical or electromechanical equipment designed primarily for home or personal use, to which increasingly integrated semiconductor circuitry is being added. Overall, in the cases of appliances and home entertainment systems, the primary function of such consumer equipment is generally not flexible information processing, in spite of the fact that limited dedicated intelligence may be added as features.

Furthermore, the objective of reporting PC production, as with all equipment, is for the purpose of estimating the semiconductor demand engendered by that type of equipment. It is not our objective to report the PC market by application segments such as home, scientific, technical, or business. Such a segmentation would represent a PC market phenomenon that is software based and has little to do with the hardware application of semiconductors. The same can be said for all electronic calculators since they too are primarily tools for information processing. Electronic games are designed with the primary objective of use in the home and, as such, are counted in the Consumer segment.

Communications

The Communications segment is subdivided into Customer Premises, Public Telecommunications, Radio, Broadcast and Studio, and Miscellaneous Equipment. These equipment designations have been developed to accommodate the equipment segmentation used by Dataquest's Telecommunications Industry Service's format and the Standard Industrial Classification (SIC) codes used in the U.S. Commerce Department's Current Industrial Reports.

Industrial

The Industrial segment comprises all manufacturing-related equipment, and it includes some scientific and dedicated systems. The Industrial segment is subdivided into the following categories: Security/Energy Management, Manufacturing Systems, Instrumentation, Medical Equipment, and Miscellaneous Equipment. Here, as with all application market segments, when we present data, subtotals or line items have been arranged so that information on particular equipment types can be easily extracted and relocated whenever possible.

Consumer

The Consumer segment has been subdivided to include Audio, Video, Personal Electronics, Appliances, and Miscellaneous Equipment. Personal Electronics includes products carried or used by individuals, such as games, cameras, or watches. Overall, because much consumer equipment production stems from Japan, the Consumer segment's definition was comprised to complement that region's perspective on the market.

Military

Dataquest has designated military electronic equipment as an application market segment called the Military segment, rather than using the broader segment of "Government," since military electronic equipment purchases constitute the majority of U.S. government spending. Military equipment is primarily dedicated, or produced to order, and can be singled out as representing an "equipment type."

Government spending by other agencies, such as Health and Education or Transportation, tends to be more heavily application-oriented, unlike defense- or military-oriented electronic equipment. For example, government purchases of data processing equipment by these agencies do not represent "government electronic equipment" production because the systems are already counted as U.S. manufacturers' production elsewhere in the equipment segmentation.

Dataquest segments military into two main areas: defense and commercial aerospace. A further segmentation under these two categories can be found in the Military Electronic Equipment Forecast located behind the tab entitled "Electronic Equipment Forecast."

Dataquest is currently researching the military market as part of the in-depth primary research done within the SAM service.

Transportation

To date, the Transportation segment forecasts the demand for electronic equipment based on auto and light truck production. However, we have used the title "Transportation" in order to incorporate future analysis and growth of different vehicle electronics, since electronics are impacting many major vehicle markets including motorcycles and off-highway and agricultural equipment. To date, the market is forecast based on the auto and light truck markets and accompanying estimates of increasing electronic equipment content and use per vehicle. We segment the market into equipment types that belong in different vehicle functional areas, such as

Entertainment, Powertrain, Body Control, Safety and Convenience, and Driver Information. Dataquest reviews technology trends and vehicle market dynamics with auto and semiconductor manufacturers to arrive at its market forecasts. This market is discussed in greater detail behind the Transportation tab of this Semiconductor Application Markets notebook.

DATA BASES

The Semiconductor Applications Markets notebook contains three major data bases. The first two were created for the purpose of deriving the third—the forecast of semiconductor consumption by application or end-equipment area.

The first data base is found behind the tab entitled "Company Electronic Equipment Companies." This data base contains historical information on the electronic equipment revenues (by application market segment) of approximately 50 North American manufacturers. The combined revenues of these companies account for a large percentage of total North American electronic equipment shipments. These electronic equipment revenues by segment are documented for the years 1979 through 1986, establishing trends and common datapoints with the second data base (described below), in which to view the potential future of North American equipment production.

A major objective of this first data base is to facilitate the development of input/output (I/O) ratios. An I/O ratio represents the relationship between the dollar value of semiconductors in a particular type of electronic equipment and the revenue generated by that equipment. For example, if $100 worth of semiconductors are used in a piece of equipment that sells for $1,000, the I/O ratio is 10 percent. This ratio of 10 percent can then be applied to forecasts for future sales of that equipment to estimate the resulting semiconductor demand. I/O ratios are discussed in detail in the following section.

Dataquest has gathered semiconductor consumption information (merchant procurement plus captive production) for many companies. This consumption information, combined with equipment revenue (both by segment and by individual equipment type), provides the basis for the development of the input/output ratios.

The second data base, the Electronic Equipment Forecast, is located behind the tab of the same name and follows the "Company Electronic Equipment Revenue" section. It comprises an extensive set of tables detailing the shipments of electronic equipment by North American-based manufacturers—a market estimated at $240 billion dollars in 1987 and $307 billion dollars in 1991. The information set begins with 1983 and forecasts estimated equipment shipments through 1991. These electronic equipment tables are divided into the six application market segments defined previously. The market forecasts of electronic equipment are used in conjunction with the I/O ratios to forecast semiconductor consumption by each equipment type and overall for each application market segment. This information creates the third data base.

Methodology

The third major set of data is located in the section entitled "Data Base Analysis" behind the tab entitled "Semiconductor Consumption Analysis" and is published in aggregate form for the forecast period. Detailed I/O estimates for each of the approximately 200 types of equipment are printed for the current year. Detailed ratios for 200 types of equipment for the entire forecast period are available to clients on-line or via an inquiry to the SAM staff. We have applied the I/O ratios to the equipment data, to provide a forecast of semiconductor consumption by each application market. The semiconductor market is then broken down by semiconductor product category and by semiconductor technology—all by application market.

This section also discusses overall trends in the application market segments and analyzes specific equipment types. Each of the six application market segments is differentiated by subtabs that follow the main semiconductor consumption tables and tab. Information will be added continuously to these sections as individual market and trend information are explored and developed for specific equipment and markets.

Transportation

The following is a list of the material in this section:

- Semiconductor Consumption--Transportation (data tables), December 1987
- Trends in Automotive Electronics, January 1988

Semiconductor Consumption--Transportation

Table 1

North American Semiconductor Consumption
Transportation
Total Semiconductor
(Millions of Dollars)

	1984	1985	1986	1987	1991	CAGR 1987-1991
Total Semiconductor	$698.0	$788.0	$848.0	$984.0	$1,482.0	10.8%
IC	534.7	573.1	604.6	698.6	1,113.6	12.4%
Bipolar	118.1	111.5	113.0	114.9	164.8	9.4%
MOS	296.4	264.9	279.5	348.2	596.3	14.4%
Linear	120.2	196.7	212.0	235.4	352.6	10.6%
Discrete	129.5	173.4	188.0	218.0	286.7	7.1%
Optoelectronic	33.7	41.3	55.3	67.6	80.4	4.4%

Table 2

North American Semiconductor Consumption
Transportation
Bipolar Logic
(Millions of Dollars)

	1984	1985	1986	1987	1991	CAGR 1987-1991
IC	$534.7	$573.1	$604.6	$698.6	$1,113.6	12.4%
Bipolar	118.1	111.5	113.0	114.9	164.8	9.4%
Logic	91.0	90.2	91.8	92.0	145.9	12.2%
Standard	88.5	81.0	82.7	81.5	103.0	6.0%
TTL	88.5	81.0	82.7	80.4	94.9	4.2%
ECL	0.0	0.0	0.0	1.1	8.1	65.0%
Other	0.0	0.0	0.0	0.0	0.0	N/A
ASIC	2.6	9.1	9.0	10.5	42.9	42.2%
Gate Array	1.3	6.1	5.1	5.9	15.2	26.5%
Cell Based	0.3	0.7	0.8	1.2	12.8	80.0%
PLD	0.0	0.0	0.8	0.9	12.0	91.3%
Full Custom	1.0	2.4	2.4	2.4	2.9	4.1%

Source: Dataquest
December 1987

N/A = Not Applicable
Note: Columns may not add to totals shown because of rounding.

Table 3

North American Semiconductor Consumption
Transportation
Bipolar Memory
(Millions of Dollars)

	1984	1985	1986	1987	1991	CAGR 1987-1991
IC	$534.7	$573.1	$604.6	$698.6	$1,113.6	12.4%
Bipolar	118.1	111.5	113.0	114.9	164.8	9.4%
Memory	27.1	21.3	21.3	22.9	18.9	(4.7%)
RAM	0.0	0.0	0.0	0.0	0.0	N/A
TTL	0.0	0.0	0.0	0.0	0.0	N/A
ECL	0.0	0.0	0.0	0.0	0.0	N/A
ROM/PROM	27.1	21.3	21.3	22.9	18.9	(4.7%)
Other	0.0	0.0	0.0	0.0	0.0	N/A

Table 4

North American Semiconductor Consumption
Transportation
MOS Microprocessors
(Millions of Dollars)

	1984	1985	1986	1987	1991	CAGR 1987-1991
IC	$534.7	$573.1	$604.6	$698.6	$1,113.6	12.4%
MOS	296.4	264.9	279.5	348.2	596.3	14.4%
Micros	187.1	145.9	152.1	178.8	325.4	16.2%
Microprocessor	2.6	1.3	1.5	0.7	0.9	7.3%
8 Bit	2.6	1.3	1.5	0.7	0.9	7.3%
16 Bit	0.0	0.0	0.0	0.0	0.0	N/A
32 Bit	0.0	0.0	0.0	0.0	0.0	N/A
Microcontroller	176.8	135.9	145.0	175.9	320.2	16.2%
4 Bit	28.9	20.5	25.0	26.5	29.6	2.8%
8 Bit	147.1	112.2	114.2	134.6	204.1	11.0%
16 Bit	0.8	3.2	5.8	14.8	86.5	55.5%
Microperipherals	7.7	8.6	5.6	2.2	4.2	18.0%

Source: Dataquest
December 1987

N/A = Not Applicable
Note: Columns may not add to totals shown because of rounding.

Table 5

North American Semiconductor Consumption
Transportation
MOS Logic
(Millions of Dollars)

	1984	1985	1986	1987	1991	CAGR 1987-1991
IC	$534.7	$573.1	$604.6	$698.6	$1,113.6	12.4%
MOS	296.4	264.9	279.5	348.2	596.3	14.4%
Logic	35.7	45.7	66.5	78.2	123.3	12.1%
Standard	9.8	13.7	22.0	22.6	33.8	10.5%
ASIC	25.9	31.9	44.5	55.5	89.6	12.7%
Gate Array	1.1	1.5	2.1	3.1	4.6	10.5%
Cell Based	14.2	19.4	25.9	32.5	80.8	25.6%
PLD	0.0	0.0	0.0	0.1	2.3	100.4%
Full Custom	10.6	11.0	16.5	19.9	1.9	(44.3%)

Table 6

North American Semiconductor Consumption
Transportation
MOS Memory
(Millions of Dollars)

	1984	1985	1986	1987	1991	CAGR 1987-1991
IC	$534.7	$573.1	$604.6	$698.6	$1,113.6	12.4%
MOS	296.4	264.9	279.5	348.2	596.3	14.4%
Memory	73.5	73.4	60.9	91.3	147.6	12.7%
DRAM	8.0	16.9	17.3	26.1	49.8	17.5%
SRAM	0.0	0.0	0.0	0.0	0.0	N/A
EPROM	35.6	28.0	22.0	25.0	41.7	13.7%
ROM	4.6	4.3	2.3	3.3	2.3	(8.9%)
EEPROM/NVRM	22.6	23.0	16.0	33.6	50.1	10.5%
Other	2.7	1.2	3.3	3.3	3.7	3.0%

Source: Dataquest
December 1987

Note: Columns may not add to totals shown because of rounding.

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Trends in Automotive Electronics

INTRODUCTION

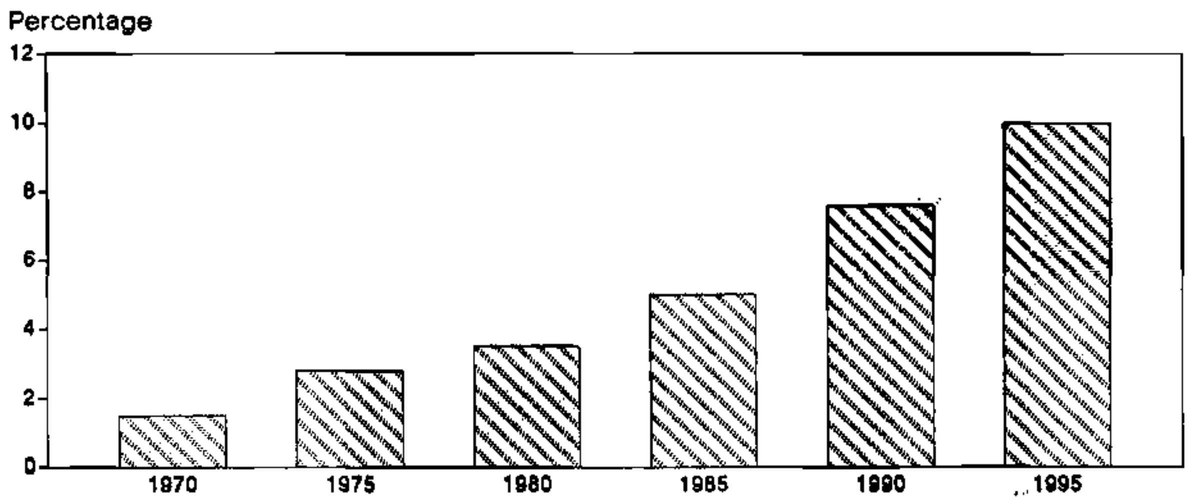
Once dependent on sleek styling and increased engine power to sell their cars, auto manufacturers have completely embraced electronics and semiconductor technology to enhance their product positions in a highly competitive world marketplace. This push by the auto industry is creating a fast-growing market of significant size for electronic subsystem manufacturers and their semiconductor suppliers. North American auto electronics production surpassed $10 billion in 1987, driving an accompanying merchant semiconductor market of slightly more than $900 million.

FERTILE GROUND

Figure 1 shows that, as recently as 1975, 3.0 percent of the value of the average automobile was attributable to electronics. In 1987, the electronic content is estimated to be 6.6 percent and, by 1990, 7.6 percent. Many automotive planners estimate that the content could rise to 15.0 percent by 1995, but 10.0 percent is easily attainable with a conservative extrapolation.

Figure 1

Penetration of Automobiles by Electronics
(Percentage of Retail Price)



Source: Dataquest
January 1988

Trends in Automotive Electronics

Twin events in the early 1970s provided the catalysts for the first wave of automotive electronics growth. The oil shock brought into focus the need for fuel efficiency, while environmental awareness highlighted air pollution by automobiles. Acting on these events, the U.S. federal government enacted policies and legislation to ensure that cars and trucks sold there would pollute less and have better gas mileage. This situation created design constraints that were difficult to address concurrently. With mechanical techniques not entirely feasible for solving the engineering problems of this situation, the auto manufacturers were enticed to try electronics for some elements of engine control. At this stage, the mechanical-design mindset of automotive engineers began to shift in earnest toward electronic control.

By the early 1980s auto electronics had become the product differentiation battleground. This period comprises the second wave of auto electronics—one that we are still witnessing. In addition to aiding the functionality of the vehicle, electronics has become the perceived selling point for manufacturers, a key element that differentiates model years of cars.

Many of the new electronic features are addressing the areas of safety, convenience, and information management. Also, a new era of improvement in powertrain and body electronics is addressing the tough problems of integrated control and treating a vehicle as a total system.

The key benefit to the vehicle manufacturers from the second wave of electronics has been to help profit margins and revenue growth, while unit production growth follows the slow growth track of a maturing industry.

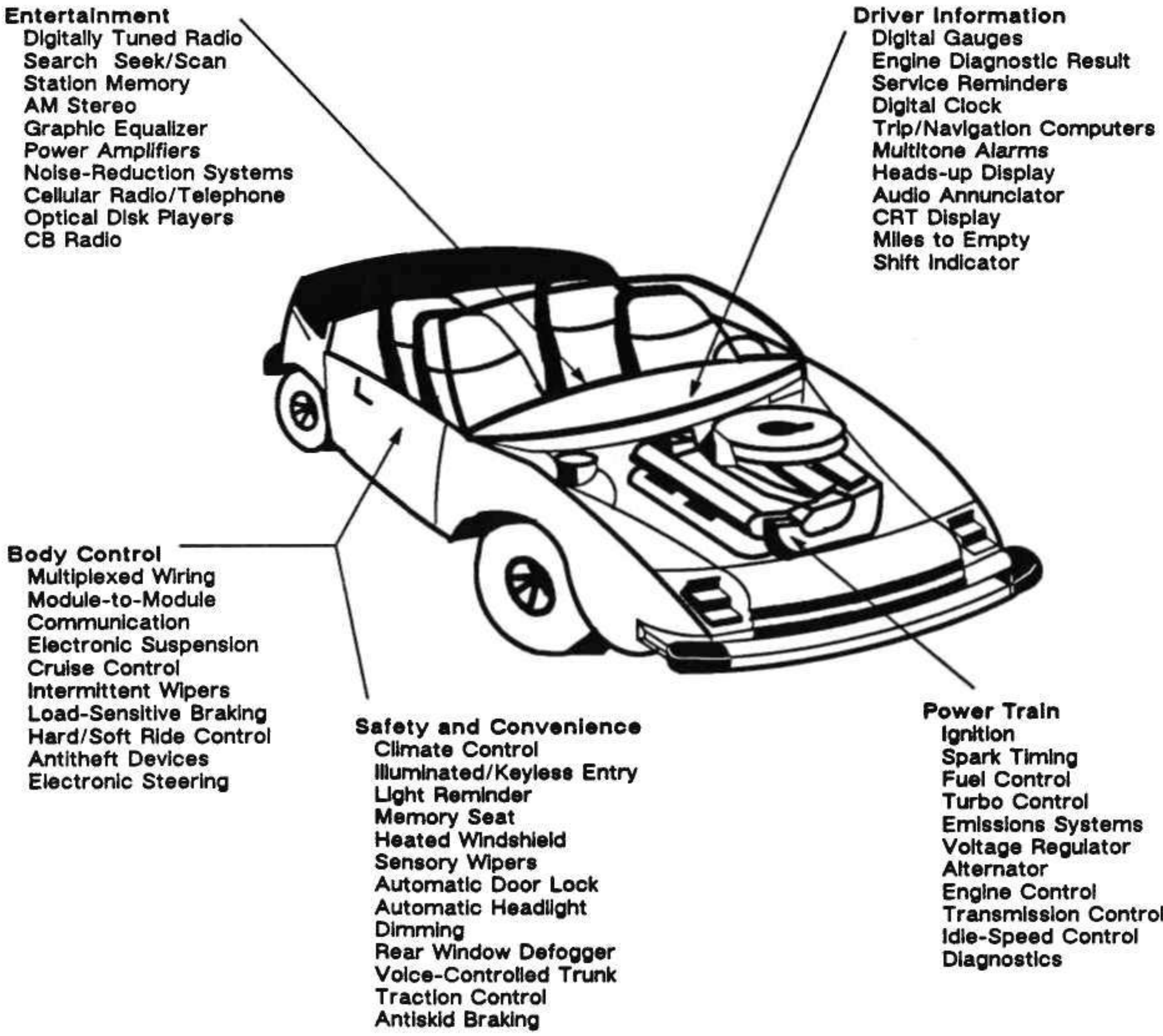
THE ROLE OF ELECTRONICS

Figure 2 illustrates the proliferation of electronics applications that are and will be found in cars and trucks. Typically, new electronic features are introduced in high-end models and migrate, in time, to the midrange and low-priced vehicles. Low-end vehicles can have as little as $200 to $300 worth of electronics, whereas high-end cars like the Cadillacs, with a full complement of options, can consume $2,000 to $2,500 worth.

Described in this section are some new electronics applications that should prove to be of interest over the the next few years.

Figure 2

Electronics in Present and Future Automobiles



Source: Dataquest
January 1988

Wire Multiplexing

The category of wire multiplexing covers the various techniques proposed to eliminate the multiplicity of wiring found in the typical vehicle, as brought on by the proliferation of electronic systems. It also addresses the communication between these various systems.

In addition to the customary 12-volt battery wiring, a rat's nest of wiring and harnesses carries low-voltage control and sensor signals in contemporary automobiles. A given sensor measurement (e.g., engine rpm) can be sent to several places simultaneously, helping to create an inefficient situation from a maintenance and reliability standpoint. Also, there is no current communications standard for the various microprocessor-controlled subsystems (e.g., engine control and antilock braking) to synchronize their operations.

A proposed standard is being offered by the team of Robert Bosch and Intel. It is called Controller Area Network (CAN), and it is essentially a local area network technique. A CAN architecture would utilize a common bus (the multiplexed wiring) and would enlist the use of bus controller ICs to handle the logistics of sending commands and data between control modules, sensors, actuators, and motors.

During 1988, a committee from the Society of Automotive Engineers (SAE) will be deliberating which multiplexing standard(s) to adopt. The key issues will be performance requirements and costs. A possible outcome is that each vehicle manufacturer will adopt its own approach.

Antilock Braking System

Antilock braking systems (ABSs) prevent vehicle skidding and swerving when the brakes are applied. When skidding occurs, the vehicle does not stop as quickly and cannot be controlled as well as when a near-skidding braking condition exists. Wheel sensors note when a skidding condition develops, and the ABS eases hydraulic pressure in the brake system. Although antilock braking is feasible with mechanical systems, the electronically controlled ABS is rapidly becoming the preferred method.

Initially used in Europe, ABSs are being introduced in the United States as a result of regulatory approval in 1984. The prime component of these systems is an 8-bit microcontroller, which uses input from wheel motion and engine torque sensors to compute when skidding occurs. The primary output of the microcontroller is a signal to an actuator, which adjusts brake fluid pressure.

Primarily found on high-end models and pick-up trucks, ABSs are also currently in 5 percent of the units shipped in North America. It is estimated that the penetration rate will exceed 30 percent by 1991. The major manufacturers of ABSs are the following:

- Bendix
- Robert Bosch

- GM Delco
- ITT Teves
- Kelsey-Hayes

A system related to ABS is traction control. This system can utilize the same sensor system to note when the wheels are slipping, for example, on ice, and to cut the rate of flow in the fuel injection system.

Electronic Steering

Electronically actuated steering is entering application reality. This system uses a microcontroller-governed electric motor to accomplish steering. In this case, power is used only when the driver is actually steering the car. The hydraulic systems currently in use draw on energy continuously through a belt hooked to the drive train. TRW, a leader in conventional steering, has also become a leader in pioneering the electronic implementation.

Another steering application for electronics is four-wheel steering. Once again, a microcontroller controls wheel movement. These systems have the additional task of determining how to steer the back wheels as a function of speed. For low speeds (parking), countersteering is needed; for higher speeds (lane changing) fractional positive steering is needed. Primarily, the Japanese auto companies are involved in this area.

Active Suspension

The active suspension application is targeted at improving the comfort of the car's ride as road conditions change. Springs, shock absorbers, and the suspension geometry are all controlled from a microcontroller that determines, in real time, the optimal settings. This feature will become more prevalent in luxury models in the near future. Currently, ride firmness can be controlled electronically in some luxury models.

Driver Information Display

Electronic dashboard displays are penetrating the new models very rapidly. The need to collect and display system status and diagnostic information made possible by digital controls is expected to accelerate. Liquid crystal display, light-emitting diode, CRT, and electrofluorescence are just some of the technologies being employed for visual information presentation. Heads-up displays utilizing holographic techniques may not be far away. In addition to microcontrollers, display-driver ICs are expected to benefit from the acceptance of advanced display technology.

Trends in Automotive Electronics

Advanced Entertainment

The notable trend in audio entertainment is the market acceptance of factory-installed equipment. This is because the vehicle manufacturers have begun to address market demand for multifeatured audio systems. An increasing percentage of the systems is utilizing digital signal processing (DSP) techniques to improve highway radio reception.

In the near future, cellular telephones are expected to be offered as factory-installed equipment.

Collision Avoidance

Utilizing radar, laser, and ultrasound techniques, alone or in combination, collision avoidance is entering the feasibility stage. Initially, systems will simply warn the driver of impending danger, but future systems will be able to influence acceleration, braking, and steering to avoid an object or accident. This application will require the best that DSP has to offer.

Navigation

The two emerging classes of vehicle navigation aid systems are dead reckoning and radio triangulation. Dead reckoning systems utilize a microprocessor-based sensor system, which keeps track of vehicle motion. One system by Etak uses a street map data base to augment location determination. Robert Bosch's Blaupunkt-Werke division, Honda, Plessy, and VDO Adolf Schindling also have innovative products in this market. Typical dead reckoning systems cost about $400 to $1,000.

Triangulation systems involve the use of two or more radio signals from either ground-based Loran C stations or from navigation satellites. Both systems employ the use of radio frequency (RF) receivers for location signal processing. Loran system vendors include II Morrow, Motorola, and Nissan. Satellite system vendors include Geostar and vendors like Rockwell and Texas Instruments with products based on the Global Positioning System (GPS). Typical Loran systems cost about $1,500, and satellite-based systems run about $2,500 to $3,000.

Common to all these systems will be in-dash displays for location presentation. These displays, in conjunction with a growing demand for trip/fuel computer displays, will help provide the critical mass for making electronic displays more widely used.

An adjunct to these navigation systems is position reporting. In this case, once location has been determined, it can also be reported back to fleet headquarters (taxi, trucking, and so forth). This would involve the use of RF transmitters and possibly modems.

Advanced Drive Train Control

Many electronic applications are still emerging in the engine and transmission areas. One general feature will be integrated engine and transmission control. This entails the optimizing of engine power and transmission gear shifting with driver commands and road conditions. Such integration would also imply the replacement of discrete electronic control modules for the engine, traction control, and other functions with a high-performance 16- or 32-bit microcontroller or a tightly coupled bus-based distributed system.

SEMICONDUCTOR TECHNOLOGY APPLIED

Recent advances in ASICs, CAD, mixed process development, reliability, and packaging have helped accelerate the penetration of semiconductors and, thus, electronics into the overall vehicle value.

Process Technology

CMOS has emerged as the digital technology of choice. With power consumption the paramount criterion, CMOS microcontrollers and logic are rapidly displacing previous NMOS and bipolar alternatives. Functional density and cost are also very important, as space requirements are tight and market volumes demand efficiently produced silicon. The inherent noise immunity of the MOS technology has also been a real benefit to the electrically noisy environment of a car.

The mixed signal, mixed transistor process will also fall under great demand. The ability to have a low-voltage, digital CMOS logic circuit on the same IC as a bipolar or MOSFET analog circuit is vitally needed to keep chip count and overall power consumption in check. Smart power ICs will be the prime beneficiaries as this technology continues to be perfected.

ASICs

Cell-based design techniques and ICs are expected to continue gaining rapid acceptance, as functional density and customization keep pushing design requirements. Successful 8- and 16-bit microcontroller cores are becoming incorporated into cell libraries, along with a variety of memory and input/output cells. This capability allows an automotive system designer to customize the A/D and D/A converters, and EPROM and RAM sizes and configuration.

Trends in Automotive Electronics

Microcontrollers

Further penetration by 8-bit controllers into system (e.g., antilock braking) control will continue into the 1990s. As automotive designers begin to integrate discrete control modules and need higher sampling rates/processing throughput, 16-bit controllers are expected to experience growth.

Smart Power

The application of smart power to the vehicle is poised for rapid growth. As high-isolation, mixed signal/transistor semiconductor processes are being perfected, and with learning curve efficiencies approaching, smart power has become a viable technology. Stimulated by the multiplexed wiring concept, every system needing battery power would be controlled by a smart power device. The logical side of the smart power device would connect to the control or data bus, and the power side to the power bus. When a signal to change the status of the controlled electrical device is detected from the data bus, the logical part of the smart power device commands the power side to change the amount of power being fed to the controlled actuator (see Figure 3).

Silicon Sensors

Silicon is rapidly emerging as a preferred choice for sensor applications. Silicon-based architectures (micromechanics) are capable of measuring pressure, humidity, motion, heat, and light. These devices are often more reliable and cheaper than the sensors that they are replacing. Since linear and logic interfaces can be built on-board with the sensor section, these devices can be calibrated and they can provide real-time, detailed diagnostic and system-status information.

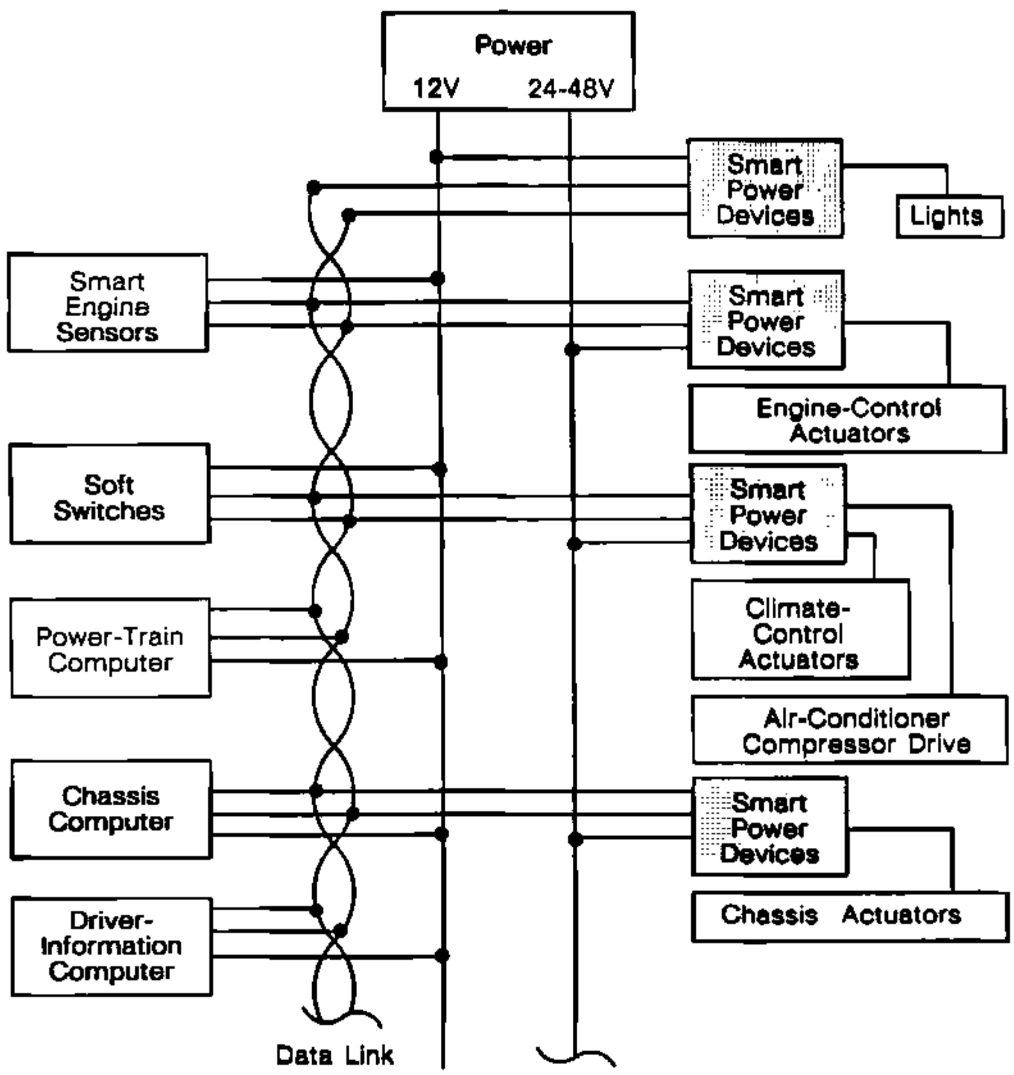
Memory

Although some EPROM functionality is migrating to the special microcontrollers, vehicle applications for EEPROM and DRAMs are emerging rapidly. EEPROMs are especially well suited to gathering vehicle performance and diagnostic data for use at a later time. Their contents, in effect, become the vehicle's maintenance record.

DRAMs will be needed for driver information computers and as data memory for the advanced signal-processing functions.

Figure 3

Vehicle System Featuring Use of Smart Power Devices



Source: Institute of Electrical and Electronics Engineers

PENETRATION OF VEHICLE PRODUCTION BY ELECTRONICS

Table 1 presents the data for auto and truck production in North America by all manufacturers, regardless of base country. After slumping badly in 1981 and 1982, North American production grew at an 18.3 percent CAGR from 1982 through 1985. In 1986, a 2.7 percent decline from 1985 was witnessed, as the American consumer began to cut back. This was in spite of massive incentive campaigns, with very low interest rates. So far, it appears that 1987 experienced more softness, as overall auto and truck production is estimated to have declined more than 6.0 percent. Given the stock market fall of October 1987 as a negative factor, many auto manufacturers are predicting that 1988 production will be cut back from 1987 levels. By 1991, assuming a positive economic cycle, production is expected to once again surpass the 13 million unit level.

Table 1

Estimated North American Auto and Truck Production (Millions of Units)

Vehicle	1983	1984	1985	1986	1987	1988	1991	CAGR 1987-1991
Auto	7.75	8.84	9.28	8.90	7.86	7.66	8.65	2.4%
Truck	2.97	3.96	4.33	4.34	4.55	4.69	4.78	1.2%
Total	10.72	12.80	13.61	13.24	12.41	12.35	13.43	2.0%

Source: Automotive News
Dataquest
January 1988

North American vehicle assembly is shown by major manufacturer in Table 2. Since 1985, General Motors' production share has dropped 7 percent to 46 percent. This reflects, in part, legitimate sales share loss, but also GM's increasing dependence on alliances (e.g., with Toyota on NUMMI) and offshore production.

Ford's production share has risen almost 4 points since 1985, to 30 percent, as it has gained sales share, primarily at the expense of GM. Likewise, foreign-based manufacturers like Honda, Mazda, Nissan, and Toyota are all ramping up their North American production to serve their current demand.

Japanese manufacturers are finding the impact of currency exchange rates and threatened trade protectionism to be strong motivators to move assembly operations onshore. Although sourced mostly in the home market, electronic systems for Japanese cars assembled in North America are beginning to be purchased in North America. Also, there is an increasing opportunity for American semiconductor companies to become designed-in for equipment produced in Japan.

Table 2

North American Auto and Truck
Production Share by Manufacturer

Company	1985	1986	1987
General Motors	53.0%	48.2%	46.4%
Ford	25.8%	28.9%	29.7%
Chrysler*	16.4%	15.9%	15.8%
Honda	1.1%	1.9%	2.6%
Nissan	1.1%	1.3%	1.7%
NUMMI	0.4%	1.6%	1.5%
Volkswagen	0.1%	0.6%	0.5%
Others	2.1%	1.7%	1.8%

*With AMC

Source: Automotive News

Table 3 presents the factory installation percentages of various vehicle electronic systems. Also noted are estimates of penetration by these systems by 1991.

The highest installation rates are found for entertainment and engine control systems. In general, the systems with the highest penetration are those that the manufacturer has decided to offer as standard equipment. This is the case for audio entertainment equipment and certain aspects of engine control systems. The highest penetration potential lays in the body control, driver information, and safety and convenience areas.

Penetration by factory-installed entertainment electronics is high at 91 percent, but the rollover into more expensive, feature-laden systems still presents an attractive opportunity. Cellular telephone systems should witness penetration as a popular option for fleet companies and business consumers. Power train electronics will continue growing, with further integration of engine and transmission control, as well as a displacement of the remaining mechanical features such as distributors.

Driver information equipment, characterized by the instrument panel of the future, is expected to grow attractively, as it further penetrates the midrange and low-end models. The microprocessor-controlled instrument cluster with advanced display technology appears to be a desired feature as many manufacturers are beginning to offer it as standard equipment. Consumer acceptance of a voice alert/reminder system appears to be in doubt, since its penetration has leveled. Navigation system penetration will be limited somewhat, until the product evolves from a predominantly aftermarket status.

Table 3

Estimated North American Factory-Installed Electronic Equipment (Percentage of Factory Unit Shipments)

System	1986	1991
Entertainment		
AM/FM Mono Radio	5%	1%
AM/FM Stereo Radio	37%	23%
AM/FM Stereo Cassette	42%	57%
AM/FM Stereo Cassette, Equalizer	7%	10%
Cellular Telephone	0	2%
Body Control		
Speed Regulator	49%	56%
Intermittent Wipers	71%	86%
Electronic Suspension	3%	14%
Electronic Steering	0	9%
Antitheft Device	2%	9%
Multiplexed Wiring	0	7%
Driver Information		
Digital Clock	76%	93%
Fuel/Trip Computer	3%	9%
Electronic Instrument Cluster	14%	36%
Warning Indicator	71%	84%
Voice Alert	1%	2%
Shift Light	10%	18%
Navigation	0	4%
Power Train		
Electronic Fuel Injection	66%	73%
Feedback Carburetor	34%	27%
Antiknock Device	18%	42%
Spark/Idle Control	84%	95%
Distributorless Ignition	10%	25%
Diagnostic System	72%	88%

(Continued)

Table 3 (Continued)

Estimated North American Factory-Installed
Electronic Equipment
(Percentage of Factory Unit Shipments)

System	1986	1991
Safety and Convenience		
Antilock Braking	5%	31%
Traction Control	0	18%
Automatic Air Conditioning	13%	42%
Headlamp Timing	7%	16%
Keyless Locks	2%	5%
Memory Seat	1%	5%
Day/Night Mirrors	2%	8%
Collision Avoidance	0	4%

Source: Wards
Automotive News
Dataquest
January 1988

Body control features, such as electronic steering, suspension, and multiplexed wiring, should experience rapid growth, as these systems move down the cost curve. Steering and suspension control will continue to move down the model/price strata, while wire multiplexing, when adopted, should experience broad application rapidly.

In serving a need for continually improving safety, antilock braking and traction control systems will experience good growth in the safety and convenience category. Automatic control for air conditioning should continue penetrating most vehicles with factory-installed systems. As collision avoidance technology is perfected, these systems are expected to make a debut before the end of this decade.

Worldwide auto and truck production data are presented by geographic area in Table 4. Of particular interest is the shift of world production to North America during the period from 1980 through 1986. This is due, in part, to the relative robustness of the U.S. market but also reflects a trend toward assembling vehicles in the United States.

Trends in Automotive Electronics

Table 4

Geographic Production Trends
(Millions of Units)

Country	1980	1982	1984	1986	CAGR 1980-1986
United States	8.01	6.88	10.92	11.38	6.0%
Canada	1.37	1.27	1.88	1.86	5.2%
Total North America	9.38	8.15	12.80	13.24	5.9%
Japan	11.04	10.73	11.39	12.26	1.8%
Korea	0.12	0.16	0.27	0.60	30.6%
Australia	0.36	0.41	0.40	0.36	0
Total Southeast Asia	0.48	0.57	0.67	0.96	12.2%
West Germany	4.08	4.16	4.40	4.71	2.4%
France	3.38	3.25	3.40	3.61	1.1%
Italy	1.61	1.60	1.75	1.81	2.0%
United Kingdom & Ireland	1.31	1.40	1.53	1.60	3.4%
Benelux	0.33	0.39	0.39	0.41	3.7%
Scandinavia	0.32	0.38	0.46	0.51	8.0%
Rest of Europe	1.20	1.09	1.46	1.44	3.1%
Total Western Europe	12.23	12.27	13.39	14.09	2.4%
Brazil	1.17	0.86	0.86	1.06	(1.6%)
Mexico	0.49	0.47	0.34	0.27	(9.4%)
Total Latin/South America	1.66	1.33	1.20	1.33	(3.6%)
Total	34.79	33.05	39.45	41.88	3.1%

missing: * China / Hong Kong / Taiwan * India

Source: Automotive News
Dataquest
January 1988

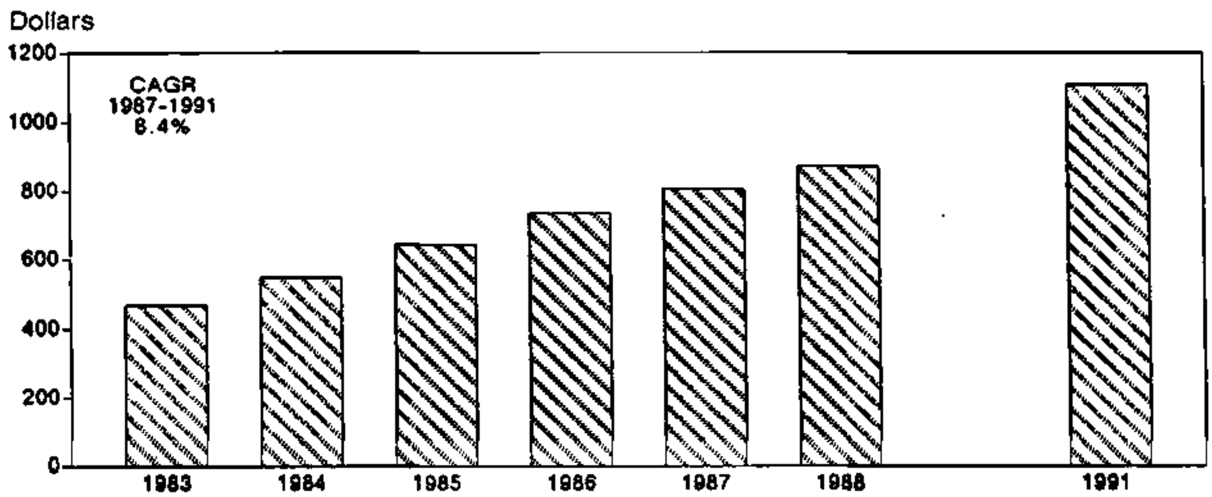
North American Auto and Truck Electronics Market

As Figure 4 points out, its estimated that the average car manufactured in North America in 1987 contains slightly more than \$800 worth of electronic systems and components. This represents a near doubling of consumption since 1982. The estimated \$1,110 worth of electronics per car by 1991 will be approximately 8 percent of the retail price. By then, electronics will represent between 13 percent and 18 percent of the vehicle manufacturer's cost of goods.

Note that the estimates for electronic systems and semiconductors found in this section represent an update from those published in the front of the "Transportation" section in December 1987.

Figure 4

Electronic Content of the Average North American Car



Source: Dataquest
January 1988

Electronic Equipment Forecast

Table 5 presents the forecast for North American automotive and truck electronics production. It includes electronic systems produced in North America but exported for assembly elsewhere. Conversely, it excludes subsystems imported to North America for incorporation into domestically assembled vehicles.

The counterinfluences of declining vehicle production and rising electronic content per average vehicle contributed to electronic growth of 6.5 percent in 1987. The CAGR from 1987 to 1991 for vehicle electronics is forecast to be 9.8 percent. This assumes the combination of continued growth in electronics penetration as well as a 2.0 percent CAGR in vehicle unit production.

The fastest growing area of vehicle electronics in the next few years will be safety and convenience systems. Part of the high growth is due to the small base, but the anticipated rapid penetration of antilock braking and traction control systems will advance this category rapidly.

Table 5

North American Transportation Electronics Forecast (Millions of Dollars)

System	1984	1985	1986	1987	1988	1991	CAGR 1987-1991
Entertainment	$2,142	$2,380	$2,647	$ 2,780	$ 2,935	$ 3,690	7.3%
Body Control	1,060	1,261	1,513	1,640	1,808	2,677	13.0%
Driver Information	1,060	1,237	1,458	1,583	1,743	2,567	12.8%
Power Train	2,473	2,782	3,007	3,155	3,326	4,156	7.1%
Safety & Convenience	706	820	955	1,041	1,152	1,719	13.4%
Total	$7,441	$8,480	$9,580	$10,199	$10,964	$14,809	9.8%

Source: Dataquest
January 1988

Growing at a 13 percent rate, body control electronics will be expanded with several new applications. Electronically assisted steering systems and the anticipated introduction of a multiplexed wiring scheme as standard equipment will help propel this category. Active suspension systems will see penetration into high-end vehicles.

As electronic instrument panels begin to emerge into the class of standard equipment for midrange vehicles, growth in driver information systems is expected to compound at 12.8 percent. Entertainment electronics, as factory-installed equipment, has clearly entered a replacement phase in its life cycle. However, with continued penetration of high-value, digitally based, fully featured audio systems (DAT, compact disk players, and so forth) a 7.1 percent CAGR through 1991 still presents an attractive market.

Although the growth of traditional power train controls like ignition modules has slowed substantially, new applications like distributorless ignitions and the integrated control of engines and transmissions will continue propelling growth. A growth rate of 7.1 percent through 1991 is forecast in this area.

North American Semiconductor Consumption

The per-vehicle estimate of merchant plus captively produced semiconductor usage is presented in Table 6. Currently, at $99 for cars and $62 for trucks, these values are expected to grow to $140 and $86, respectively, by 1991. These numbers represent a continued excellent opportunity for suppliers of semiconductors.

Table 6

Estimated Semiconductor Content of the Average
North American Vehicle
(Dollars)

Vehicle	1983	1984	1985	1986	1987	1988	1991	CAGR 1987-1991
Auto	$57	$66	$78	$90	$99	$108	$140	9.0%
Truck	$40	$49	$54	$58	$62	$ 67	$ 86	8.5%
Weighted Average	$52	$61	$70	$80	$85	$ 92	$121	9.0%

Source: Dataquest
January 1988

Merchant-produced semiconductors consumed for vehicle applications grew an estimated 7.3 percent in 1987 (see Table 7). The estimated CAGR through 1991 for merchant semiconductors is 10.8 percent. This is slightly faster than the electronic equipment growth rate of 9.8 percent for the same period of time. Merchant semiconductor penetration of vehicle electronics is expected to increase from 8.9 percent today to 9.3 percent in 1991. Demand for electronic devices for cars will grow at a 10.7 percent rate through 1991, whereas the less-penetrated but fertile area of trucks and buses will grow faster, at 11.2 percent.

Table 7

Estimated North American Vehicle
Merchant Semiconductor Consumption
(Millions of Dollars)

Vehicle	1983	1984	1985	1986	1987	1988	1991	CAGR 1987-1991
Auto	$412	$522	$583	$621	$661	$710	$ 992	10.7%
Truck	110	176	205	227	249	277	381	11.2%
Total	$522	$698	$788	$848	$910	$987	$1,373	10.8%

Source: Dataquest
January 1988

Merchant demand for semiconductors is expected to remain about constant, as a percentage of total consumption, into the foreseeable future. The captive portion of total consumption is estimated at 20 percent. GM-Delco is by far the largest captive supplier. In the past, these captive capabilities have served an exclusive "make" or "buy" role for the hard-to-find products and packaging technologies. This situation has evolved, somewhat, as the merchants have developed extensive design libraries and CAD tools as well as advanced surface-mount technology. Except for reasons proprietary in nature, merchant suppliers are in a position to supply chips more efficiently than the captive operations.

Table 8 details the use of merchant-supplied semiconductors by electronic system category. Once again, the semiconductor growth rates reflect the growth rates of the target equipment. The strongest growth areas are safety and convenience, compounding at 17.7 percent through 1991; body controls at 16.3 percent; and driver information at 15.8 percent. Only entertainment systems, growing at 9.2 percent through 1991, and power train equipment, at 8.7 percent, are expected to grow less than the average. This is due to the fact that these areas are entering their life cycle maturity phase and are growing from a large base that represented 75.0 percent of all usage in 1987. The combined usage of entertainment and power train equipment will decline to 70.0 percent by 1991.

Table 8

Estimated North American Auto and Truck Semiconductor Consumption Forecast by System (Millions of Dollars)

System	1983	1984	1985	1986	1987	1988	1991	CAGR 1987-1991
Entertainment	$ 91	$129	$136	$146	$157	$168	$ 223	9.2%
Body Control	37	53	62	71	82	93	150	16.3%
Driver Information	45	60	69	79	89	102	160	15.8%
Power Train	325	421	481	508	531	565	742	8.7%
Safety & Convenience	24	35	40	44	59	59	98	17.7%
Total	$522	$698	$788	$848	$910	$987	$1,373	10.8%

Source: Dataquest
January 1988

Trends in Automotive Electronics

The increasing penetration of semiconductor value into the overall value of vehicle systems is reflective of a general phenomenon in all electronic equipment. First, there is a continuing displacement of mechanical control with electrical control. Also, with the advent of VLSI and ASIC design approaches, chip count has been greatly reduced, while the need for passives, connectors, and board space has leveled. Even though the chip count is down, and the price per gate keeps declining, the desire to add more functionality keeps the IC value per system about constant.

The merchant semiconductor market for automotive and truck applications is expected to grow from $909.9 million in 1987 to $1,372.9 million in 1991. This represents a 10.8 percent CAGR. Over the same time period, ICs are expected to compound at 12.4 percent, discretes at 7.1 percent, and optoelectronics at 4.5 percent. Table 9 presents a summarized estimate of merchant semiconductor consumption and forecast growth through 1991.

Table 9

North American Semiconductor Consumption by Type (Millions of Dollars)

	1987	CAGR 1987-1991
Total Semiconductor	$909.9	10.8%
IC	646.0	12.4%
Bipolar	106.3	9.5%
Logic	85.1	12.3%
Memory	21.2	(4.7%)
MOS	322.0	14.4%
Logic	72.3	12.1%
Microdevice	165.3	16.2%
Memory	84.4	12.8%
Linear	217.7	10.7%
Discrete	201.6	7.1%
Optoelectronic	62.5	4.5%

Source: Dataquest
January 1988

Bipolar standard logic, which is used primarily as glue logic around the various microcontrollers, is expected to grow somewhat less than the IC average, as it continues to be displaced by the ASIC solutions. Bipolar gate arrays and PLDs will absorb some of the general move to ASICs, especially for applications requiring high-performance and drive capabilities. Bipolar cell-based designs will begin serving high-performance applications by the end of the decade. Serving primarily existing designs, bipolar PROMs are expected to yield gradually to MOS alternatives.

MOS microdevices constitute the fastest growing segment of vehicle semiconductors of significant size. Growing at 16.2 percent through 1991, they are expected to rival linear devices in market size. The category of MOS microdevices is dominated by 8-bit microcontrollers used primarily in engine control. By 1991, the further proliferation of controllers into braking/traction control, suspension systems, and driver information processing is expected. The 16-bit controllers are expected to grow six times, to $80 million, as integrated power train control emerges into reality.

MOS standard and ASIC logic are expected to grow at 14.4 percent as they expand with microcontroller applications. Cell-based designs are expected to be the technology of choice, as silicon efficiency becomes a primary decision criterion. Eventually, in the 1990s, the bulk of the popular microcontrollers will end up as cores in libraries, so that specialized I/O and memory can be easily combined, and further chip count reductions can be realized. The quest for increased reliability because of lead count reductions as well as shrinking of the circuit card area will continue pushing designers toward highly integrated solutions.

MOS memory ICs will grow at a 12.8 percent rate through 1991. Although the EPROM functionality will be integrated, to a degree, onto the microcontroller, EEPROMs and DRAMs will be in rising demand. As noted earlier, EEPROMs can serve as the car status and maintenance log, and DRAMs will find increasing use as main memory for the various signal-processing and driver information applications.

As in other electronic systems, digital control is taking over in the automobile, but analog devices are expected to continue growing near the average for all semiconductors. Linear devices, in conjunction with discrete devices, will continue to address the analog measurement, processing, distribution, and control functions. While the traditional exemplary applications of radio circuits and voltage regulators will continue to saturate the market, the upcoming use of discrete power MOSFETs, smart power, DC/DC converters, and smart silicon sensors will help propel overall growth.

Optoelectronics is expected to grow below average, as new driver information displays are implemented primarily in LCD and electrofluorescent technologies. However, by the mid-1990s, as power dissipation and noise become more critical issues, fiber-optic communications techniques utilizing either laser diodes or LEDs should become popular.

In general, the bulk of current MOS usage is in NMOS or similar technologies. By the early 1990s the majority of microcontrollers and memories are expected to be low-power CMOS. Nearly all of the MOS ASICs will be done in CMOS, simply because NMOS ASIC technology was never fully available.

AUTOMOTIVE ELECTRONICS PARTICIPANTS

Electronic System Manufacturers

The big three—GM, Ford, and Chrysler--produce an estimated 50 percent of their electronic system needs internally. This percentage is up from 45 percent five years ago. GM, which produces an estimated 60 percent of its needs internally is benefiting from the electronics strengths found in its Hughes acquisition.

Chrysler is also tapping into its military subsidiary for advanced, ruggedized electronics design. Based in Huntsville, Alabama, Electronics City produces an estimated 40 percent of Chrysler's automotive needs. The EED group at Ford also produces an estimated 40 percent of that company's needs.

The other 50 percent of the vehicle manufacturer's electronics needs come from the cadre of independent suppliers that typically specialize in various application areas.

Listed in Table 10 are the primary manufacturers of vehicle electronic systems in North America.

Table 10

Primary North American Manufacturers
of Vehicle Electronic Systems

Company	Principal Electronic System(s)
Allied-Bendix	Fuel injection and ABS
Robert Bosch	Audio and ABS
Chrysler	Audio and engine control
Eaton	Engine and body control
Ford	Engine control
General Motors-Delco	Audio, engine control, and ABS
ITT	ABS and audio
Motorola	Audio and engine control
Rockwell International	Driver information
TRW	Steering, engine, and body control

Source: Dataquest
January 1988

Key Semiconductor Suppliers

Listed in Table 11 are the key suppliers of merchant semiconductors for the North American vehicle electronics manufacturers.

Table 11

Key Merchant Semiconductor Suppliers

Company	Principal Automotive Products
AMD/MMI	Logic devices and microcontrollers
GE Solid State	Linear, discrete, and logic devices
Hitachi	Microcontrollers, linear devices, and memory
Intel	Microcontrollers and memory
Motorola	Microcontrollers, linear, and discrete devices
National	Microcontrollers, linear and logic devices
NEC	Microcontrollers and optoelectronics
Oki	Microcontrollers
Siemens	Microcontrollers and optoelectronics
Signetics	Linear and logic devices
Spraque	Linear and discrete devices
Texas Instruments	Linear and logic devices
Toshiba	Discrete devices and memory

Source: Dataquest
January 1988

DATAQUEST CONCLUSIONS

The viability of the automotive electronics market is assured through the 1990s. Driven by market requirements for utility and efficiency, social requirements for resource and environmental conservation, and vehicle manufacturer profitability, electronics has become the high ground of survivability.

Electronic control of the key vehicle systems like engine management has offered not only efficiency but also a level of functionality not previously feasible. Although mechanical techniques exist for many automotive electronic applications, electronics most often offers size, weight, cost, reliability, and maintainability advantages.

Trends in Automotive Electronics

Real-time, microcontroller-based control and data communication have provided the automobile of the late 1980s with a stepping stone toward a truly automated status. With most of the key systems like the power train, steering, and braking under electronic control already, and with the advent of collision avoidance and navigation, the major challenge in achieving full automation lies in system integration.

The net result is that the automotive designs of the next decade will continue to demand the presence of more sophisticated electronics. In their role as the heart of electronic systems, semiconductors must continue to push the state of the art in economic efficiency and design flexibility, as well as in improved performance and reliability.

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Trends in Electronic Printers

MARKET OVERVIEW

The North American printer market has seen dramatic evolution during this decade—highlighted by annual double-digit unit growth in the early 1980s, negative growth in 1985 and 1986, and then, last year, another explosion in shipments of nearly 30.0 percent. As seen in Table 1, Dataquest expects the industry to shift now into a period of more stable and sustainable growth, estimated at 7.5 percent compound annual growth rate (CAGR) through 1992.

Table 1

Estimated North American Market
All Electronic Printers

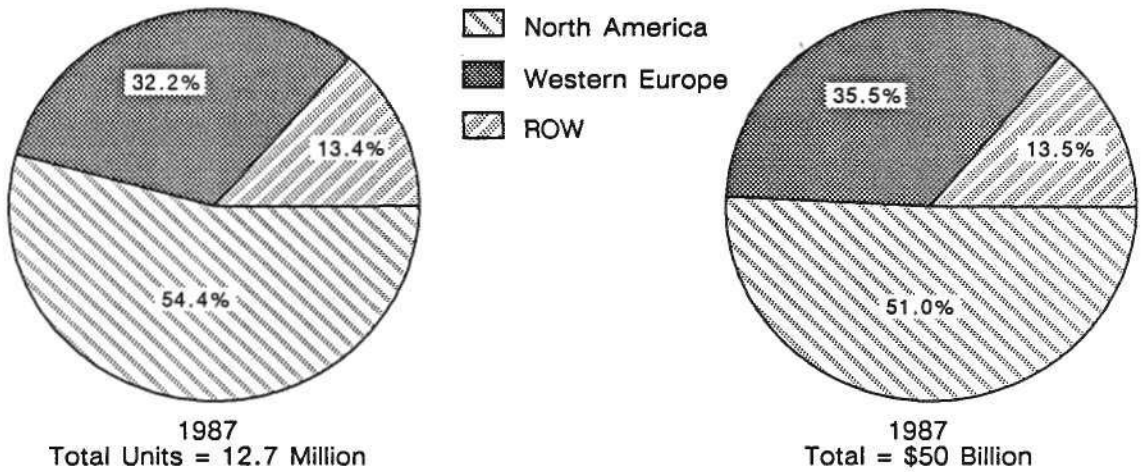
	1985	1986	1987	1992	CAGR 1987-1992
Units Shipped (K)	5,346	4,943	6,933	9,970	7.5%
ASP ($K)	$ 1.3	$ 1.2	$ 1.1	$ 1.1	0.3%
If-Sold Value ($M)	$5,934	$5,977	$7,855	$11,442	7.8%

Source: Dataquest
April 1988

On a worldwide basis, as seen in Figure 1, about 12.7 million printers were shipped last year, generating revenue of $15.5 billion. North America was the largest consumer, accounting for more than half of the total unit demand and spending. By 1992, Dataquest expects the worldwide market to reach $23 billion, with more than 19 million printers shipped. Consumption and spending by region are forecast to closely track 1987's split-out on a percentage basis.

Figure 1

Worldwide Printer Demand Forecast
(Millions of Units)



Source: Dataquest
April 1988

The leap in printer shipments in 1987 was fueled primarily by the robust personal computer market, which itself grew nearly 13 percent to 17.4 million units last year in worldwide shipments. Dataquest estimates that more than 9.0 million of those units were shipped into North America. Other factors contributing to last year's printer growth (and factors that we expect to support continued growth) include:

- More integrated systems sales (including printers) for applications such as desktop publishing, presentation graphics, and technical applications
- A boom in nonimpact printers, with more that 150 product introductions in the North American market last year alone (141 of those in the page, nonimpact, plain paper (PNPP) category
- Continued improvement in the price/performance trade-off
- Further development in distribution channels and product support

Trends in Electronic Printers

SEGMENT ANALYSIS

Dataquest divides the electronic printer market by region, category, technology, speed segment, and source of manufacture. Table 2 shows shipment and if-sold value forecasts for each print category—serial, line, or page.

As shown in the table, serial printers will account for the majority of unit shipments. In 1987, serial printers accounted for 88 percent of all printers shipped. This ratio will decline to about 72 percent in 1990. The ratio is more telling when we look at the if-sold values of these printers. Serial printers, now representing 44 percent of revenue, will account for less than one-third of the if-sold value of all electronic printers by 1992.

Table 2

Estimated North American Market
All Electronic Printers

Shipments (K Units)

	1985	1986	1987	1992	CAGR 1987-1992
Serial Printers	5,092	4,508	6,135	7,204	4.0 %
Line Printers	125	120	120	141	3.2 %
Page Printers	129	315	678	2,364	28.5 %

If-Sold Value ($M)

	1985	1986	1987	1992	CAGR 1987-1992
Serial Printers	$3,362	$2,745	$3,456	$3,630	1.0 %
Line Printers	$1,476	$1,487	$1,403	$1,447	0.6 %
Page Printers	$1,095	$1,745	$2,996	$6,365	16.3 %

Source: Dataquest
April 1988

Trends in Electronic Printers

IMPACT VERSUS NONIMPACT PRINTERS

In 1987, nonimpact printers accounted for 20 percent of unit shipments. A number of manufacturers are expected to continue introducing nonimpact technologies such as thermal transfer and ink jet, increasing the share of nonimpact printers to 49 percent over the forecast period.

SERIAL PRINTERS

Definition

Dataquest defines serial printers as those that print only one character at a time. Serial printers fall into one of the following categories:

- All printers that use a single head or striking mechanism to print characters sequentially across the page
- Electronic devices that produce hard copy from computer-generated data
- Electronic devices that produce hard copy in formats of 80 columns or more

This definition does not include electronic typewriters—that is, letter-quality printers that receive primary data from a keyboard. They are covered by Dataquest's Electronic Typewriter Industry Service.

Dataquest categorizes the serial printer market by imaging technology:

- Impact technology—Serial, impact, fully formed (SIFF) and serial, impact, dot matrix (SIDM)
- Nonimpact technology—Serial, nonimpact, direct thermal (SNDT); serial, nonimpact, thermal transfer (SNTT); and serial, nonimpact, ink jet (SNIJ)

Trends—1987 to 1992

General Trends

Price/performance ratios have stabilized because manufacturers offer enhanced print speeds at higher prices. However, manufacturers are increasing their retail prices in response to the strong Japanese yen.

Competitive pressures are coming not only from similar products but also from alternative print technologies.

Trends in Electronic Printers

Software Trends

Key applications for serial printers are in business and personal productivity. Spreadsheets, data base management, and word processing are the most popular applications software packages, followed by graphics packages. Spreadsheets and data base management require wide-carriage printers, so dot matrix technology has been the primary choice. Word processing packages call for correspondence quality and therefore require fully formed character, high-resolution dot matrix, or thermal resistive (IBM Quietwriter) printers.

Graphics applications software is becoming more prevalent and user friendly. Graphics packages require dot addressability, so the logical output is a dot matrix printer; however, thermal resistive and some ink jet printers can now meet the requirements for dot addressability.

Feature Trends

With the exception of fully formed character printers, many manufacturers are offering both narrow- and wide-carriage printers with similar specifications.

Although nonimpact printers have the most potential for color mixing, dot matrix printers have made the greatest advances in developing color capability. Color capability is offered as a standard feature on some serial printers, while others may carry a premium as high as 15 percent for the color option. The increased use of color displays brings with it increased interest in color hard copy.

Multiple print speeds are now standard on most matrix printers; the speeds are typically listed as draft, correspondence, and near letter quality or letter quality. A new letter-quality market has emerged that consists of 20+ cps SIFF printers, high-resolution SIDM printers (18- and 24-wire), electrothermal resistive printers, and low-end page printers (0 to 10 ppm).

Quiet operation is becoming a key advantage. Nonimpact technologies typically have a noise level of less than 49 dBA. Matrix printers are now achieving noise levels below 55 dBA. Fully formed printers have had limited success in reducing noise levels.

Connectivity and increased implementation of networks, both local area and long haul, allow efficient use of "shared resource" printing at the work group, departmental, and organizational levels. On all levels, more attention is being directed toward the details of the word processing application (i.e., cut-sheet paper handling, variety of typefaces).

Distribution Trends

Most successful products have established service and technical support in distribution channels because users are not generally technically oriented. Successful products also achieve brand recognition using pull-through advertising. They provide compatibility with de facto interface standards, both electrical and protocol (parallel/serial, Diablo 630/Epson).

Impact Technology

Serial, Impact, Fully Formed (SIFF)

Table 3 shows Dataquest's unit shipments and if-sold value (ISV) forecasts for SIFF printers. As can be deduced, the SIFF printer is quickly approaching the end of its product life cycle. Slowed consumer demand and competition from other printer technologies drove a drop in 1987 unit shipments of nearly 34.0 percent over the previous year. From 1985 to 1986, unit shipments plunged 90.0 percent; the year before, 49.0 percent. If-sold value dropped 41.0 percent last year as a result of the price erosion and lower shipments, and it is expected to fall by 16.3 percent each year through 1992.

The 0- to 20-cps segment showed a 1987 shipment drop of approximately 60 percent from the 1986 level, with a sharp decline of approximately 74 percent in average end-user price. Dataquest expects shipments in this segment to decline approximately 23 percent annually through the forecast period, and the average selling price (ASP) in this segment to decline about 27 percent per year, resulting in a rapidly shrinking market in terms of dollar volume. The companies that lead in this market include Brother, IBM, NEC, Qume, and Xerox.

Table 3

Estimated North American Market
Serial, Impact, Fully Formed Printers
(All Speed Segments)

	1985	1986	1987	1992	CAGR 1987-1992
Units Shipped (K)	589	310	232	126	(11.5%)
If-Sold Value ($M)	$437	$247	$175	$72	(16.3%)

Source: Dataquest
April 1988

Serial, Impact, Dot Matrix (SIDM)

SIDM printers continued to lead the market, accounting for approximately 85 percent of all impact printers and 71 percent of all unit shipments in 1987. However, Dataquest expects SIDM printers to drop to less than half of all shipments by 1992, as nonimpact printing technologies, particularly thermal transfer and ink jet, become more popular. Within the impact segment, however, the dot matrix category will gain share, accounting for 96 percent of all impact printers by 1992. Most SIDM printers shipped in 1985 were of Japanese origin.

Table 4 shows our shipment and if-sold value forecasts for SIDM printers. In 1987, the low-speed (0- to 120-cps) segment dropped 23 percent. Midrange (121- to 250-cps) SIDM printers enjoyed a healthy 52 percent jump, and the high-speed (251+) segment had an even more impressive 71 percent increase. Major manufacturers participating in this market include Epson, Okidata, and Star Micronics.

The highest growth over the forecast period will continue to come from high-resolution (24-wire) SIDM printers. The total if-sold value of shipments of all SIDM printers is expected to decline at a negative 1.8 percent CAGR through 1992; however, the high-speed segment will see some growth.

Table 4

Estimated North American Market
Serial, Impact, Dot Matrix Printers
(All Speed Segments)

	1985	1986	1987	1992	CAGR 1987-1992
Units Shipped (K)	3,916	3,761	5,456	5,923	1.7%
If-Sold Value ($M)	$2,487	$2,262	$3,016	$3,090	(1.8%)

Source: Dataquest
April 1988

Nonimpact Technology

Serial, Nonimpact, Direct Thermal (SNDT)

The maturity of SNDT technology resulted in 1987 unit shipments declining 33.0 percent from 1986 levels and if-sold value declining 40.0 percent (see Table 5). Dataquest expects SNDT printer shipments to decline 8.4 percent from 1987 to 1992. However, price erosion due to competition from other emerging nonimpact technologies will cause the if-sold value to decline about 15.7 percent during the same period. The leading companies in this market include Canon, 3M, and Texas Instruments.

Table 5

Estimated North American Market
Serial, Nonimpact, Direct Thermal Printers
(All Speed Segments)

	1985	1986	1987	1992	CAGR 1987-1992
Units Shipped (K)	137	97	65	36	(11.3%)
If-Sold Value ($M)	$82	$49	$29	$13	(15.7%)

Source: Dataquest
April 1988

Serial, Nonimpact, Thermal Transfer (SNTT)

The first full year of volume shipments of printers embodying SNTT printing technologies was 1984. Most of these printers were sold with home computers and show some promise to be low-cost, reliable output devices for the home market. Higher-priced, letter-quality SNTT printers displaced existing midrange SIFF printers. SNTT printer shipments actually declined 22 percent last year, but this segment is forecast to grow slightly, both in unit shipments and in revenue, over the forecast period (see Table 6). This growth is expected for both home and office SNTT printers. Major manufacturers in the market include Brother, Canon, IBM, Okidata, and TEC.

Table 6

Estimated North American Market
Serial, Nonimpact, Thermal Transfer Printers
(All Speed Segments)

	1985	1986	1987	1992	CAGR 1987-1992
Units Shipped (K)	273	216	167	176	8.4%
If-Sold Value ($M)	$246	$116	$120	$135	4.2%

Source: Dataquest
April 1988

Serial, Nonimpact, Ink Jet (SNIJ)

The promise that SNIJ technology had held for more than 30 years was finally realized in very recent years. In 1984, SNIJ shipments grew more than twentyfold from 1983 levels. After a marketwide drop for two years, SNIJ printers have regained momentum in 1987, growing by 72 percent. Shipments are forecast to increase at approximately a 39 percent CAGR from 1987 through 1992, and the if-sold value of SNIJ printers is expected to grow 41 percent (see Table 7). SNIJ printers' versatility makes them suitable for various applications requiring speed, color, graphics, and letter-quality printing. Dataquest anticipates further intense activity in the SNIJ printer market as more manufacturers introduce products with varying price/performance ratios and features. The companies that lead in this market include Canon, Hewlett-Packard, and Siemens.

Table 7

Estimated North American Market
Serial, Nonimpact, Ink Jet Printers
(All Speed Segments)

	1985	1986	1987	1992	CAGR 1987-1992
Units Shipped (K)	185	176	125	1,120	39.1%
If-Sold Value ($M)	$110	$71	$115	$281	41.0%

Source: Dataquest
April 1988

LINE PRINTERS

Definition

Dataquest defines line printers as those that print one line of characters at a time. Line printers fall into one of the following categories:

- Printers with a printhead that covers a full line of the printed page and a striking mechanism that prints one full line at a time
- Printers with an electronic device that produces hard copy from computer-generated data that have been buffered for printing one line at a time
- Printers that produce hard copy in formats of eighty columns or more

Trends in Electronic Printers

Dataquest categorizes the line printer market according to the printing technology:

- Impact technologies include line, impact, fully formed (LIFF) and line, impact, dot matrix (LIDM).

- Nonimpact technologies include line, nonimpact, direct thermal (LNDT); line, nonimpact, thermal transfer (LNTT); ink jet; and any other nonimpact technologies capable of buffering and printing one line at a time.

Trends—1987 to 1992

Line, Impact Printers

The swing from centralized to decentralized computing will make it necessary for printing to follow a similar pattern. This swing will cause the demand for high-duty-cycle printers to decrease and will create a need for printers in applications other than the computer room. High-speed printers continue to be used in computer rooms serving data processing applications, and midspeed printers are found in distributed printing networks where they are used as a shared resource.

Recent gains have been made in reducing the cost of hardware, while performance improvements have caused zero preventive maintenance to become almost the norm. Improvements have also been made in the print quality of multispeed band printers and high-resolution dot matrix printers. Printer noise level and user friendliness have become prominent issues in applications outside the computer room.

Line, impact printers are expected to gradually lose market share to emerging page, nonimpact, plain paper (PNPP) technologies because those technologies are perceived as offering new applications potential based on these current capabilities:

- Ability to print on cut-sheet paper

- Improved price and performance ratios

- High print quality

- Graphics capabilities

Price and performance ratios for all line printers continue to improve. Line, impact, dot matrix (LIDM) printers with speeds of 900 to 1,200 lpm are available. These printers are designed to provide the end user with more print flexibility and to compete with high-duty-cycle PNPP printers that have been configured as line printer emulators.

LIDM technology is expected to be the bridge between line technologies and PNPP technologies because of its graphics capabilities. This is evident in the growing number of applications that use LIDM printers for printing bar codes, graphics, and on-line forms generation.

Line, Nonimpact Printers

The line, nonimpact printer market has recently evolved. Current products are aimed at niche market applications that demand high-quality color output, such as CAD/CAM, IC design, solids modeling, and special business graphics.

The following factors make line, nonimpact technologies unsuited for broader applications such as text processing:

- High cost of hardware
- High cost per page of consumables (special paper and ribbon requirements)
- Printer speeds seldom exceeding 450 lpm
- Lack of software support for driving color applications

This market is currently dominated by Japanese manufacturers, and present shipment levels remain low. Line, thermal transfer printers are expected to gradually increase in shipments over the next five years; line, direct thermal printer shipments will gradually decline until shipment levels are negligible.

Impact Technology

Line, Impact, Fully Formed (LIFF)

LIFF printer shipment levels in 1987 declined from 1986 levels. For a long time, LIFF printers have been a cost-effective technology with good reliability; however, they are becoming obsolete with the increase in competing technologies. Dataquest's forecasts of LIFF printer unit shipments and if-sold value are shown in Table 8.

Table 8

**Estimated North American Market
Line, Impact, Fully Formed
(All Speed Segments)**

	1985	1986	1987	1992	CAGR 1987-1992
Units Shipped (K)	76	63	55	54	(0.2%)
If-Sold Value ($M)	$1,114	$1,031	$881	$811	(1.6%)

Source: Dataquest
April 1988

Printers rated at speeds of less than 650 lpm accounted for 58 percent of all LIFF printers in 1987. This percentage is expected to remain steady, as will shipments into the entire segment. This stunted growth can be attributed to the growth in shipments of page printers that offer line printer emulation and improved price/performance ratios. The midrange of LIFF printers (i.e., between 651 lpm and 1,250 lpm) will also have to contend with line, dot matrix printers as the latter become available. Major manufacturers participating in this market include Centronics, Dataproducts, and IBM.

Line, Impact, Dot Matrix (LIDM)

Due to the inherent flexibility of any dot-based printing method, the life of the LIDM printer market is expected to be prolonged through 1992, although this market will not grow. A number of manufacturers have either announced or started to deliver high-performance products in this segment. Efficient form and paper handling will keep this class of printers a viable alternative in terms of features and performance, in spite of the vast strides made by page and serial printers. Major manufacturers participating in this market include CIE Terminals, Hewlett-Packard, IBM, Mannesmann Tally, and Printronix.

Dataquest's forecasts of shipments and if-sold value over the forecast period are shown in Table 9. Price erosion for the entire segment is expected to be minimal, and both shipments and revenue are forecast to be stable over the next five years.

Table 9

Estimated North American Market
Line, Impact, Dot Matrix Printers
(All Speed Segments)

	1985	1986	1987	1992	CAGR 1987-1992
Units Shipped (K)	48	53	53	53	(0.3%)
If-Sold Value ($M)	$353	$421	$421	$412	(0.4%)

Source: Dataquest
April 1988

Nonimpact Technology

Line, Nonimpact, Direct Thermal (LNDT)

LNDT special-applications printers have virtually disappeared in both shipments and if-sold value (see Table 10) as alternative technologies begin to offer features previously unique to LNDT printing.

Table 10

Estimated North American Market
Line, Nonimpact, Direct Thermal Printers
(All Speed Segments)

	1985	1986	1987	1992	CAGR 1987-1992
Units Shipped (K)	0.2	0.1	0	0	0
If-Sold Value ($M)	$353	$421	$421	$412	(0.4%)

Source: Dataquest
April 1988

Line, Nonimpact, Thermal Transfer (LNTT)

Much of LNTT printing's potential remains to be realized. We believe that performance limitations, the high cost of consumables, and special paper requirements may limit the widespread, high-volume acceptance of this technology for the foreseeable future. LNTT technology's excellent color capability shows promise of picking up in niche applications such as CAD/CAM and business graphics, however. Table 11 shows our forecasts for unit shipments and if-sold value. Manufacturers participating in this market include Calcomp, Mitsubishi, Seiko, Shinko, and Toshiba.

Table 11

Estimated North American Market
Line, Nonimpact, Thermal Transfer Printers
(All Speed Segments)

	1985	1986	1987	1992	CAGR 1987-1992
Units Shipped (K)	0.9	4.0	13.0	34.0	20.5%
If-Sold Value ($M)	$9	$34	$102	$224	17.2%

Source: Dataquest
April 1988

PAGE PRINTERS

Definition

Dataquest defines page, nonimpact, plain paper (PNPP) printers as those that can buffer, in part or in whole, a page of images received from an electronic source and then transmit these images to a receiving substrate. The printer's hard copy must be produced from computer-generated data, and it must be in a format of 80 columns or more. The page is printed in its entirety once the substrate begins to move through the print engine.

Trends—1985 to 1990

Dataquest foresees greater acceptance of nonimpact printers as an alternative to impact printers. We also expect continued product introductions throughout the various printer speed segments as hardware prices decline and performance improves.

Products based on ink jet, ion deposition, and magnetic technologies continue to gain greater acceptance, especially as line printer replacements. However, printers based on electrophotography will continue to dominate the market.

Dataquest expects further development of software and interfaces for nonimpact technologies to increase functionality. The boom in electronic publishing is creating a growing and potentially large market niche for high-quality PNPP printers. Color research will open up more market opportunities. Price continues to remain a function of processing power.

Page, Nonimpact, Plain Paper (PNPP) Printers

PNPP printer technologies include the following:

- Electrophotography
  - Laser
  - LED (light-emitting diode)
  - LCS (liquid crystal shutter)
- Ionography
- Magnetography
- Ink jet

PNPP printers are the most dynamic segment of the electronic printing industry. The PNPP printer market, which constituted only 9 percent of shipments but 38 percent of the value of the total 1987 electronic printer industry, will account for about 20 percent of unit shipments and 36 percent of revenue (ISV) for the printer market in 1992. Table 12 shows unit shipment and if-sold value forecasts for all PNPP printer segments.

Table 12

Estimated North American Market
Page, Nonimpact, Plain Paper Printers
(All Speed Segments)

70%

	1985	1986	1987	1992	CAGR 1987-1992
Units Shipped (K)	129	315	678	2,375	28.5%
If-Sold Value ($M)	$1,095	$1,745	$2,996	$6,365	16.3%

Source: Dataquest
April 1988

Unit shipments are forecast to grow at an impressive 28.5 percent during the next five years. The unit shipment growth rate of the 0- to 20-ppm segment of the PNPP printer market represented 98.0 percent of these shipments in 1987 and is expected to maintain that share through 1992. In terms of revenue (ISV), the sub-21-ppm segment will account for the lion's share of revenue, although not to the same extreme. Last year's share for the 21- to 50-ppm segment captured 15.0 percent, and two-thirds of the remainder fell in the sub-150-ppm category. We expect continued growth in all speed categories of PNPP printers except the 81- to 150-ppm and 151+-ppm segments, which will fall by 0.7 percent and 29.3 percent, respectively.

DATAQUEST CONCLUSIONS

In our opinion, the overall steady growth and expansion of electronic printers (summarized in Table 13) will help maintain a healthy level of revenue for printer manufacturers and the companies supplying components to those manufacturers. Dataquest estimates that associated semiconductor revenue for electronic printers, for instance, was more than $320 million in 1987.

Table 13

Estimated North American Printer Market

	Units (Millions)				If-Sold Value (Millions of Dollars)			
	1985	1986	1987	1992	1985	1986	1987	1992
Nonimpact								
Page	128.5	314.7	677.7	2,067.3	1,095.4	1,745.3	2,996.3	6,365.2
Serial, Ink Jet	176.3	124.8	214.7	1,119.7	110.4	71.2	115.2	642.7
Serial, Thermal Transfer	273.0	215.6	167.3	250.3	245.7	116.0	119.6	147.0
Serial, Direct Thermal	137.0	97.0	65.1	35.7	82.2	48.5	29.3	12.5
Line, Thermal Transfer	0.9	3.7	13.4	34.0	8.5	33.6	101.6	224.2
Line, Direct Thermal	0.2	0.1	0	0	0.9	0.4	0.1	0
Page, Plain Paper	128.5	314.7	677.7	2,374.5	1,095.4	1,745.3	2,996.3	6,365.2
Total	844.4	1,070.6	1,815.9	5,881.5	2,638.5	3,760.3	6,358.4	13,756.8
Impact								
Serial, Fully Formed	589.3	309.6	231.8	125.7	436.9	247.0	175.2	72.0
Serial, Dot Matrix	3,916.0	3,761.2	5,456.3	5,923.2	2,487.0	2,261.8	3,016.3	2,775.8
Line, Dot Matrix	47.9	53.2	52.6	53.4	352.5	421.4	420.6	412.0
Line, Fully Formed	76.3	62.8	54.5	54.0	1,114.3	1,031.3	880.9	810.6
Total	4,629.5	4,186.8	5,795.2	6,156.3	4,390.7	3,961.5	4,493.0	4,050.4
Total All Printers	5,473.9	5,257.4	7,611.1	12,037.8	7,029.2	7,721.8	10,851.4	17,807.2
Percent Nonimpact	15.43%	20.36%	23.86%	48.86%	37.54%	48.70%	58.60%	77.25%
Percent Impact	84.57%	79.64%	76.14%	51.14%	62.46%	51.30%	41.40%	22.75%

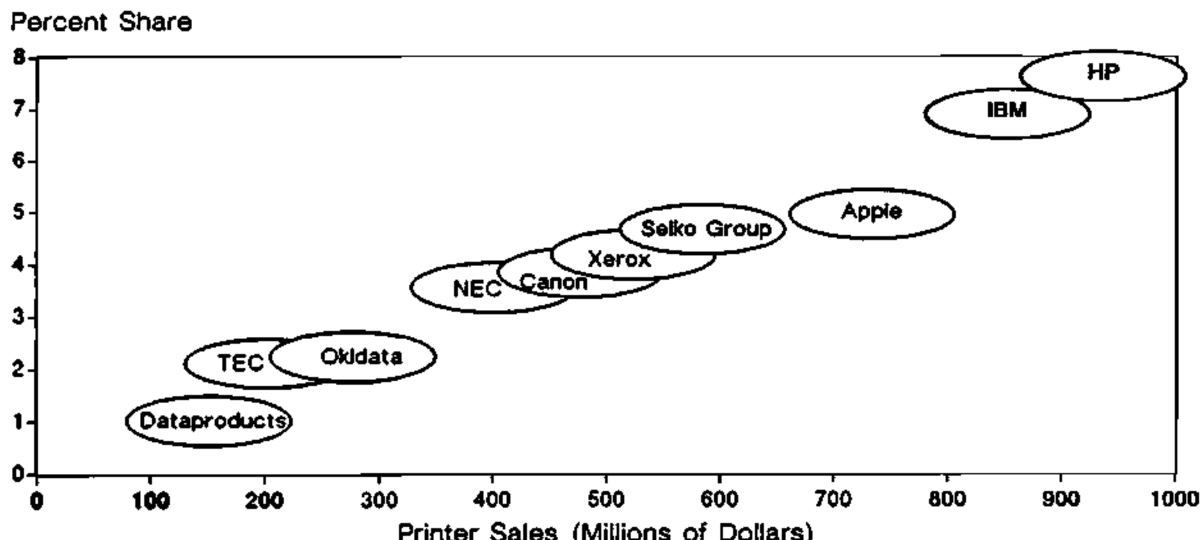
Source: Dataquest
April 1988

We also believe that the industry will undergo a shakeout of suppliers. Already, as shown in Figure 2, just 10 companies account for almost 40 percent of worldwide printer revenue. Interestingly, the top two market participants are full-line suppliers of computer systems, software, and peripherals. The total systems capability status is becoming more important as users increasingly seek complete solutions from a vendor for their various data processing requirements. Another significant strength that these top suppliers boast is very high volume, cost-effective manufacturing capabilities—ever more critical as original equipment manufacturers (OEM's) seek greater margins of relatively steady ASPs.

Growth will also come in part from strategic acquisitions and joint ventures—a trend already evidenced à la the Cannon-HP, HP-QMS, Apple-TEC, and QMS-Imagen relationships. Alliances will be equally critical between printer OEMs and component suppliers, as those in the computer market now readily acknowledge. As specialized printer processors and memory chips are needed to provide the price/performance leaps users demand, manufacturers will seek long-term relationships to thwart being left out if, and when, supplies run short.

Figure 2

Worldwide 10 Leading Printer Companies
Relative Market Shares



Source: Dataquest
April 1988

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Trends in Manufacturing Automation

INTRODUCTION

This section profiles the status and future of manufacturing automation in the United States. Market forecasts, key equipment suppliers, and important technology trends are examined by major category of equipment. The source of this material is Dataquest's Manufacturing Automation Service.

The following are the various categories of equipment covered within this section:

- Manufacturing systems
  - Automated material handling equipment
  - Electronic automated test equipment
  - Factory data collection systems
  - Electronic process control systems
  - Programmable machine tools
  - Robotics
  - Specialized manufacturing equipment
- Manufacturing computer systems
- Manufacturing local area networks

Before exploring each of these aspects of manufacturing, we present an integrated overview of manufacturing automation.

MANUFACTURING AUTOMATION OVERVIEW

Market Forecast and Issues

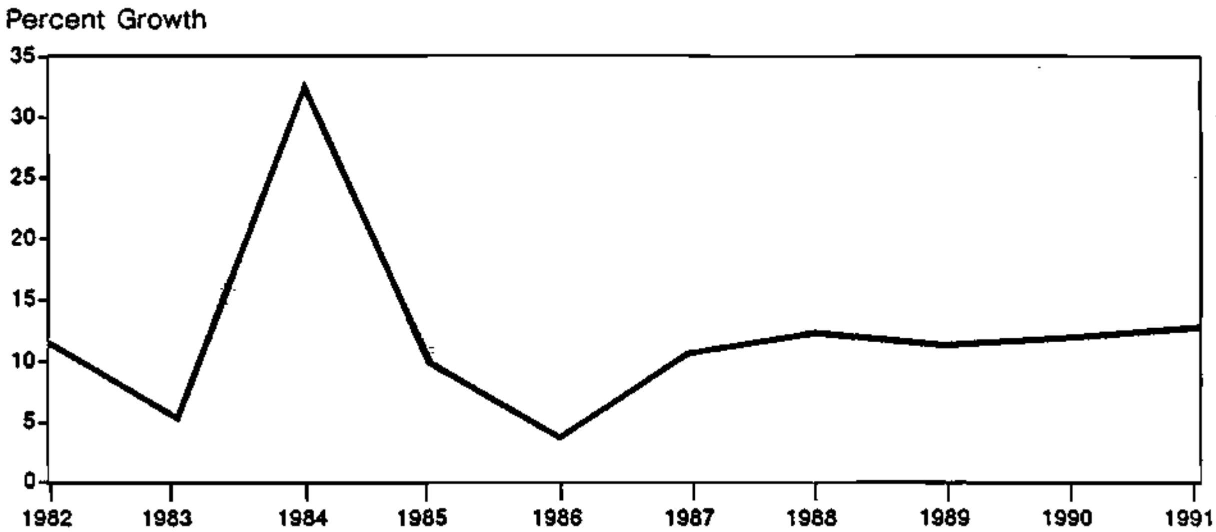
As illustrated in Figure 1, 1986 marked the low point of manufacturing automation growth in the United States during this decade. The market growth should rise sharply through 1991. Manufacturing automation buyers have been slow to adopt new technology as a result of the following factors:

- Long machine tool life cycles of 10 to 20 years
- The need for stable, well-proven computing technology on large-scale manufacturing lines to avoid the risk of shutting down production lines

- The ability to solve many applications with low-technology computer products, which accounts for the high demand at the low end
- The fact that many software applications, once written, are rarely changed (Thus, the increased computer capabilities of newer products are not always needed as with other applications, such as design automation.)
- Top executives in U.S. manufacturing industries who are unfamiliar with the technologies and are reluctant to invest in these areas without having a better understanding of the risks
- Traditional investment justification methods, which do not accurately reflect the competitive benefits of manufacturing automation

Figure 1

U.S. Manufacturing Automation Market
Estimated Annual Growth Rates in Factory Revenue
1982–1991



Source: Dataquest
April 1988

Trends in Manufacturing Automation

Robotic market growth has been disappointing for the following reasons:

- Robots must be part of a system, yet few robot suppliers have been effective or profitable systems integrators.

- Robots were initially considered as replacements for human workers, yet their capabilities fall far short of human flexibility.

- Overblown market growth forecasts caused many competitors to enter the market with a low pricing strategy that undermined the profits for all of the suppliers.

We believe that the U.S. manufacturing automation market will experience accelerated growth rates in factory revenue, as shown in Figure 2. The reasons for these increases are as follows:

- Increasing concerns in the United States about the adverse balance of payments and the lack of U.S. manufacturing competitiveness

- Increasing government support for manufacturing technology research and technology that transfer into users' businesses

- Reduction of short-term profit emphasis and greater emphasis on long-term stability to prevent unwelcome government interference in manufacturing caused by massive labor work force displacements

- Increasing emphasis on producing close to the markets, together with a decrease in labor content, making offshore production that uses cheap labor less attractive

- Manufacturing of more complex, higher-quality products, requiring automation and close ties between design and production, particularly in the electronics and semiconductor industries

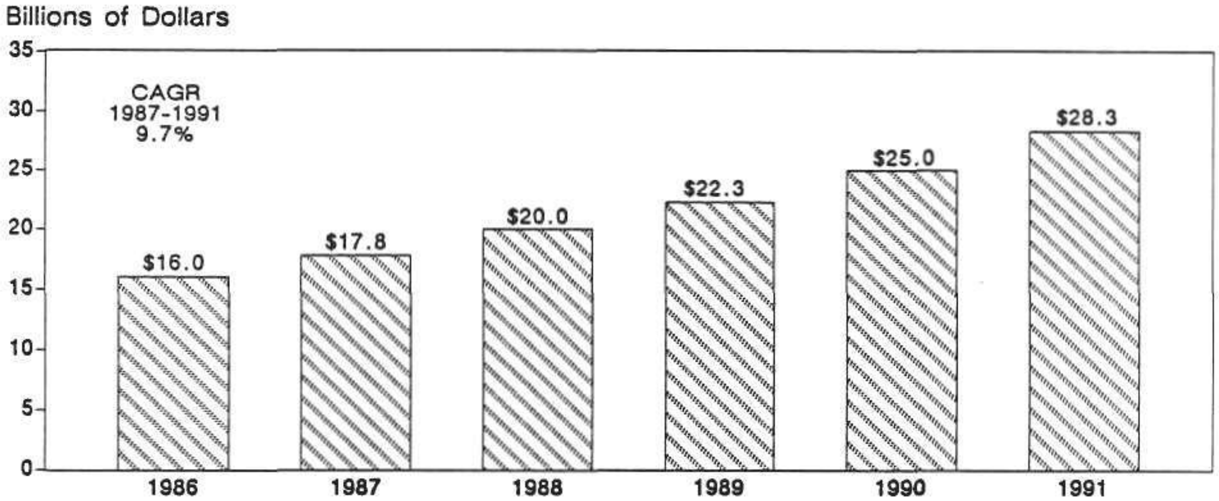
- Increasing amounts of automation used in manufacturing stages that are hazardous to workers

- A trend toward pulling back from offshore manufacturing to more closely tie vendors and users in a just-in-time supply environment

Figure 3 is a graphic presentation of the worldwide regional manufacturing automation revenue breakdown.

Figure 2

U.S. Manufacturing Automation Market
Estimated Factory Revenue
(Billions of Dollars)

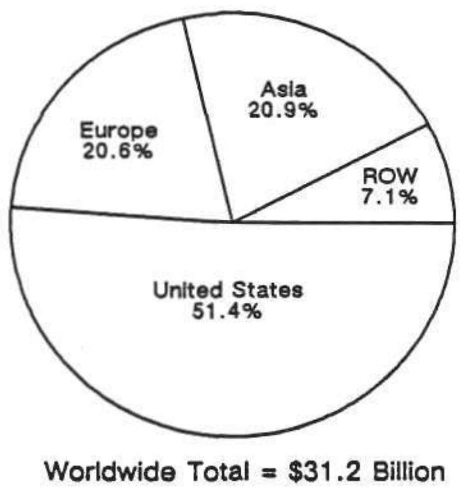


Note: Estimates include computers, software, networks and decision support systems, and manufacturing systems. Design automation, lab automation, and office automation are excluded.

Source: Dataquest
April 1988

Figure 3

Worldwide Manufacturing Automation Market
Factory Revenue Distribution by Region
1986



Worldwide Total = $31.2 Billion

Source: Dataquest
April 1988

Companies and Market Share

Table 1 lists the 1986 manufacturing automation revenue estimates for the top 10 U.S. vendors. Dataquest estimates that the total U.S. revenue for 1986 was $16.0 billion, excluding the CAD/CAE segment, which accounted for an additional $2.9 billion.

IBM is the largest vendor, and, if the design automation functions (CAD/CAE, including engineering workstations and software) were included in our analysis, IBM would be the dominant vendor, with U.S. revenue of $2.7 billion. Its strengths in both the CAD/CAE and CAM software applications segments together with its manufacturing systems and CAM hardware products provide IBM with a wide scope across the manufacturing automation industry.

Hewlett-Packard ranks second in U.S. revenue, with more than $600 million in 1986. This is due to its diverse product lines in automatic test systems and its strengths in manufacturing computer system product lines in both hardware and applications software packages.

Table 1

Top 10 U.S. Manufacturing Automation Vendors by Estimated Factory Revenue (Millions of Dollars) 1986

Vendor	Computers	Software	DSS/ Networks	Systems	Total Revenue	Market Share
IBM	$1,342	$ 98	$ 2	$ 125	$ 1,567	9.8%
Hewlett-Packard	145	12	1	466	624	3.9
Allen-Bradley	348	1	16	105	470	2.9
Digital Equipment	376	7	25	18	426	2.7
Cross & Trecker	25	0	0	349	374	2.3
Cincinnati Milacron	25	1	0	325	351	2.2
Schlumberger	0	18	0	273	291	1.8
Honeywell	15	15	0	170	200	1.2
General Electric	75	4	4	82	165	1.0
Gould	150	2	8	0	160	1.0
Other	1,466	1,264	513	8,169	11,412	71.1
Total	$3,967	$1,422	$569	$10,082	$16,040	100.0%
Segment Share	24.7%	8.9%	3.5%	62.9%	100.0%	

Source: Dataquest
April 1988

Allen-Bradley, a division of Rockwell International, is the third-largest vendor. This position is derived mainly from its leadership in programmable logic controllers (PLCs), computer numerical control and distributed numerical control devices, and its proprietary factory LAN product. Allen-Bradley holds 2.9 percent of the total manufacturing automation market.

Digital Equipment ranks fourth in U.S. revenue, with $426 million. This position does not really fairly represent Digital's strength in manufacturing automation, however, because Table 1 represents direct sales to users. Digital primarily sells its hardware to OEMs. If the content of Digital's hardware that is incorporated by vendors into manufacturing automation systems were included in Table 1, Digital's market share position would be much higher.

Cross & Trecker ranks fifth with 2.3 percent market share. The company has become the largest machine tool vendor as a result of recent mergers and acquisitions. Its machine tool products, together with computer numerical control, distributed numerical control, and flexible manufacturing system devices for its machining systems, give Cross & Trecker a strong base for expanding into other manufacturing automation segments, such as material-handling systems and robotics.

General Electric is both a major vendor and user of manufacturing automation systems. The acquisition of Calma in 1981 gave GE a strong presence in the CAD/CAE market segment. Although GE's systems integration service has not been as successful as the company had originally hoped, it nevertheless is one of the major vendors for this service. Dataquest expects this market segment to grow in the late 1980s, thus augmenting GE's position in the overall manufacturing automation industry.

No vendor dominates all of the manufacturing automation market segments. The highly fragmented nature of this market is shown in Table 1. In every segment, the Other vendor category is larger than any single vendor. This indicates the immaturity of the industry and is one reason why profits have been so elusive for many participants. All of the top 10 vendors of the manufacturing automation industry together account for $4.6 billion in revenue, representing 28.5 percent of the total market.

Technology Trends

There are several evolving technologies that will impact the future course of manufacturing automation. These are as follows:

- Integrated manufacturing
- Artificial intelligence (AI)
- Group technology (GT)
- Computer graphics
- PCs and microcomputers
- Speech recognition

Although integrated manufacturing is a management rather than a technical issue, it relies on the adoption of communications and data base standards for effective implementation. In particular, the integration of small networks based on department level functions through a "backbone" local area network (LAN) or a mainframe-based hierarchical system is a growing technology development. Important standards projects that are currently under way include:

- MAP—Manufacturing automation protocol
- IGES—International graphic exchange system
- ICAM—Integrated computer-aided manufacturing program sponsored by the U.S. Air Force
- CAM-I—Computer-Aided Manufacturing-International's advanced factory management system
- IDS—Integrated design support system
- AMRF—Advanced Manufacturing Research Facility (National Bureau of Standards)

Figure 4 presents an integrated view of an automated factory, complete with interfaces to engineering, finance, and marketing.

AI systems (including the so-called expert systems) are just beginning to show up in the manufacturing environment. While primarily a software technology, AI will create a demand for hardware at least as great in dollar value as will software.

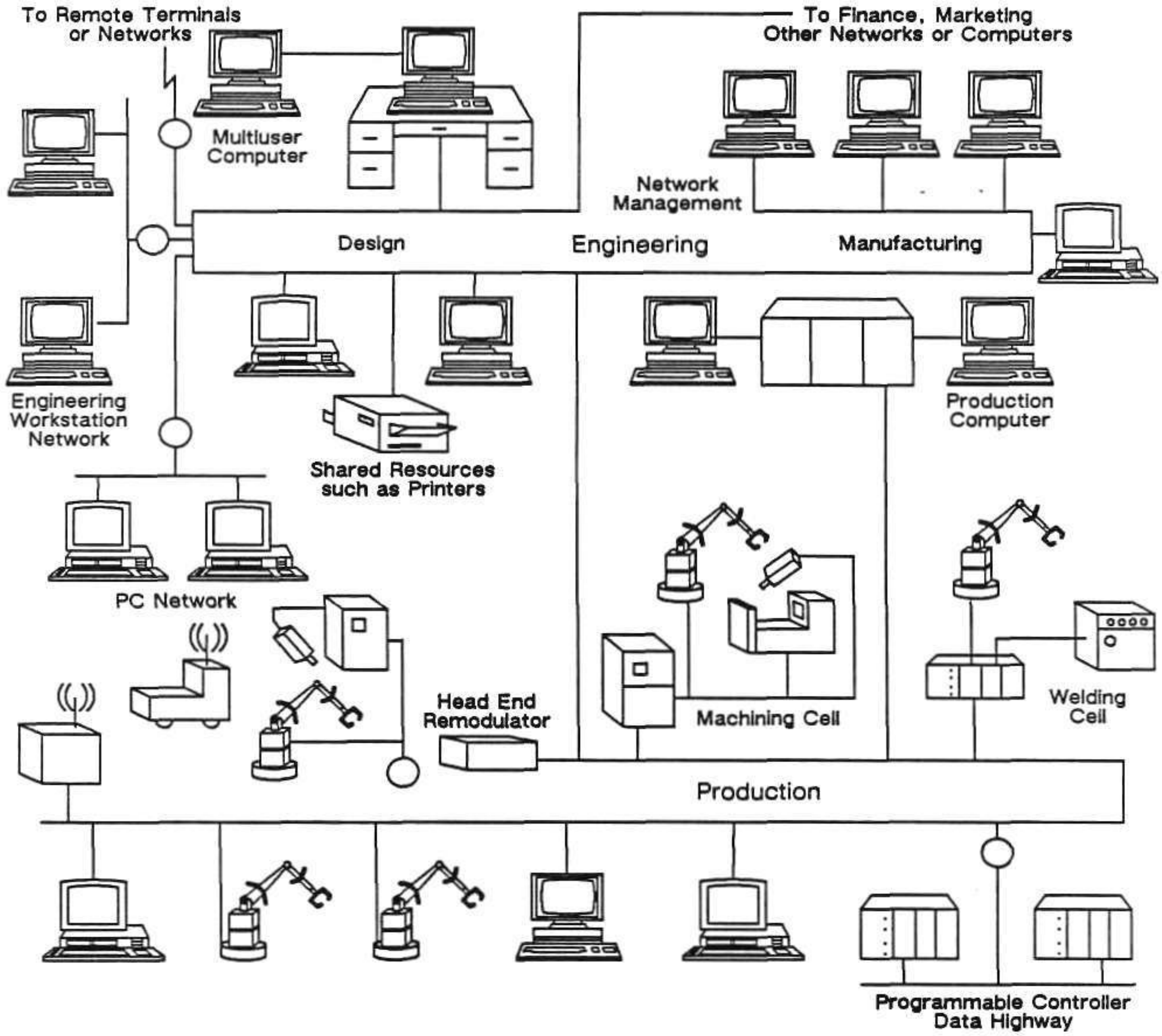
GT organizes parts and processes according to their similarities, and is a fundamental concept behind cellular and flexible manufacturing systems. Using computers to implement GT where thousands of parts and processes must be managed can be both expensive and time-consuming. Nevertheless, GT's benefits are beginning to be understood, and much wider use can be expected in the future.

Computer graphics are increasingly being used in the manufacturing environment. This is happening as the cost of graphics drops rapidly due to advances in both graphic algorithms and semiconductor technology. Graphics can be an important tool in importing skilled characteristics to unskilled workers.

PCs are becoming as common on the factory floor as they are in the office. Both general-purpose PCs and specialty systems based on off-the-shelf microprocessor board components will be increasingly used at the cell and workstation level for applications in both operations and logistics. The 32-bit microcomputer will have a major impact on high-end PCs and PLCs.

Figure 4

Automated Factory Concept



Source: CAE
Dataquest
April 1988

Speech recognition systems are just beginning to appear in the factory. One barrier to their use that must be overcome is an environment with a high ambient noise level. This problem notwithstanding, these systems will grow in acceptance for such applications as attendance reporting, tool tracking, materials requisitioning, and inspection reporting.

AUTOMATED MATERIAL HANDLING EQUIPMENT (AMHE)

Description and Definitions

AHME types are defined below:

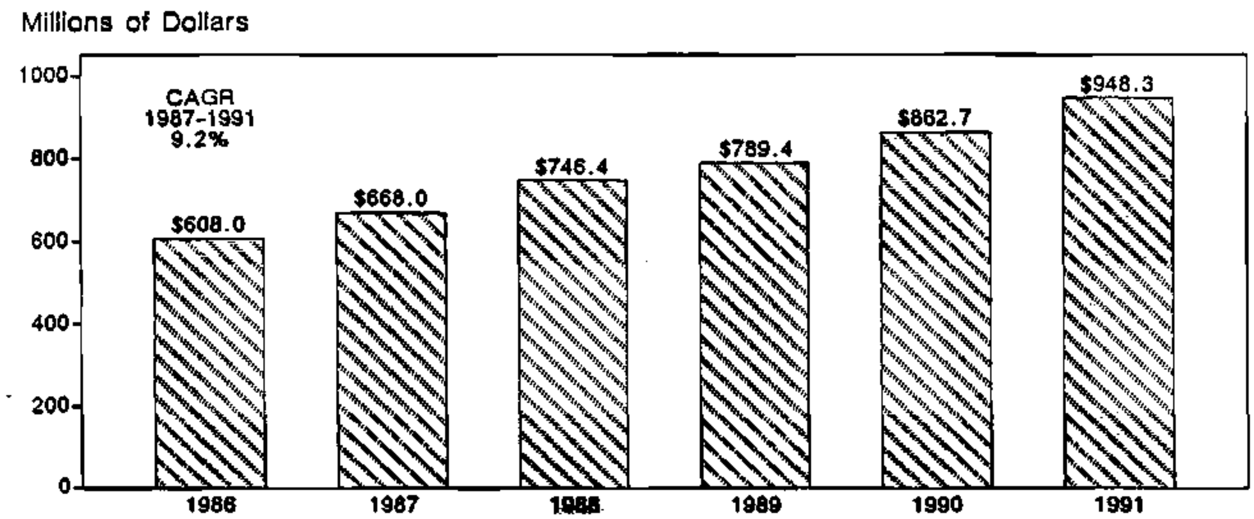
- Automated Guided Vehicle Systems (AGVSs)—AGVSs include unmanned mobile transporters under programmable control that are used to move materials and tooling throughout the factory and warehouse.
- Automated Storage and Retrieval Systems (AS/RSs)—AS/RSs include all hardware that is used for mechanical hoists and carriages, and that interface with racks and bins for automatic storage and retrieval of unit loads, pallets, and individual parts.
- Automated Warehouse Systems (AWSs)—AS/RSs as used in warehouses rather than on the factory floor.
- Conveyers—Conveyers are transporting devices for moving materials along a pathway. They are driven by a chain, sliding belt, moving slats, or powered rollers.
- Monorails—A monorail system transports loads in a suspended carrier, or trolley, that runs on wheels along a fixed overhead rail.

Market Forecast

Figure 5 presents the forecast for material handling equipment through 1991. On a revenue basis, it is expected to compound at a 9.2 percent rate.

Figure 5

Automated Material Handling Equipment
Estimated U.S. Consumption
(Millions of Dollars)
1987–1991



Source: Dataquest
April 1988

Companies and Market Share

The AMHE industry is dominated by large vendors that typically manufacture more than one product and that offer systems integration capabilities. Some of the vendors manufacture all, or nearly all, of the equipment for the systems that they provide. Others manufacture only certain lines of equipment, but purchase or license the items needed for complete customer solutions. Conveyors and storage racks for AS/RSs are normally purchased items, whereas AGVSs and monorails are typically licensed items. Table 2 lists the major AMHE vendors and the products that they offer internally, although most will purchase the necessary equipment to provide a total system.

Table 2

Major AMHE Systems Vendors and Product Offerings

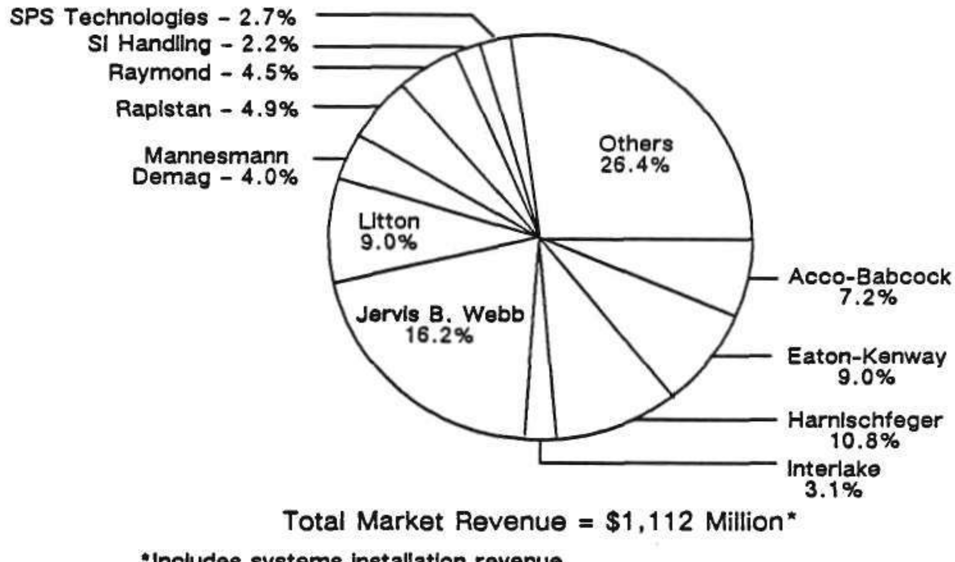
	AGVS	AS/RS	Conveyer	Monorail
Acco Babcock	X	X	X	X
Aero-Go	X	X		
Allen Automated Systems	X	X	X	X
Buschman Company			X	X
Clark Equipment-Automated Sys.	X	X	X	
Eaton-Kenway			X	X
Elwell-Parker Electric Co.	X	X		
Harnischfeger		X		X
Interlake	X	X	X	
Jervis B. Webb	X	X	X	X
Litton Corp.	X	X	X	X
Mannesmann Demag	X	X	X	X
Munck Automation Technologies	X	X		
Rapistan		X	X	
Raymond	X	X	X	
Roberts Corp.	X	X	X	X
SI Handling Systems	X		X	
SPS Technologies		X	X	X
Translogic	X			X
Twin City Monorail		X		X
White Storage & Retrieval Systems		X	X	

Source: Dataquest
April 1988

As shown in Figure 6, Jervis B. Webb is the largest vendor, with 16.2 percent market share.

Figure 6

Estimated AMHE Market Share by Vendor
1986



Source: Dataquest
April 1988

Technology Trends

The growth of real-time information systems for industrial environments has been the main growth proponent behind AMHE. In the area of AGVS, free-ranging guidance techniques employing laser position referencing, or optically encoded dead reckoning and gyroscopes, are the trends to come. Conveyer control is being changed by the use of programmable logic controllers (PLCs) that can simultaneously govern the motor, drive speed and speed changes, transfers, sensors, accumulation modes, steps, brakes, diverters, and pneumatic devices. PLCs have also greatly enhanced control of monorails.

ELECTRONIC AUTOMATIC TEST EQUIPMENT (EATE)

Description and Definitions

EATE refers to computer-controlled testing and measuring systems that verify the performance and parametric conformance of electronic components, printed circuit cards, subassemblies and complete electronic systems. EATE was developed largely by electronic component manufacturers to test their own products. These products had overwhelmed manual testing methods with their increasing complexity and escalating production volumes.

Dataquest includes the following electronic testing equipment in the EATE marketplace:

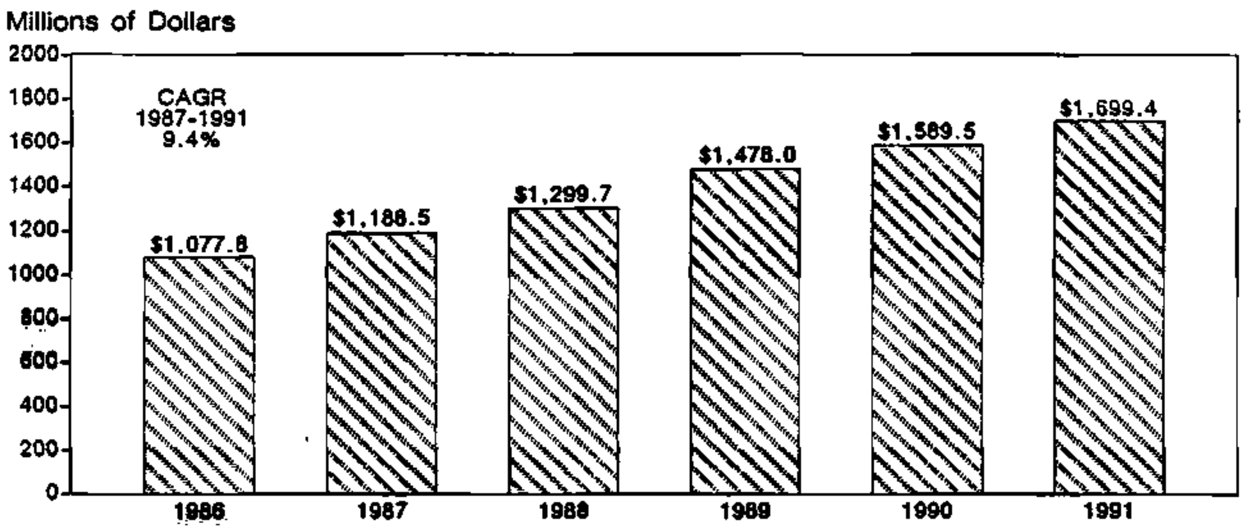
- Discrete component testers
- Semiconductor testers
- Interconnect and bare PCB testers
- In-circuit PCB testers
- Functional PCB testers
- Combined PCB testers
- System testers

Market Forecast

Total revenue is expected to grow from $1,188.5 million in 1987 to $1,699.4 million in 1991, as shown in Figure 7. Figure 8 shows total unit shipments increasing from 9,049 in 1987 to 11,722 in 1991.

Figure 7

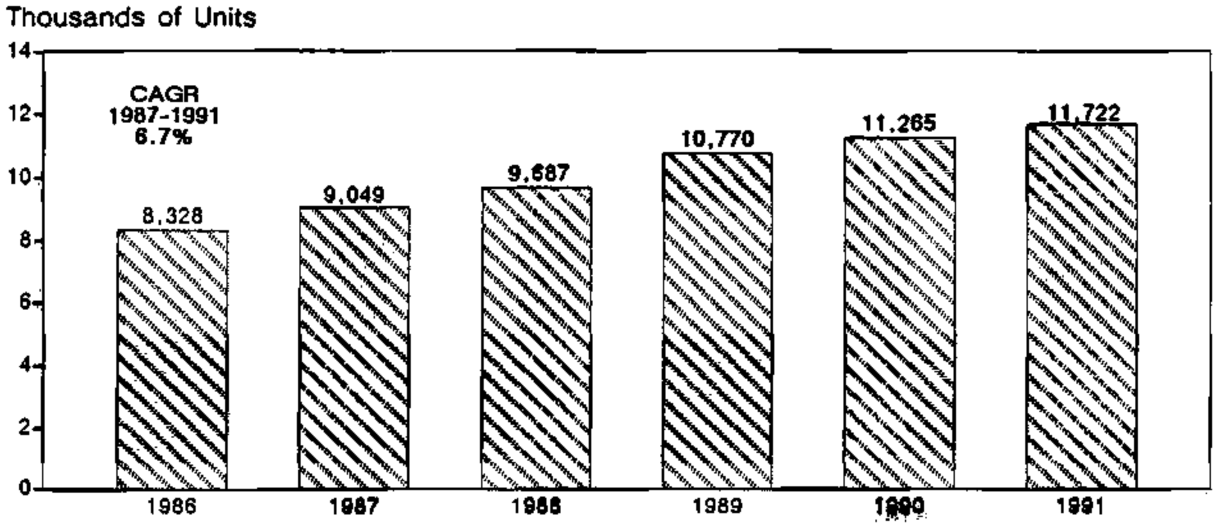
Electronic Automatic Test Equipment
Estimated U.S. Consumption
(Millions of Dollars)



Source: Dataquest
April 1988

Figure 8

Electronic Automatic Test Equipment
Estimated U.S. Consumption
(Units)



Source: Dataquest
April 1988

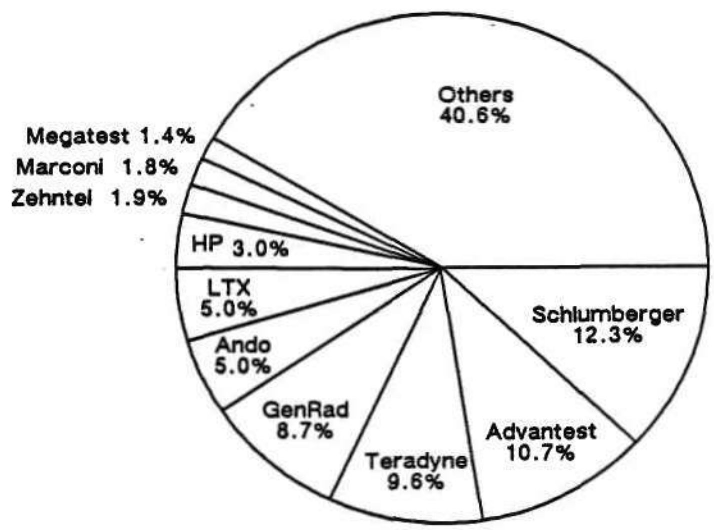
Companies and Market Share

Electronic ATE

Figure 9 presents Dataquest's estimate of 1986 worldwide market shares for electronic ATE of all types. Companies that increased sales in 1986 did so by concentrating on Japanese and European markets. The Japanese companies have increased their market share in recent years, and though the rising value of the yen against the dollar has slowed their penetration, they maintained share through 1987.

Figure 9

Electronic ATE
1986 Worldwide Market Shares



Source: Dataquest
April 1988

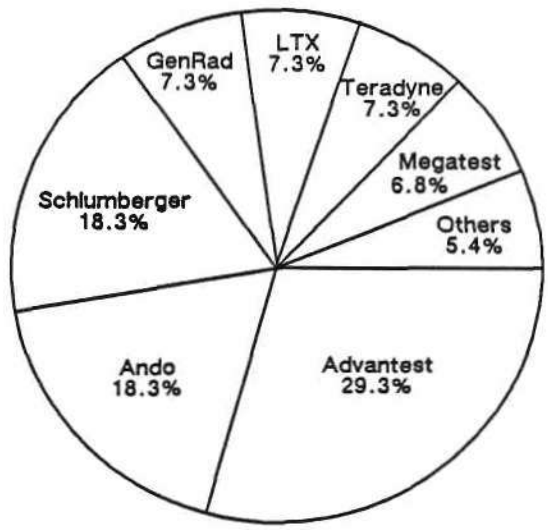
The greatest growth is expected in the VLSI testing area. The following paragraphs discuss market shares in this segment.

VLSI Electronic ATE

Figure 10 presents Dataquest's estimate of 1986 worldwide market shares for VLSI test equipment only. The dominance of Advantest in the worldwide marketplace is clearly visible. Dataquest believes that it is the failure of U.S. manufacturers to penetrate the Japanese market that accounts for the approximately 48 percent market share captured by Japanese firms.

Figure 10

VLSI Electronic ATE
1986 Worldwide Market Shares



Source: Dataquest
April 1988

Technology Trends

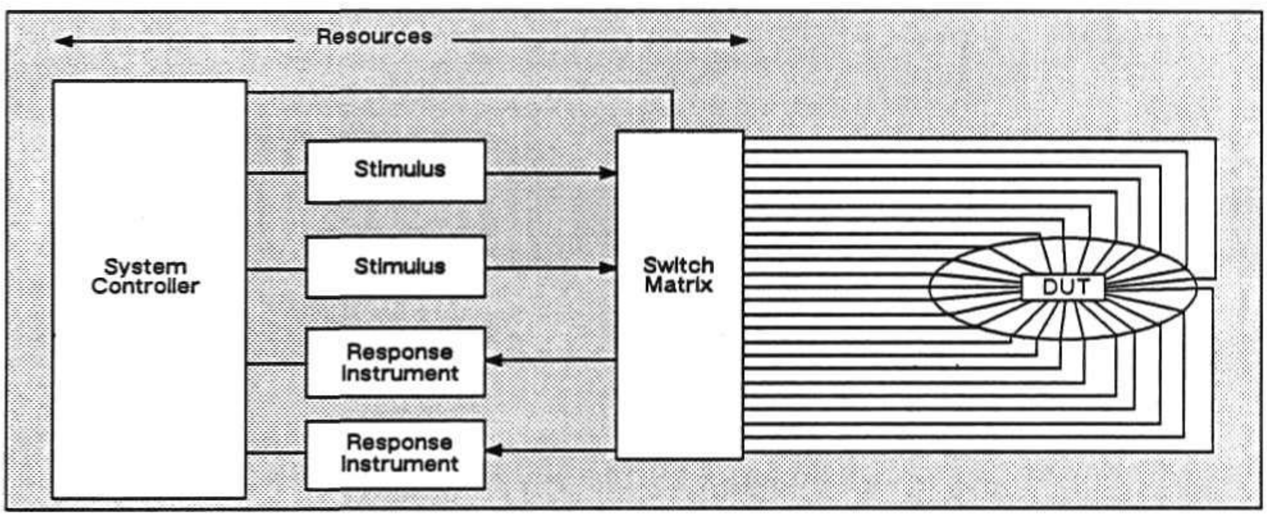
Trends in Device Testing

Device tester technology has evolved from the shared-resource concept to tester-per-pin architectures. Future successful testers will probably incorporate aspects of both of these two technologies. The following sections discuss these trends in device testing.

Shared-Resource Architecture. The traditional IC tester configuration is shown in Figure 11. This shared-resource architecture distributes system measurement resources among the DUT pins via a complex switching matrix. When pin counts are low, this is an economical approach that offers adequate performance. The benefit of this arrangement is that only one type of expensive test instrument (i.e., a multimeter or the power supply) is needed.

Figure 11

IC Test: Shared-Resource Architecture



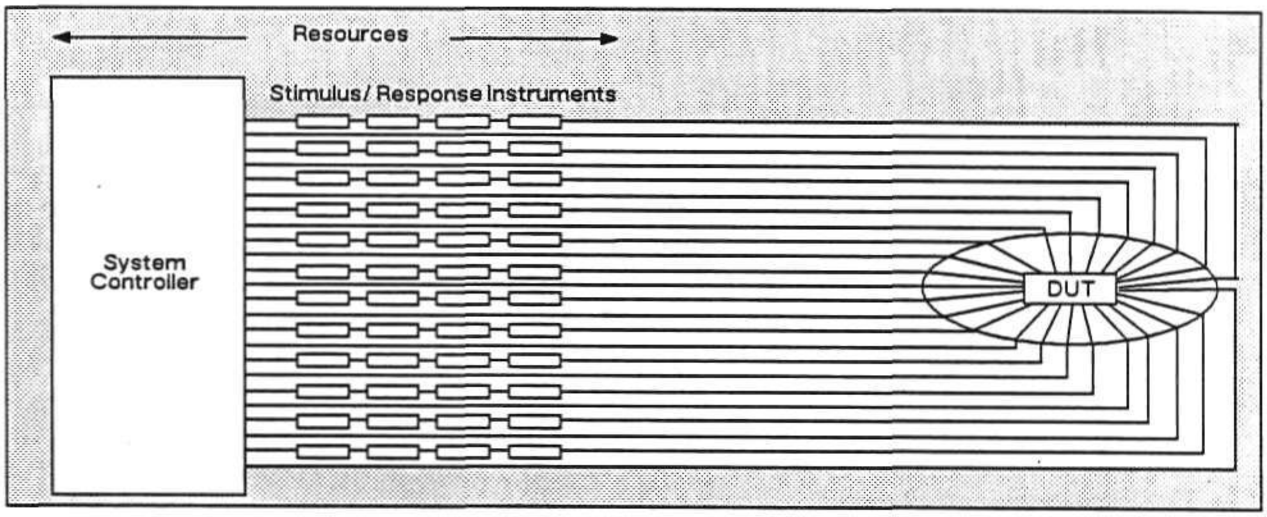
Source: Electronics Test
August 1986

Tester-per-Pin (TTP) Architecture. Improvements in semiconductor design and processing capability have led to extremely dense and high-speed circuits, and the cost of testing these circuits has risen rapidly. A new type of tester architecture has emerged that combines traditional and novel approaches to cost reduction and accuracy improvement in VLSI testing.

TTP architecture is a relatively new approach to the problems encountered in VLSI testing. TTP provides dedicated stimulus and measurement resources for each DUT pin, as shown in Figure 12. With TTP architecture, most switching and cabling problems are eliminated. The proximity of instrumentation resources to the DUT means that less measurement degradation is experienced. Because each pin is equipped with independent timing generation and output pattern acquisition, many tests can be run simultaneously, accelerating the testing process. Any test pattern may be used, without regard to its complexity.

Figure 12

IC Test: Tester-per-Pin Architecture

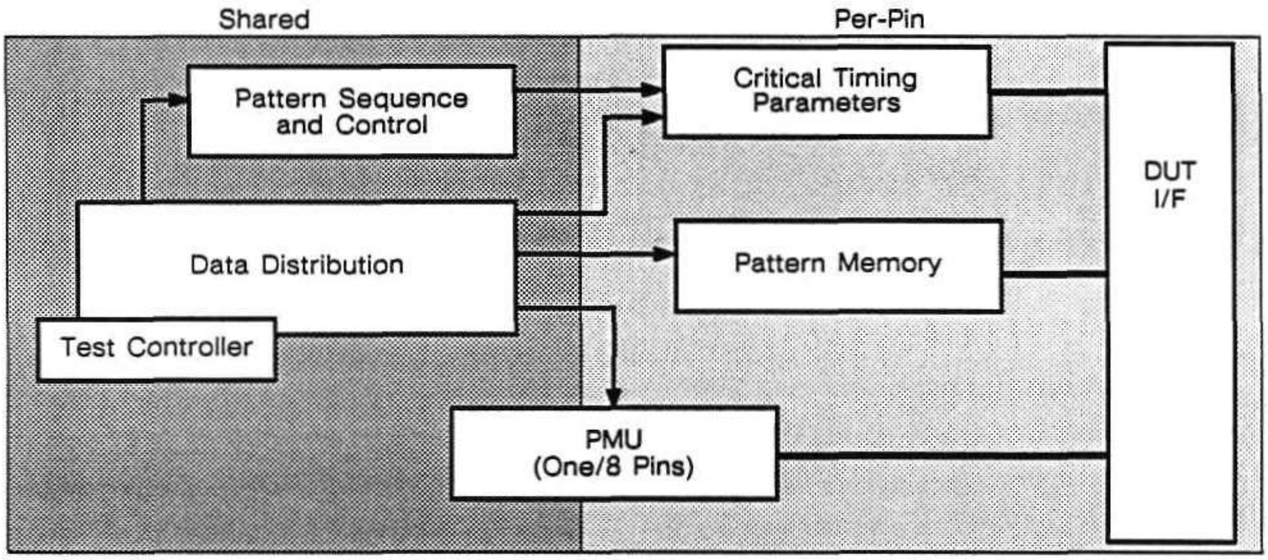


Source: Electronics Test August 1986

Mixed-Architecture Testing. As a solution to the limitations of shared-resource and TTP systems, mixed-architecture testers are designed to combine the advantages of both previous architectures. A typical mixed architecture is diagrammed in Figure 13. As is shown, those resources that are required at each pin (such as drivers, comparators, timing generators, formatters, and active loads) are duplicated for each I/O channel. In other areas, resources can be shared to reduce cost and improve performance.

Figure 13

IC Test: Mixed Architecture



Source: Electronics Test August 1986

Subsystem Test Trends

At the board level, functional and in-circuit testing vie for dominance. It is probable that a combination of these two technologies will find increasing acceptance. The following sections discuss these developments in subassembly test technology.

Functional Testing. New functional emulation test techniques use the board to test itself. One emulation technique takes over the electronic pathways through which the microprocessor controls the memory and peripheral chips. Another technique emulates the board's microprocessor itself. A third technique uses a memory emulator. None of these emulation techniques has proven itself best as yet. While memory emulation eliminates the need to remove the microprocessor from the circuit, it does not recreate the board's environment. Microprocessor emulation may fail to copy the exact performance of the chip.

In-Circuit Testing. As boards become more complex, in-circuit tester manufacturers have responded by adding capabilities to their systems, producing higher speeds, better timing control, and higher backdriving currents. Today's in-circuit testers are performing tasks that were once the domain of only functional testers.

Some in-circuit testers now allow users to test groups of components or even the entire board from the edge. Options may include data probe and other diagnostics that can be combined with analysis software to resolve measurements down to the failing component. The in-circuit tester has, therefore, undergone a transformation into a full-featured product, at a time when the need for such functions is filled by a wide variety of alternatives.

Combinational Testing. One means of bypassing the drawbacks of either of the functional and in-circuit testers is to combine the benefits of both in one machine. New EATE of this type perform shorts/opens testing; in-circuit analog, digital, and hybrid tests; and analog-functional and integrated digital-functional tests. Users can decide which tests are appropriate for a particular board.

Test During Burn-In (TDBI). Accelerated-life testing (stressing components to decrease time-to-failure) has become a means of responding to worldwide pressure for improvements in product quality. Burn-in is the most widely accepted accelerated-life testing technique currently in use. Three types of device burn-in are used: static, dynamic, and TDBI.

In static burn-in, parts are placed in an oven, power and DC bias voltages are applied to the appropriate pins, and the devices are subjected to elevated temperatures. Static burn-in is a stress test, but it does not exercise a device's internal logic. Dynamic burn-in also stimulates logic pins with a clock or other signal, and may load output with resistance or capacitance.

TDBI is similar to dynamic burn-in except that output signals are monitored to determine whether the tested devices are responding as expected. The devices may be monitored continuously, or a few may be checked at a time; each device is checked several times during the burn-in cycle.

The primary advantage of TDBI is that it produces failures as a function of time. Quality engineers can determine when a part failed and what caused the failure. The approach yields more data while reducing the handling costs that are associated with periodic removal of devices for testing, as some static and dynamic procedures require.

FACTORY DATA COLLECTION SYSTEMS

Description and Definitions

For any integrated manufacturing system to be effective, it must be directed through information collected at the point where fabrication or assembly takes place. Specialized factory data collection systems (FDCS) have been designed to operate in the harsh environment of the shop floor, with design features that make operation by shop personnel as easy as possible.

FDCS consist of any or all of the following types of products:

- Input stations and readers
- Portable and standalone devices
- Central controllers
- Software

Dataquest estimates that about 80 percent of the data generated in a typical manufacturing enterprise is operational data. This data comes from about 20 percent of the activity that takes place within the company (most activity is administrative). Operational data suitable for capture by FDCS include these applications:

- Time and attendance
- Inventory control
- Work-in-process control
- Quality control
- Shipping and receiving
- Security

FDCS may also be classified by the technology used by the data entry terminal. The most important data entry technologies include:

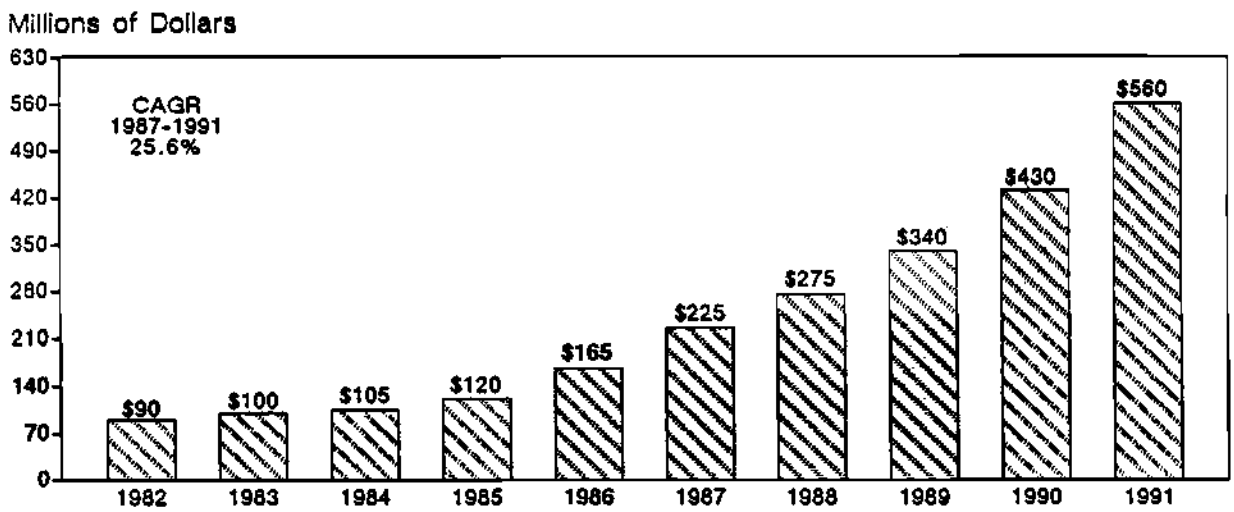
- Bar code
- Magnetic stripe
- Optical character recognition
- Voice data entry
- Radio frequency tagging

Market Forecast

Factory data collection system (FDCS) sales, which were $90 million in 1982, are projected to reach $560 million in 1991, as shown in Figure 14. Dataquest believes long-term growth in the factory data collection industry will be continued and steady, not explosive. Growth in the FDCS market is expected to average 22.5 percent annually during this 10-year period.

Figure 14

Factory Data Collection Systems
U.S. Consumption
1982–1991



Source: Dataquest
April 1988

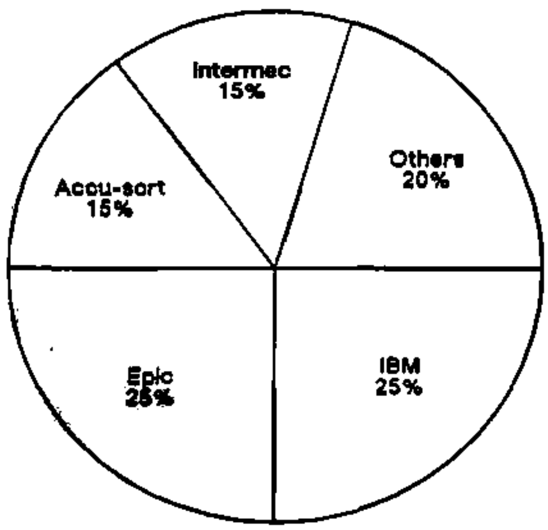
Among the forces influencing the growth of the FDCS market, Dataquest considers the three most important to be the U.S. government, the trend toward networking and integrated manufacturing systems, and increased functionality resulting from advances in microprocessor control and software development.

Companies and Market Share

Figure 15 presents Dataquest's estimate of the market shares of the major FDCS suppliers. This estimate is based on systems shipments to users only, not on individual components supplied on an OEM or direct basis.

Figure 15

Factory Data Collection Systems
1986 Market Share



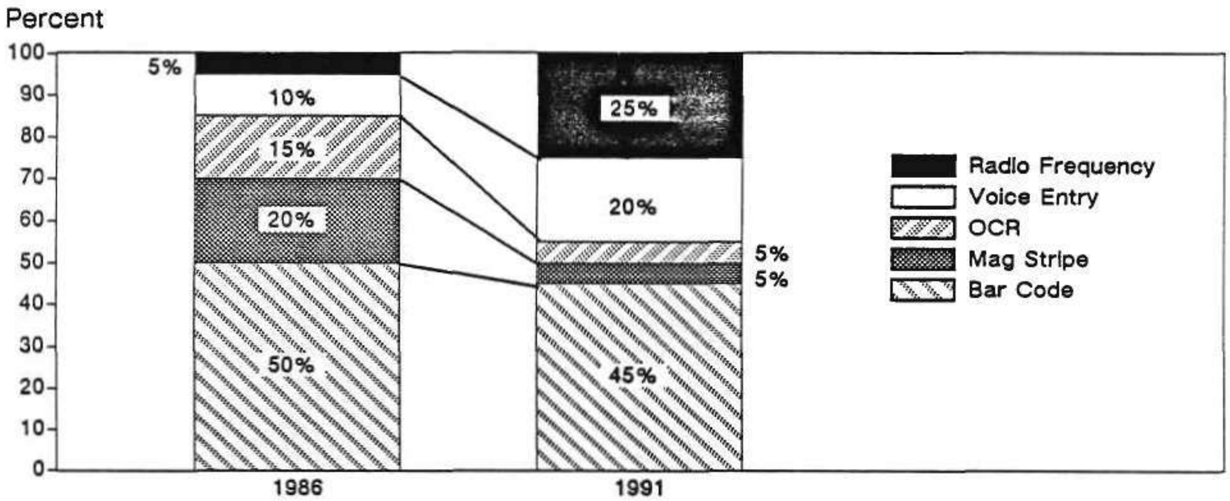
Source: Dataquest
April 1988

Technology Trends

The important data collection technologies for use in an automated factory include bar code, magnetic stripe, optical character and mark recognition, voice entry, and radio frequency (RF) tagging. Vision systems, in the form of charge-coupled-device (CCD) cameras, have been used for some character reading applications. Dataquest expects the change in mix of these technologies on the factory floor to resemble that in Figure 16. The following sections discuss some of the more important developments in each of these technologies.

Figure 16

Factory Data Collection Systems
U.S. Consumption by Technology
1986–1991



Source: Dataquest
April 1988

ELECTRONIC PROCESS CONTROL SYSTEMS

Description and Definitions

Process control refers to monitoring and maintaining the operation of plants that manufacture homogeneous materials such as oil, chemicals, and paper. By controlling process variables such as temperature and pressure, these products may be produced on a continuous basis with little variation in quality. An interruption of one part of the process, however, can have drastic effects both on product quality and on the safety of the operation. Process control systems are capable of detecting these adverse circumstances and taking corrective action. They may also send an alarm to an operator who can then decide on the appropriate response.

Electronic process control (EPC) represents the oldest and strongest trend in the process control field. Analog electronic controllers based on transistor operational amplifiers began to enter the market around 1960, surpassing the market value of pneumatic controllers by about 1970. Today, through expanding application of microprocessors, the trend toward digital control of continuous and batch processes is clearly irreversible. Digital process control (DPC) systems offer distinct advantages over analog controls in the areas of capability, precision, cost, ease of implementation, communication, and simplicity of operation.

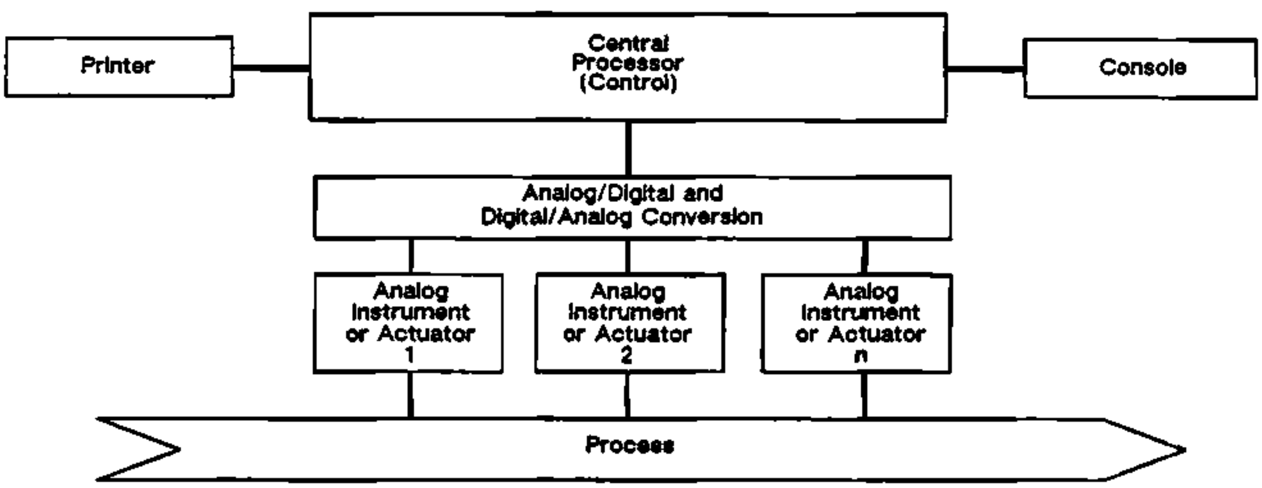
Characteristics of EPC

EPC may be open-loop or closed-loop in nature. An open-loop control system does not automatically adjust a process based on the error signal. Rather, an operator must make one or more adjustments to control the process. The adjustments may be made on a continual basis, in which case the operator becomes part of the control system. Closed-loop control uses feedback from process parameter measurements to maintain process variables at their proper set point, or target condition.

DPC systems may also be classified as direct or distributed. In direct digital control, the capabilities of a large, centralized computer system are used to replace analog instruments, interpret data, activate actuators, and report operations. Distributed control divides the process into several subsystems, each of which is controlled by microprocessor. Thus, a malfunction in one portion of the process does not affect the entire system. Figures 17 and 18 diagram the architecture of these two types of control systems.

Figure 17

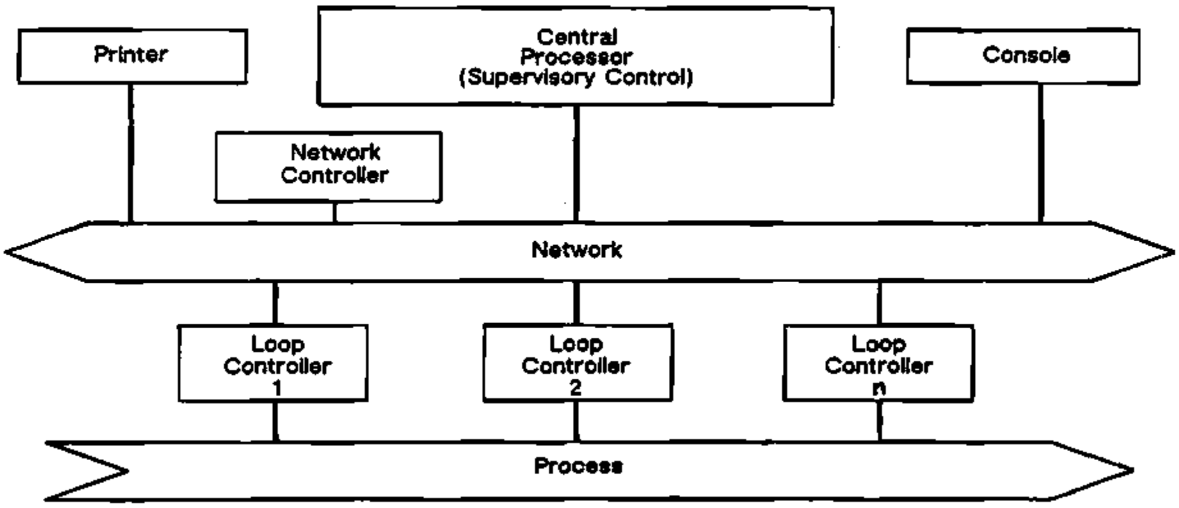
Direct Digital Control



Source: Dataquest April 1988

Figure 18

Distributed Digital Control



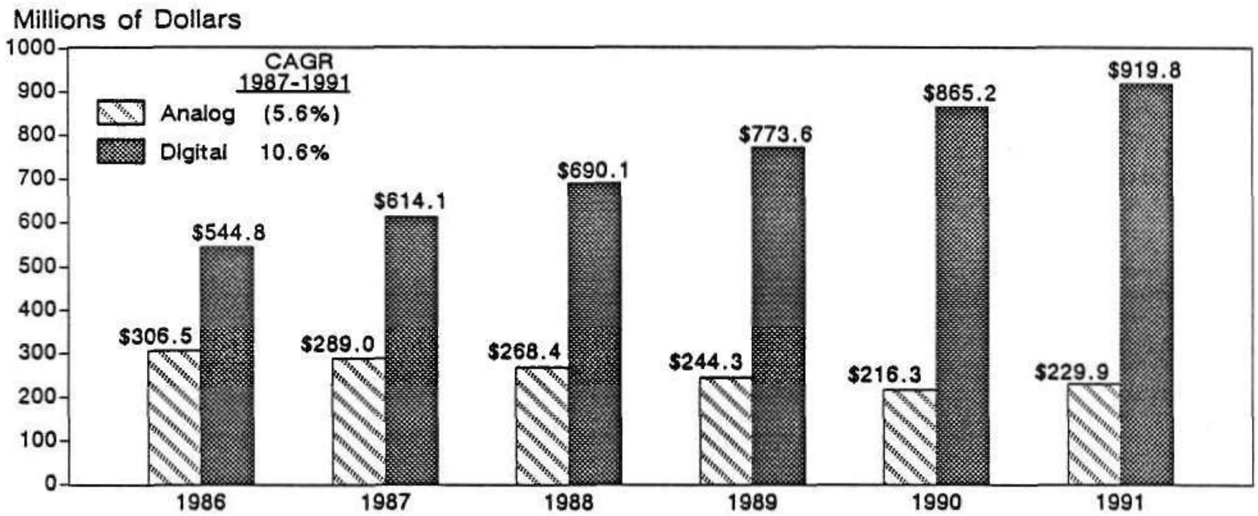
Source: Dataquest
April 1988

Market Forecast

As noted in Figure 19, digital controls are expected to grow at a 10.6 percent rate from 1987 through 1991. These are displacing the older analog controls that are declining at a negative 5.6 percent CAGR from 1987 through 1991.

Figure 19

Electronic Process Control Equipment
Estimated U.S. Consumption
(Millions of Dollars)



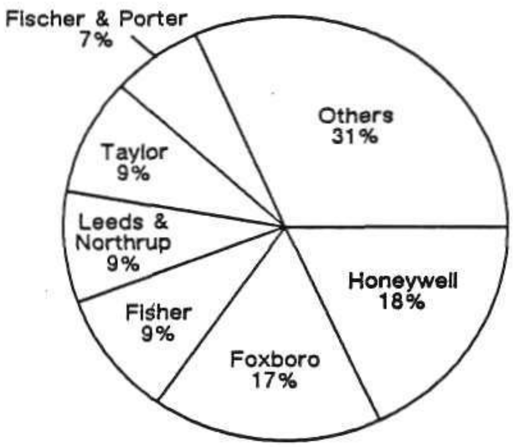
Source: Dataquest
April 1988

Companies and Market Share

The electronic process control marketplace is highly fragmented. Figures 20 through 24 show the estimated 1986 market shares by industry for both analog and digital electronic process controls.

Figure 20

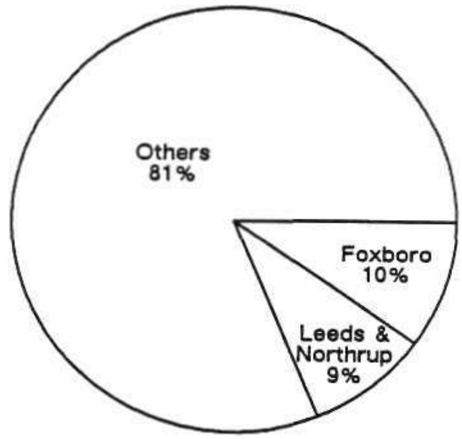
Electronic Process Controls
Chemical Industry Market Shares
1986



Source: Dataquest
April 1988

Figure 21

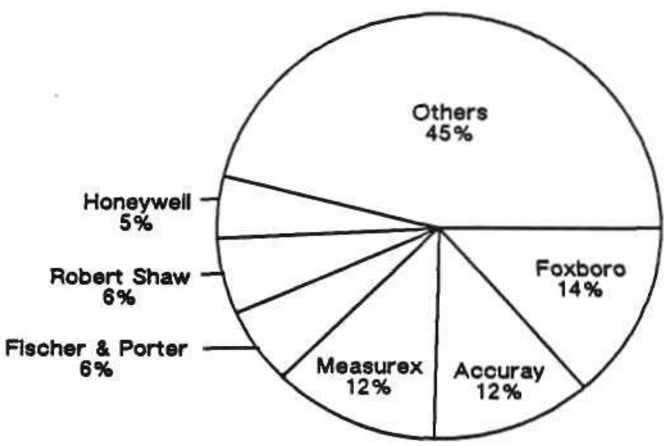
Electronic Process Controls
Food and Beverage Industry Market Shares
1986



Source: Dataquest
April 1988

Figure 22

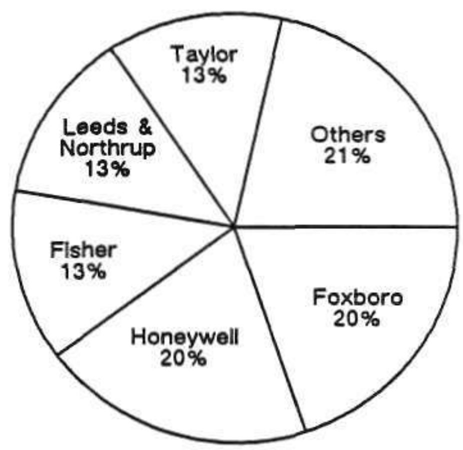
Electronic Process Controls
Paper and Pulp Industry Market Shares
1986



Source: Dataquest
April 1988

Figure 23

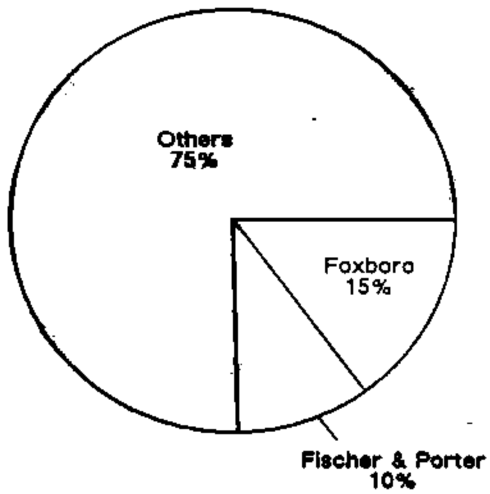
Electronic Process Controls
Petroleum Industry Market Shares
1986



Source: Dataquest
April 1988

Figure 24

Electronic Process Controls
Primary Metals Industry Market Shares
1986



Source: Dataquest
April 1988

Chemical Industry

Figure 20 presents Dataquest's estimate of the 1986 market shares for the U.S. chemical industry. In this market segment, Honeywell's estimated share of 18 percent is slightly larger than Foxboro's 17 percent.

Food and Beverage Industry

Figure 21 presents Dataquest's estimate of the 1986 market shares for the U.S. food and beverage industry. Foxboro and Leeds and Northrup are leaders in the segment, with Foxboro holding a nominal edge. No other vendor is known to have more than a 5 percent share of this segment.

Paper and Pulp Industry

Figure 22 presents Dataquest's estimate of the 1986 market shares for the U.S. paper and pulp industry. Foxboro is again the market leader in this segment, but both Accuracy and Measurex have established positions of approximately equal significance. Foxboro, Fisher Controls, and Honeywell all supply much of the control instrumentation for processes peripheral to the operation of this industry, such as waste water treatment.

Petroleum Industry

Figure 23 presents Dataquest's estimate of the 1986 market shares for the U.S. petroleum industry. Foxboro and Honeywell have established approximately equal positions. Much of the processing power for the petroleum industry is supplied by Digital Equipment Corporation's minicomputers. These are generally supplied through OEM arrangements with the control system vendors.

Primary Metals Industry

Figure 24 presents Dataquest's estimate of the 1986 market shares for the U.S. primary metals industry. Foxboro is the leader in the mining and metals industries. Fischer and Porter is estimated to hold a close second place. No other vendor is known to hold more than a 5 percent market share in primary metals industry control.

Technology Trends

Programmable Logic Controllers

Programmable logic controllers (PLCs) were originally applied to control problems in discrete or sequential manufacturing operations. Their purpose was to provide a programmable method of replacing the complicated electromechanical systems used to control assembly lines.

Recently, added functionality has provided PLCs with the ability to operate as part of a distributed control system in large process plants in such industries as food, chemicals, petroleum, paper, and metals. This functionality generally derives from the added processing power and speed of microprocessor technology. The trend is to provide the PLC with auxiliary data processing capabilities so that time-consuming computations can take place without interfering with the execution of control programs. This enhances their ability to control the comparatively rapid events of a continuous process.

Advanced Sensor Technology

The sensor has been called the foundation on which process control is based. DPC exists to process and exchange data that has been provided by sensors. The advances in productivity and quality promised by digital control are predicated on the validity of this data. Sensor development is expected in several areas. Static or dynamic accuracy will increase, while calibration periods are extended. Design improvements will reduce installation and repair times. Applications flexibility, the ability of a single sensor to measure a wider range of variables, will serve to reduce spares inventories and simplify control system design.

A number of recent developments have contributed to the accuracy of sensors, including silicon machining and microprocessor-based intelligence. Silicon machining technologies allow sensor manufacturers to create three-dimensional structures such as diaphragms and chambers directly on the wafer used to form an integrated circuit. The sensing element and signal conditioning circuit are thereby produced on a single chip. The sensor benefits from the same low manufacturing costs as the integrated circuit.

Sensors manufactured in this way can also be calibrated automatically as they are fabricated. Because the materials can be extremely stable over the operating life of the product, maintenance expense for these sensors is greatly reduced.

Microprocessor control aims to incorporate signal conditioning and transmission circuitry into the sensor. As a further means of reducing initial and life-cycle costs, this technology also serves to distribute intelligence closer still to the actual process being measured. Local processing power allows self-calibration, diagnosis, and remotely controlled reranging.

Fiber Optics. Until recently, optical fiber has been used only to replace metallic conductors in communications systems for industrial applications, or as part of a location/presence sensing system. By measuring changes in reflectance, absorbence, or luminescence, new sensors based on fiber optics are capable of quantifying such events as changes in liquid level, pressure, or chemical composition.

As data links, optical fibers offer large bandwidth, low attenuation, high transmission rates, security, and immunity to electromagnetic interference. The medium is also flexible, lightweight, and resistant to corrosion, high temperatures, crushing, shock, abrasion, and impact. Optical fiber offers complete electrical isolation as well. Fiber-optic systems also have the advantages of simplicity and reliability; they have no moving parts. As sensors, fiber-optic systems are generally more sensitive than their mechanical or solid-state counterparts.

PROGRAMMABLE MACHINE TOOLS

Description and Definitions

Numerical Control

Numerical control (NC) has been the major force driving the changes now taking place in the metalworking industries. NC is the operation of a machine by a series of coded instructions which, translated into electrical or other output signals, activate motors and other devices that run the machine.

Computer Numerical Control

Computer numerical control (CNC) represents the preponderance of all machine control techniques today. CNC incorporates a complete computer into the control unit.

Direct Numerical Control

Direct numerical control uses a central computer unit to control as many as several hundred machine tools.

Flexible Machining Centers

Flexible machining centers do a number of different operations, frequently on four or more faces of the workpiece, in a single setup.

Flexible Manufacturing Systems

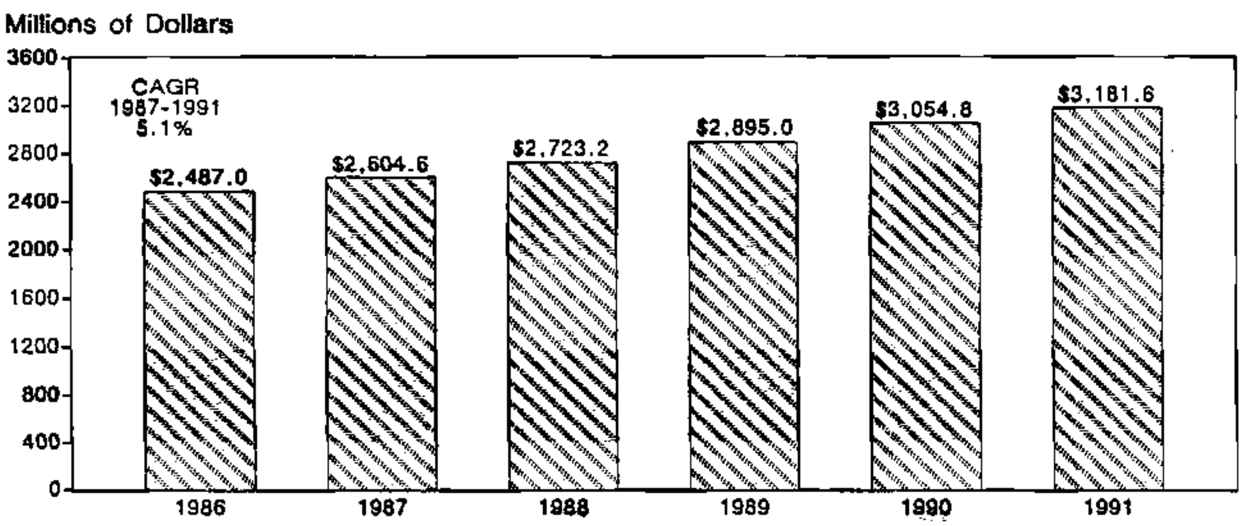
Flexible manufacturing systems represent an expansion of the flexible machining center concept. A flexible manufacturing system typically consists of a computer-integrated group of NC machines or workstations linked together with material-transfer devices for the complete automatic processing of differing product parts or the assembly of these parts into different units.

Market Forecast

Growth of programmable machine tools is expected to compound at a 5.1 percent CAGR from 1987 through 1991 on a revenue basis, and 2.6 percent on a unit basis, as shown in Figures 25 and 26, respectively.

Figure 25

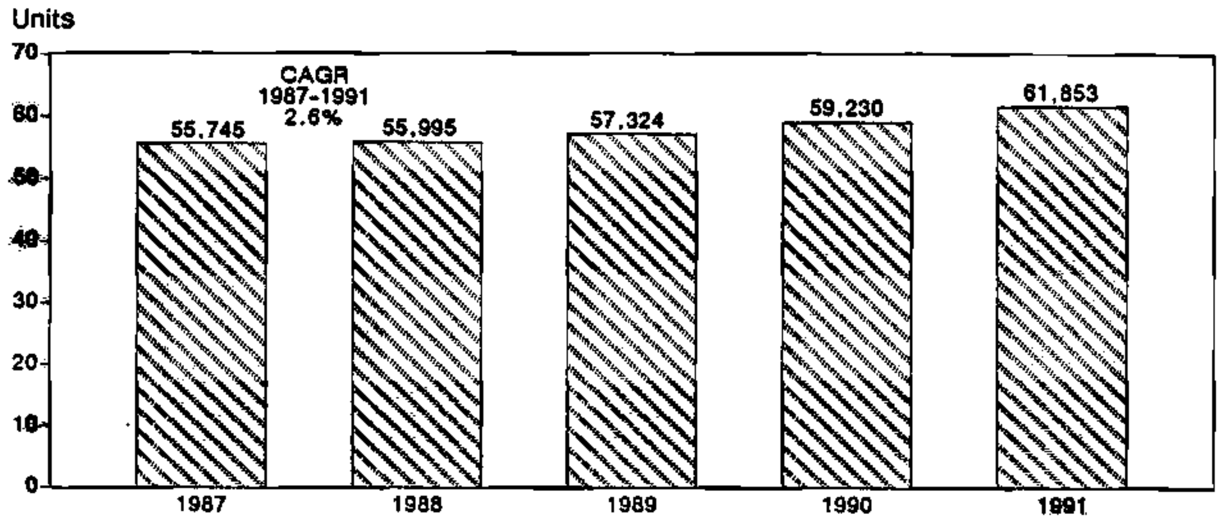
Programmable Machine Tools Estimated U.S. Consumption (Millions of Dollars)



Source: Dataquest April 1988

Figure 26

Programmable Machine Tools
Estimated U.S. Consumption
(Units)



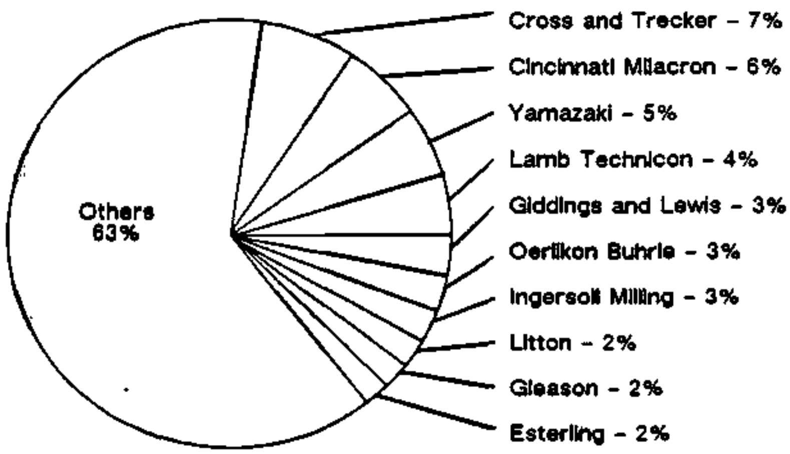
Source: Dataquest
April 1988

Companies and Market Share

The top 10 vendor positions are shown in Figure 27. The market share ranking is based on estimates made by American Machinist, and includes only those firms having substantial manufacturing capacity in the United States. The ranking includes both public and private companies and includes both U.S. and non-U.S. production. The "Others" category includes all other U.S. and non-U.S. competitors.

Figure 27

Machine Tool Industry
Top 10 Vendor Market Shares
1986



Total Market Revenue = $2,487 Million

Source: Dataquest
April 1988

Technology Trends

Demands for increased productivity have led to the development of means of machining at higher speeds. But these greater machining speeds have required the development of means to manage waste stock once it has been removed. Chip-removal systems will become more prominent in the future, as will cutting systems, such as laser and waterjet, that generate less waste.

Chip Removal Systems

In improving the productivity of metal-parts manufacturing, a programmable machining system is not only producing parts faster, it is producing waste material faster as well. This situation has led to serious consideration of chip-removal technologies as an important part of automated manufacturing systems.

Cutting Systems

Laser Applications. The following trends have been identified in laser applications for computer numerical control and direct numerical control:

- Welding and cutting continue to be the major applications for lasers in manufacturing. These constitute about 45 percent of the current applications.
- Heat treating may represent another 10 percent of laser applications for manufacturing. This area may also be the fastest-growing application.
- Laser marking capabilities will continue to evolve, with greater positioning accuracy, improved working distances, and standard fonts.

Waterjet Cutting. Waterjet cutting, with or without the use of abrasive additives, is also expected to become another important form of nontraditional cutting technology. The typical waterjet cutting system uses an extremely thin stream of water traveling at greater than 3,000 feet per second.

ROBOTICS

Description and Definitions

The following describes the key industrial applications for robots.

Fabrication

Fabrication applications use machining, welding, painting, and machine loading robots.

Assembly

Assembly processes use the following types of robots:

- Assembly—The robot collects parts and puts them together.
- Painting—The robot carries a spray gun and applies a coating material. The term "finishing robots" also describes this category.
- Spot Welding—The robot carries a resistance welding gun to produce welds.
- Arc Welding—The robot carries an arc welding torch to produce welds.

Material Handling/Machine Loading

Material handling/machine loading robots pick up parts and place them in a new location.

Inspection/Test

Inspection/test robots manipulate a camera or gauge to inspect or test a part for conformance to standards.

Process Control

Process control robots are used in process control applications.

Machining—Other

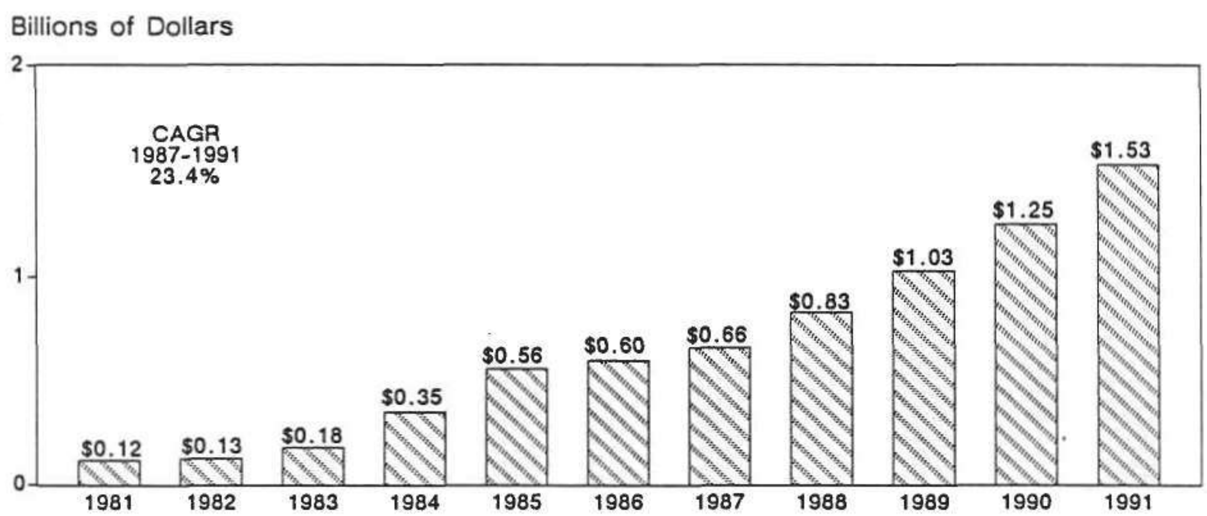
The machining—other category includes robots used for machining and other applications. In general, a machining robot carries a tool to modify a part, such as in polishing, grinding, drilling, and deburring.

Market Forecast

U.S. market revenue for robots is expected to grow at a 23.4 percent rate, reaching slightly more than $1.5 billion in 1991, as shown in Figure 28. Unit shipments are expected to grow 28.9 percent to more than 23,000 units by 1991, as shown in Figure 29.

Figure 28

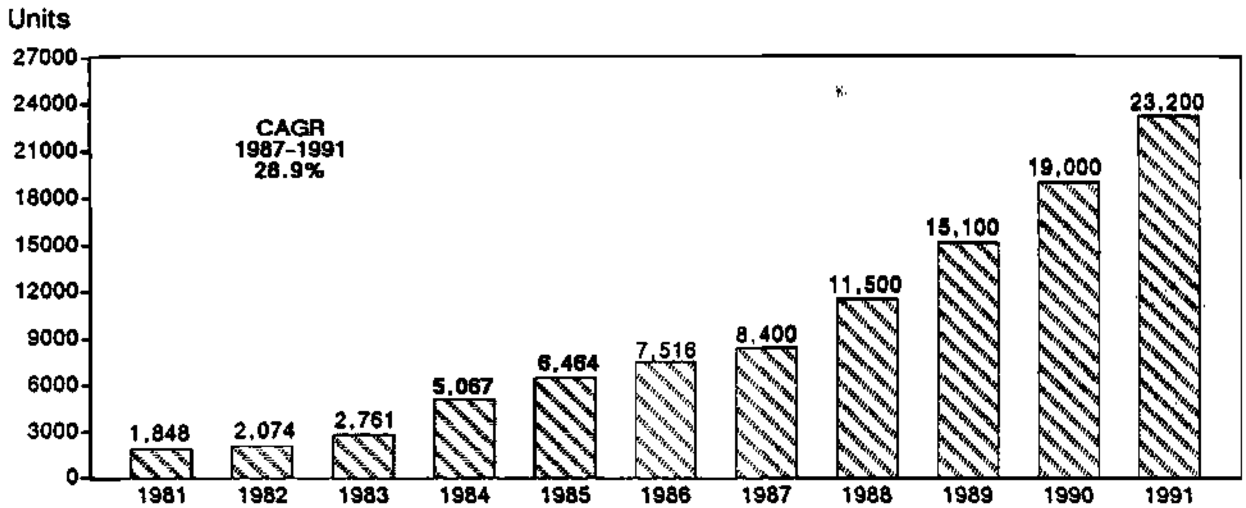
Estimated U.S. Robotics Market Revenue
1981–1991



Source: Dataquest
April 1988

Figure 29

Estimated U.S. Robotics Market Shipments
1981–1991

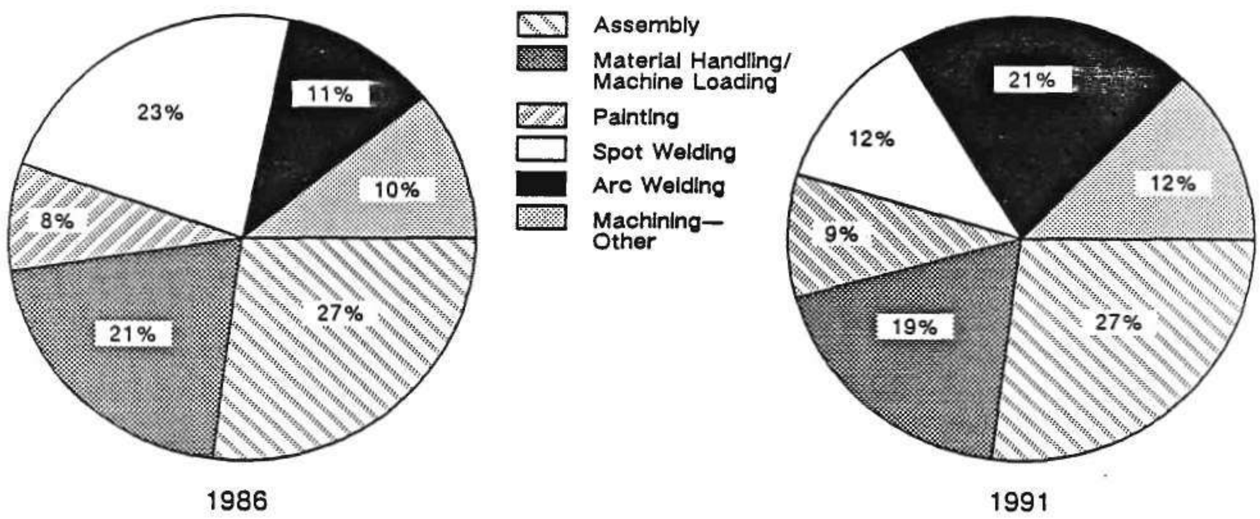


Source: Dataquest
April 1988

Figure 30 shows that assembly robots are expected to remain the largest application segment until 1991. Spot welding applications will decline from 23 percent to 12 percent between 1986 and 1991, while arc welding will grow from 11 percent to 21 percent. The electronics industry is predicting to use 24 percent of all robots by 1991, as shown in Figure 31.

Figure 30

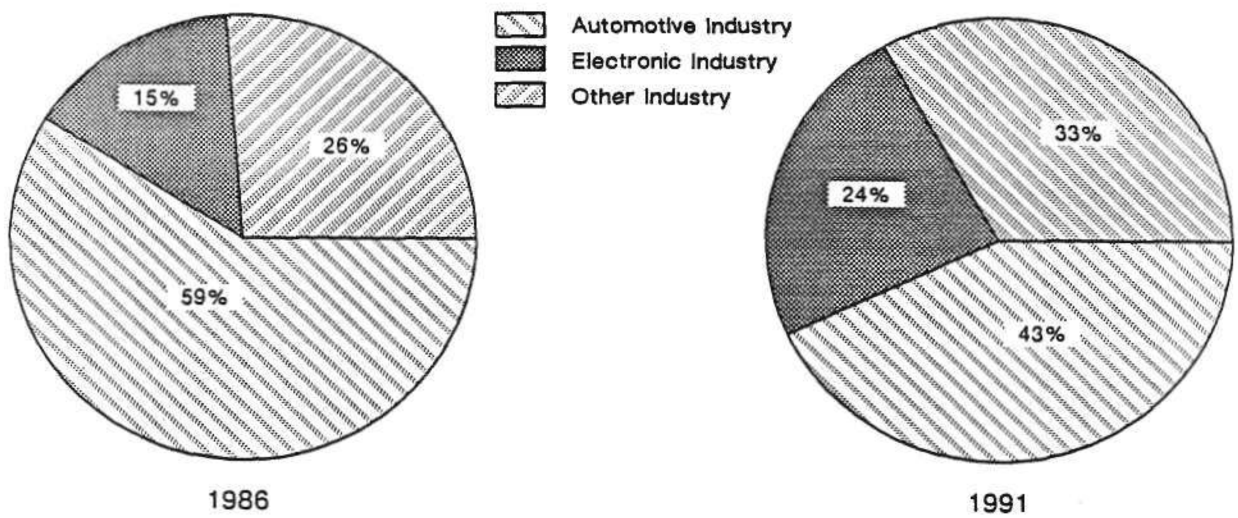
U.S. Robotics Industry
Percent of Total by Application
1986 and 1991



Source: Dataquest
April 1988

Figure 31

U.S. Robotics Industry
Percent of Total by Industry
1986 and 1991



Source: Dataquest
April 1988

Companies and Market Share

Table 3 summarizes company market share performances in the U.S. market. GMF remained the largest producer of robots in 1986 with a 25.0 percent share. In 1986, ASEA moved into the number two spot with 10.0 percent by increasing its market share from 7.7 percent the year before.

Table 3

U.S. Robotics Industry Market Share

Company	1984 Market Share	Company	1985 Market Share	Company	1986 Market Share
GMF	22.6%	GMF	26.8%	GMF	25.0%
Cinc Milacron	10.7	Cinc Milacron	10.0	ASEA	10.0
ASEA	7.2	ASEA	7.7	Cinc Milacron	9.3
Unimation	6.0	GCA	6.0	DeVilbiss	5.2
DeVilbiss	5.4	DeVilbiss	5.4	Unimation	5.0
IBM	3.9	Unimation	4.7	GCA	4.2
GCA	3.8	Graco	3.5	Adept	4.0
Cybotech	3.2	Automatix	2.8	Graco	3.8
Graco	3.1	Yaskawa	2.6	Automatix	3.3
Prab	3.0	Adept	2.3	Amer Cimflex	3.0
Automatix	3.0	Amer Cimflex	2.2	Yaskawa	2.8
	71.9%		74.0%		75.6%

Source: Dataquest
April 1988

Technology Trends

Robot Intelligence

The goal of robot intelligence (or machine intelligence) is to develop a robot that can operate in a flexible manner or in an unstructured environment. This involves a connection between perception (the interpretation of sensory data) and action (the corresponding decisions and movements taken to accomplish the task). Intelligence is necessary for robots to cope with ever-increasing levels of flexibility in their work environments.

Robot intelligence requires greater system and processing complexity. Sensory input from multiple sensors guides task planning and execution. Progress is occurring in the development of distributed processing hardware, including dedicated very large scale integrated circuits (VLSI) to support distributed decision making and control, and the use of multiple sensory devices for robot perception.

Adaptive Control

Adaptive control is a subset of robot intelligence that interprets sensory feedback and automatically adjusts parameters in order for the robot to adapt to the situation it is facing. In adaptive control, the control parameters are continuously and automatically adjusted in response to feedback of measured process variables, such as torque, pressure, or proximity. This control method recognizes and responds to unexpected or adverse conditions. An adaptive response may mean interrupting a cycle, notifying an operator of error, or replacing a faulty part with a new one.

Sensors

Sensors are growing in their importance to robotic applications for two main reasons. One reason is that sensors reduce the need for system engineering and allow robots to be more general-purpose. When a robot uses sensors to get information about its environment, such as its position relative to the workpiece, it requires less structure and fixturing in the environment. In addition to allowing a robot to operate in a less structured environment, the use of sensors lets the robot flexibly adapt to new environments and operations. Sensors allow applications to be developed more quickly and at a lower cost.

The second reason for the growing importance of sensors is machine intelligence. Sensors provide information to a robot that allows the robot to make decisions about its work, to spot and correct errors, and to adjust to changes in its environment.

Sensor Types. A number of sensor types are used to sense a variety of conditions about the environment and the workpiece, including those listed below:

- Machine vision
- Touch/tactile
- Temperature
- Ultrasonic
- Fiber optics
- Proximity/range
- Direction
- Vibration
- Odor

SPECIAL MANUFACTURING MACHINERY

Description and Definitions

The special manufacturing machinery segment consists of new and emerging automated technologies for industries other than metal parts fabrication. This segment is rapidly adopting microprocessor control, and is expected to represent major long-term growth opportunities for both vendors and users of the equipment.

The special manufacturing machinery segment includes assembly equipment for mechanical products, integrated circuit fabrication and assembly equipment, printed circuit board (PCB) assembly equipment, and primary processing equipment for plastics products. With the exception of mechanical assembly machines, the products considered in this section are included in the special industrial machinery classification of the U.S. Department of Commerce. While assembly machines for mechanical applications are categorized as metalworking machinery, they are included here to differentiate them from the metal-cutting and metal-forming machines generally associated with metalworking.

The following is a list of applications that, for the purposes of our research, constitute the special manufacturing machinery marketplace:

- Mechanical assembly equipment
  - Dial or rotary assembly machines
  - In-line transfer machines
  - Flexible assembly equipment (except robots)
- Electronic manufacturing equipment
  - Semiconductor assembly machines
    - Dicing saws
    - Die bonders
    - Wire bonders
    - Packaging
  - PCB assembly machines
    - Radial inserters
    - Axial inserters

- Other through-hole inserters
- Surface-mount, pick-and-place equipment

– Semiconductor wafer fabrication equipment

- Lithography
- Automatic photoresist processing equipment
- Etch and clean
- Deposition
- Diffusion
- Rapid thermal processing
- Ion implantation
- Process control
- Other equipment

• Plastic processing machinery

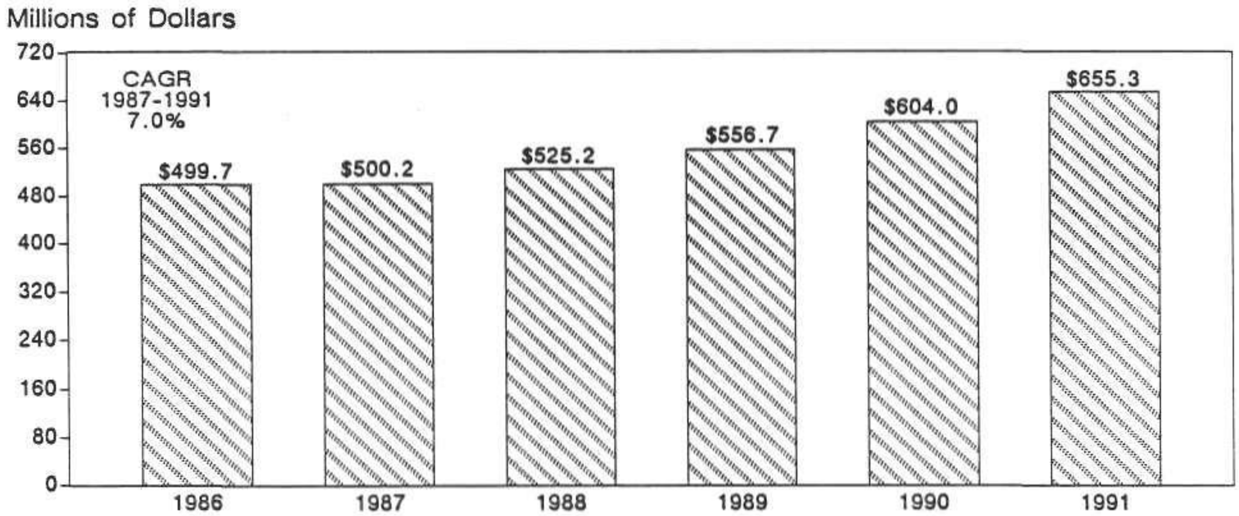
- Injection
- Structural foam
- Extrusion
- Blow molding
- Thermoforming
- Reaction injection
- Other

Market Forecast

Figures 32, 33, and 34 present consumption estimates for mechanical assembly, plastic processing, and electronics manufacturing equipment. Electronics equipment is expected to be the fastest growing, as it is forecast to expand at a 14.3 percent rate from 1987 through 1991.

Figure 32

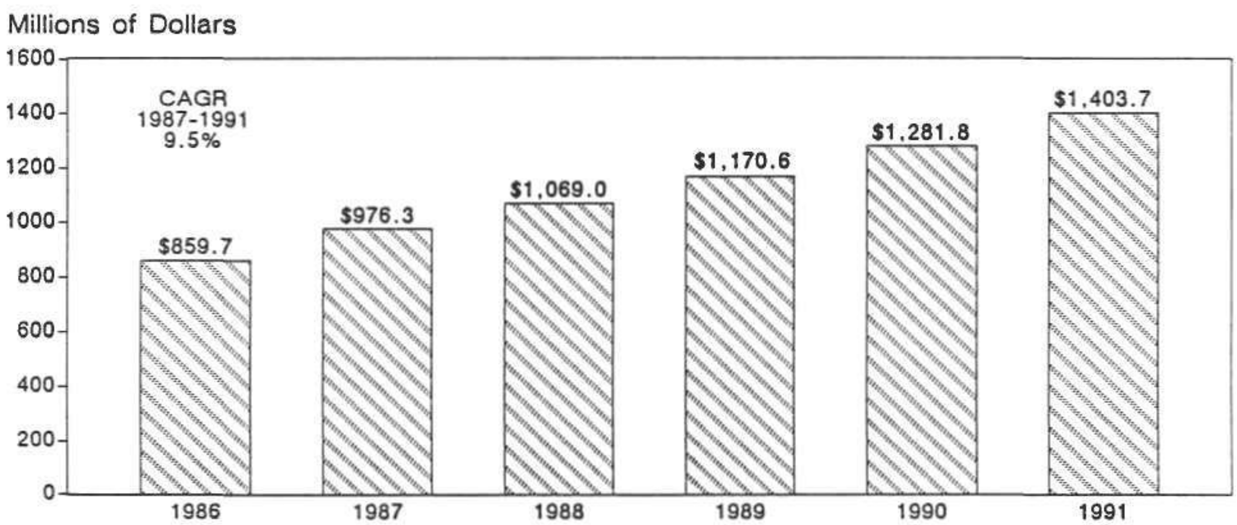
Mechanical Assembly Equipment
Estimated U.S. Consumption
(Millions of Dollars)



Source: Dataquest
April 1988

Figure 33

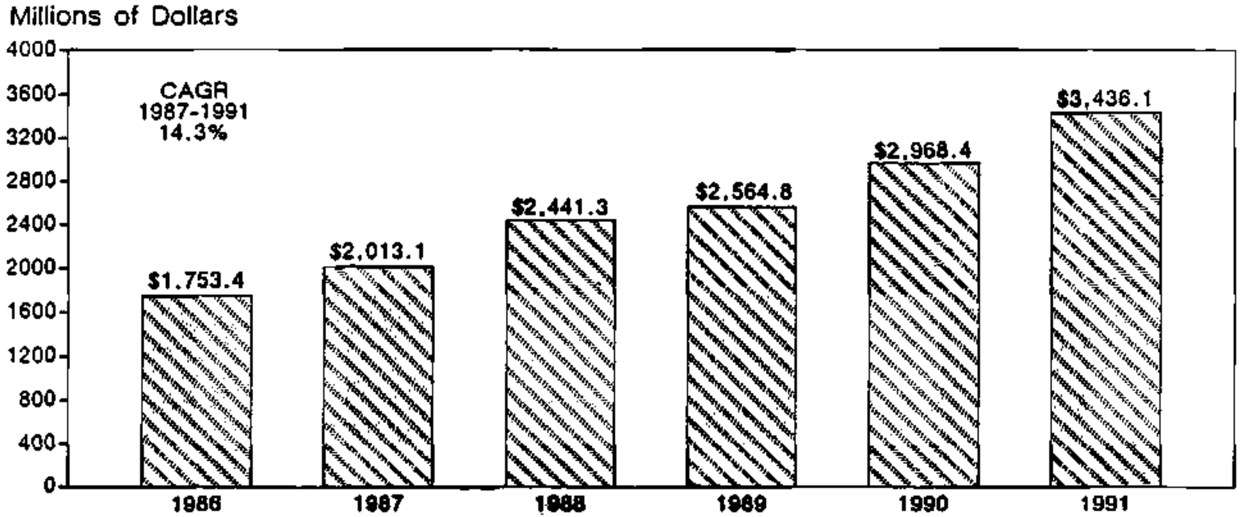
Plastic Processing Machinery
Estimated U.S. Consumption
(Millions of Dollars)



Source: Dataquest
April 1988

Figure 34

Electronics Manufacturing Equipment
Estimated U.S. Consumption
(Millions of Dollars)



Source: Dataquest
April 1988

Companies and Market Share

Mechanical Assembly

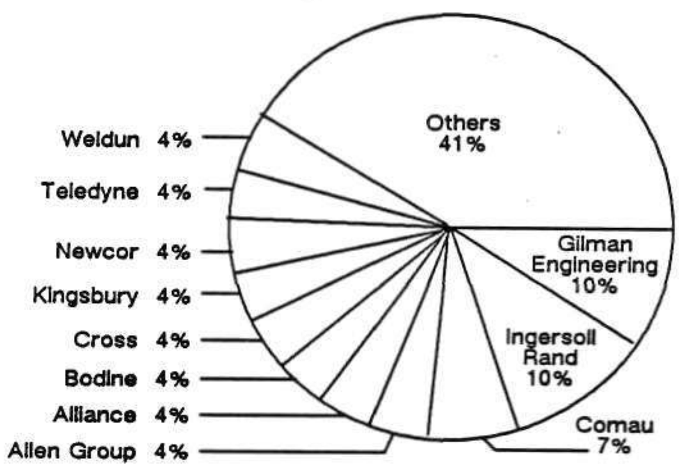
Figure 35 presents Dataquest's estimate of 1986 U.S. market shares for mechanical assembly equipment. This listing includes builders of special-purpose assembly systems, excluding welding and robotic assembly. Less than a dozen firms dominate the market, accounting for an estimated 59 percent of sales. Scores of other firms make parts assembly systems, but the majority of them do so on a piecemeal basis. Many do less than $5 million annually in sales of such systems.

Semiconductor Fabrication

Figure 36 presents Dataquest's estimate of 1986 U.S. market shares for semiconductor fabrication equipment. Perkin-Elmer is the overall leading supplier, with 15.0 percent market share.

Figure 35

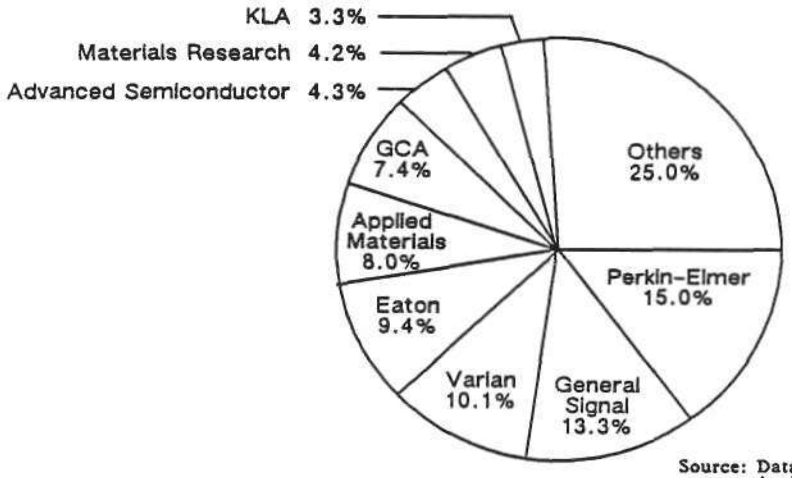
U.S. Mechanical Assembly Equipment Market
Top Vendor Market Shares
1986



Source: Dataquest
April 1988

Figure 36

U.S. Semiconductor Fabrication Equipment Market
Top Vendor Market Shares
1986



Source: Dataquest
April 1988

Semiconductor Assembly

Figure 37 presents Dataquest's estimate of 1986 U.S. market shares for semiconductor assembly equipment. Kulicke and Soffa is the largest semiconductor assembly equipment maker, with a 16.1 percent share.

Printed Circuit Board Assembly

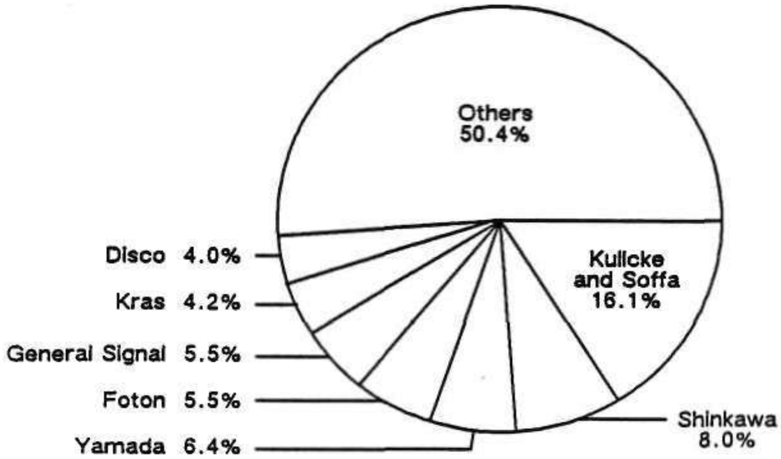
Figure 38 presents Dataquest's estimate of 1986 U.S. market shares for PCB assembly equipment. The traditional leaders in the United States have been Universal and Dynapert, due to their dominance in the inserter market. Increasing interest in surface mounting has given the Japanese vendors an opportunity to increase market share, having led the conversion to the technology in their own electronic products. Universal and Dynapert have adopted aggressive campaigns to acquire total system capabilities in surface mounting, including training and demonstration facilities. Leveraging off of their installed base, these companies should retain their leadership positions, at least for the short term.

Plastic Processing Machinery

Figure 39 presents Dataquest's estimate of 1986 U.S. market shares for plastic processing machinery. The market in the United States is dominated by Cincinnati-Milacron. The company has targeted plastic processing as an important growth area for its newly restructured company and is expected to compete aggressively, maintaining market share for some time to come. It is expected that more Japanese companies will enter the U.S. market, recognizing it as an area of better than average growth opportunities.

Figure 37

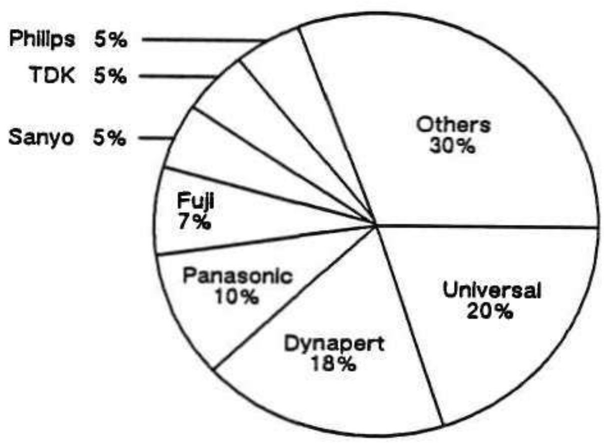
U.S. Semiconductor Assembly Equipment Market
Top Vendor Market Shares
1986



Source: Dataquest
April 1988

Figure 38

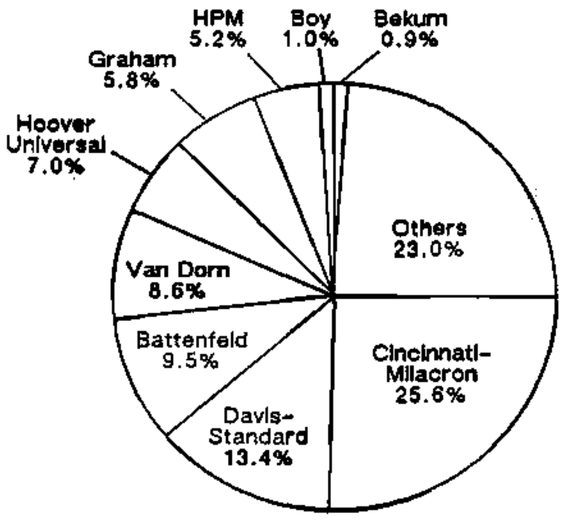
U.S. PCB Assembly Equipment Market
Top Vendor Market Shares
1986



Source: Dataquest
April 1988

Figure 39

U.S. Plastic Processing Machinery Market
Top Vendor Market Shares
1986



Source: Dataquest
April 1988

Technology Trends

Mechanical Assembly—Adhesives

Because products are being redesigned for improved energy efficiency and performance, plastics, composite materials, and lightweight metals are being specified in increasing quantity by product designers. Traditional fasteners require strong clamping forces inappropriate to the new materials. This has led to a new interest in adhesive assembly.

Programmable dispensers are now available for mechanical assembly systems. These are designed to meter amounts of adhesive at one point or several simultaneously or in flowing ribbons that outline contours.

Electronic Assembly—Surface-Mounted Devices

Surface-mount technology (SMT) has produced changes in traditional component configurations as well as in the means of assembling circuits containing these devices. Pick-and-place machines for the selection and mounting of active and passive surface-mount components continue to become more accurate and reliable. Much attention in the future will be paid to the attachment of these devices, with completely new technologies such as conductive epoxies proliferating, all in pursuit of a reliable method of connecting the large number of finely spaced leads expected in new components.

The assembly of the components themselves is also expected to change. Designers of new integrated circuits desire to increase the capabilities of these products while decreasing their size. Tape automated bonding (TAB) is expected to grow as a solution to the complicated problems of packaging and assembling these circuits.

Plastics Processing—Smart Sensors

Sensors have become essential to meeting the demands of automated processing with specialized manufacturing machinery. Especially important for primary plastics processing machinery, more rapidly responsive, accurate, and versatile sensors have contributed to productivity improvements in such new commercial processes as multilayer film extrusion and barrier bottle blow molding. Sensor applications for plastics processing are discussed in the following paragraphs.

Position Sensing. Transducers are used to replace the many electromechanical limit switches that formerly controlled mold closing and injection movements.

Sonic position transducers are gaining acceptance due to their many advantages: noncommittal operation, no mechanical wear, no noise generation, high reliability, infinite resolution, high linearity, excellent repeatability, and direct digital readout. These transducers operate on a principle similar to that used to measure distances with radar.

Temperature Sensing. Type J thermocouples are the device of choice for almost all temperature sensing applications in plastics processing. Despite some susceptibility to electrical interference and difficulties with remote mounting, their cost advantages and versatility have made them very popular.

Pressure Sensing. In most plastic processes, strain-gauge pressure transducers are essential to effective operation. These represent an improvement over the mechanical variety and are claimed to be more stable, reliable, and accurate. In injection molding, these devices monitor hydraulic oil pressures and melt pressures in molds. In extrusion, they monitor pressure drops, detect pressure buildups and surging, and control screw speed. They are the preferred device when pressure feedback is used in closed-loop process control.

COMPUTER SYSTEMS

Market Forecast

U.S. factory revenue for computers used in manufacturing automation will grow at a compound annual rate of 10.1 percent from 1987 through 1991. In 1991, shipments will exceed $6.4 billion. Approximately 5.0 percent of U.S. factories (those with more than 250 employees) account for 80.0 percent of the market.

The fastest-growing computer systems are the superminicomputer and the low-end products (performance classes I and II, PLCs). Classes I and II are growing at about 11 percent annually as measured by factory revenue. Unit growth, however, is much higher, indicating a rapid reduction in average selling price. For example, consider the following:

Performance Class	CAGR (1986-1991) Revenue	Units	ASP
I and II	11	21.2	(12%)
PLCs	12	32.0	(20%)

Like the general computer industry, the trend in low-end systems classes is migration of larger systems to smaller ones as price/ performance ratios decrease. Thus we find more systems being used at the workstation and cell levels within an organization than at corporate and factory levels.

The proliferation of these small systems has created the need for control over operations, data sharing, and communications. This is another reason why superminicomputers (with their extensive I/O and control facilities) are also growing more rapidly than other system classes.

Computer applications in manufacturing fall into two primary categories:

- Plant logistics (which includes applications that deal with planning, analysis tracking, decision-making, and back-office functions)
- Plant operations (which refers to control operations for physical processes such as product fabrication and materials handling)

Logistics currently account for nearly three-quarters of the manufacturing automation market and this percentage is increasing in the United States. There are several reasons for this:

- One of the primary justifications for automating operations is labor replacement. With most U.S. manufacturing moving offshore, the need to replace labor with machines is reduced accordingly.
- Aside from labor, the other major manufacturing cost and investment items are overhead and materials. Logistics applications address the planning and control problems in these areas.
- Even when manufacturing operations move offshore, many of the logistics functions (such as planning, scheduling, and distribution) remain in the United States.
- As competition increases (resulting in a shorter product life), the need to accelerate the manufacturing cycle increases. This need is mostly met by logistics functions.

U.S. factory revenue for computers in manufacturing automation is summarized in Table 4.

Table 4

U.S. Factory Revenue for Computers in Manufacturing Automation (Millions of Dollars)

Performance Class	1986	1991	CAGR
VII	$ 610	$ 706	2.9%
VI	908	1,578	11.7%
IV and V	662	975	8.1%
III	396	455	2.8%
I and II	559	1,071	13.9%
PLCs	741	1,475	14.8%
Boards	91	160	12.0%
Total	$3,967	$6,420	10.1%

Companies and Market Share

Table 5 lists the 1986 factory revenue and market share estimates for the top U.S. vendors of computer and controller hardware used in the U.S. manufacturing market.

Table 5

Top U.S. Vendors of Computers and Controllers in Manufacturing by Factory Revenue (Millions of Dollars) 1986

Vendor	Computer	Controller	Total Revenue	Market Share
IBM	$1,342	0	$1,342	33.8%
Unisys	490	0	490	12.4
Digital Equipment	376	0	376	9.5
Allen-Bradley	0	$348	348	8.8
Gould	0	150	150	3.8
Hewlett-Packard	145	0	145	3.7
Prime	128	0	128	3.2
Data General	105	0	105	2.6
Honeywell	90	11	101	2.5
Other	459	323	782	19.7
Total	$3,135	$832	$3,967	100.0%

Source: Dataquest
April 1988

IBM is the largest vendor of computer products for the manufacturing automation market, with a dominant 33.8 percent market share. Its products, covering a broad range from large mainframes to personal computers, are particularly strong in the planning, control, and analysis applications. Although IBM does not market PLCs or board-level computers for this market, it has alliances with the leading vendors of these classes of computers and controllers.

In second position is Unisys, with a 12.4 percent market share (based upon the combined shares of Sperry and Burroughs). Its position is derived from production planning, logistics, and analysis applications of mainframes and minicomputers.

Digital Equipment is the third largest vendor in this segment of the manufacturing automation industry, with a 9.5 percent revenue share. Digital sells a broad line of computers, ranging from the powerful VAX 800 series to the MicroVAX line.

Allen-Bradley is in fourth position, with an 8.8 percent revenue share, and is the leading vendor of programmable logic controllers (PLCs). The company's product line also offers communications capabilities, both in a proprietary network and via a MAP-compatible protocol. Allen-Bradley also has begun selling PLC programming microcomputer hardware and software systems.

Together the top vendors accounted for an estimated 80.3 percent of the 1986 manufacturing automation computer and controller factory revenue, $3.97 billion.

NETWORKS

Descriptions and Definitions

The following descriptions are of various types of networks:

- MAP Broadband—Complies with MAP standards, operates at a data transmission rate of 10 megabits per second, and specifies a broadband coaxial LAN and the IEE's 802.4 token bus protocol with access methods

- MAP Carrierband—Complies with MAP standards, using IEEE's 802.4 phase-coherent signaling specification and operates at a data transmission rate of 5 megabits per second

- TOP—Specified as a baseband-type LAN and IEEE 802.3 carrier sense multiple access with collision detection (CSMA/CD)

- Ethernet—A single-channel baseband network and IEEE 802.3 CSMA/CD

- Proprietary Broadband—Uses some channels in an IEEE 802.3 or 802.4 network that does not comply with MAP or OSI standards

- Proprietary Programmable Control—A twisted-pair network used by PLC vendors to connect their equipment in the factory

- Proprietary Distributed Control—Used by instrument vendors to connect their equipment primarily in process industries

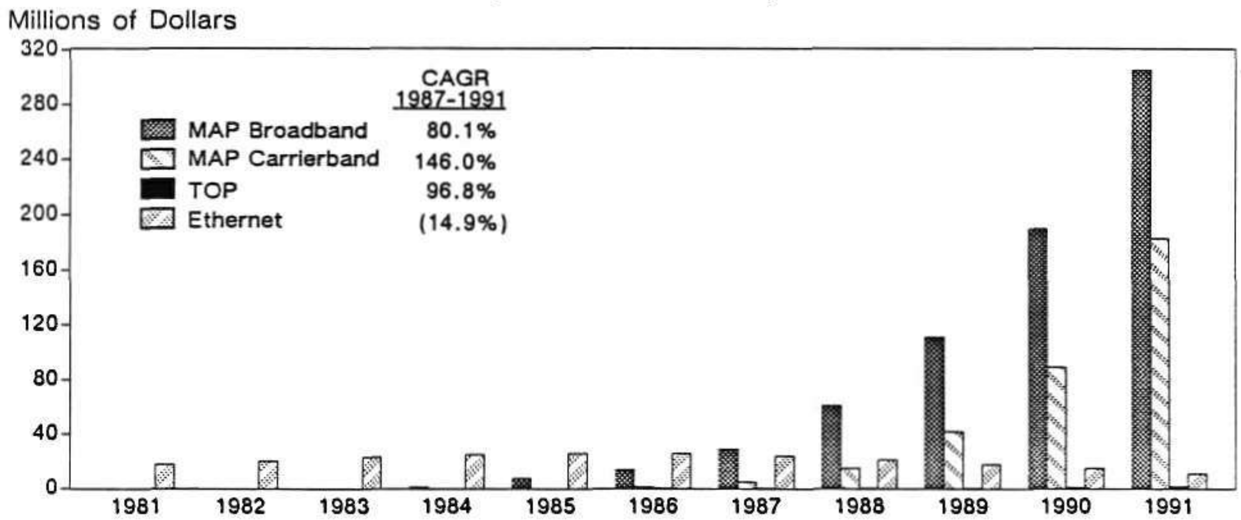
Market Forecast

Figures 40 through 43 show Dataquest's is estimates for historical and forecast revenue and shipments for the U.S. manufacturing LAN market from 1982 through 1991. Projections for factory revenue include the following:

- Revenue growth will be strong in MAP broadband networks, with a CAGR of 80.1 percent from 1987 through 1991.
- MAP carrierband networks will exhibit a CAGR of 146.0 percent from 1987 through 1991. Although revenue will be less than than that of MAP broadband, unit costs of MAP carrierband are one-third those of MAP broadband, resulting in lower revenue.
- TOP networks will exhibit a CAGR of 96.8 percent from 1987 through 1991.
- Users will migrate away from Ethernet and proprietary broadband networks toward MAP/TOP. These networks will exhibit CAGRs of negative 14.9 percent and negative 15.9 percent, respectively.
- Proprietary programmable controller and proprietary distributed controller networks decrease at CAGRs of negative 2.3 percent and negative 1.4 percent, respectively, from 1987 through 1991.

Figure 40

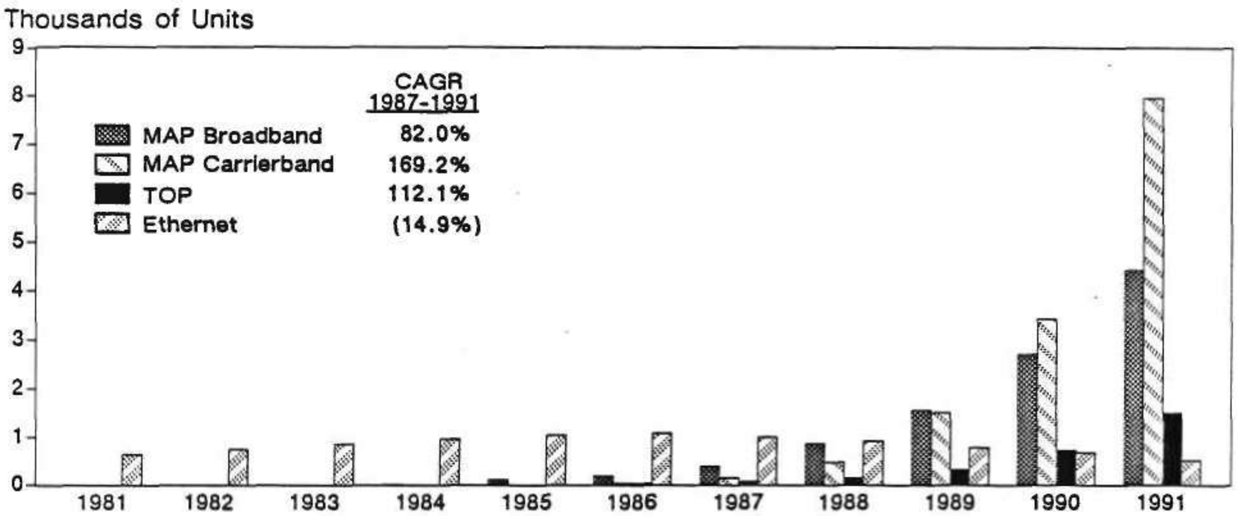
Nonproprietary LAN Market
Estimated U.S. Revenue
(Millions of Dollars)



Source: Dataquest
April 1988

Figure 41

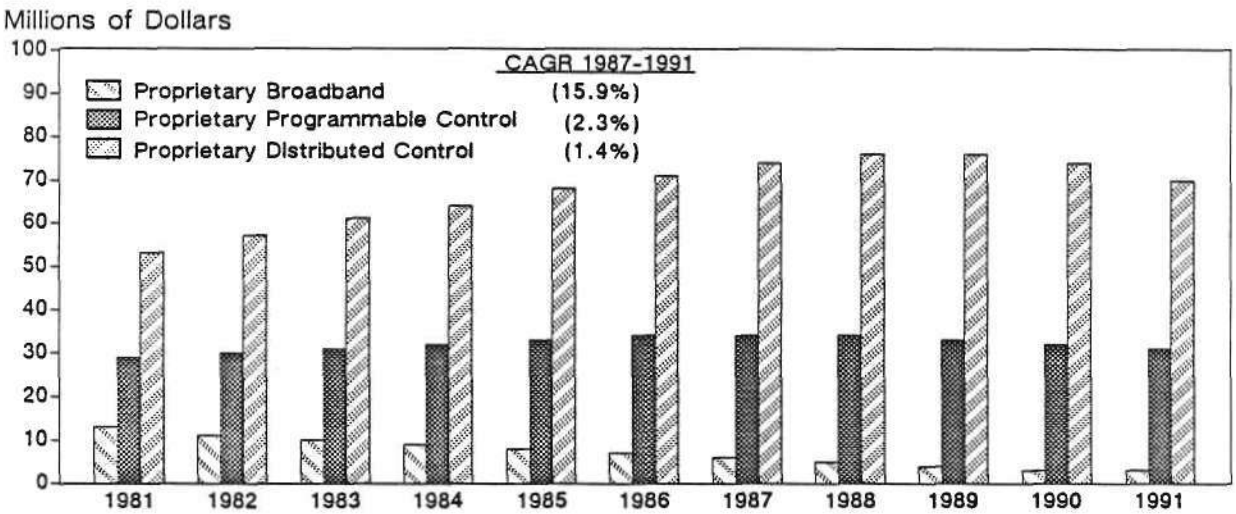
Nonproprietary LAN Market
Estimated U.S. Shipments
(Thousands of Units)



Source: Dataquest
April 1988

Figure 42

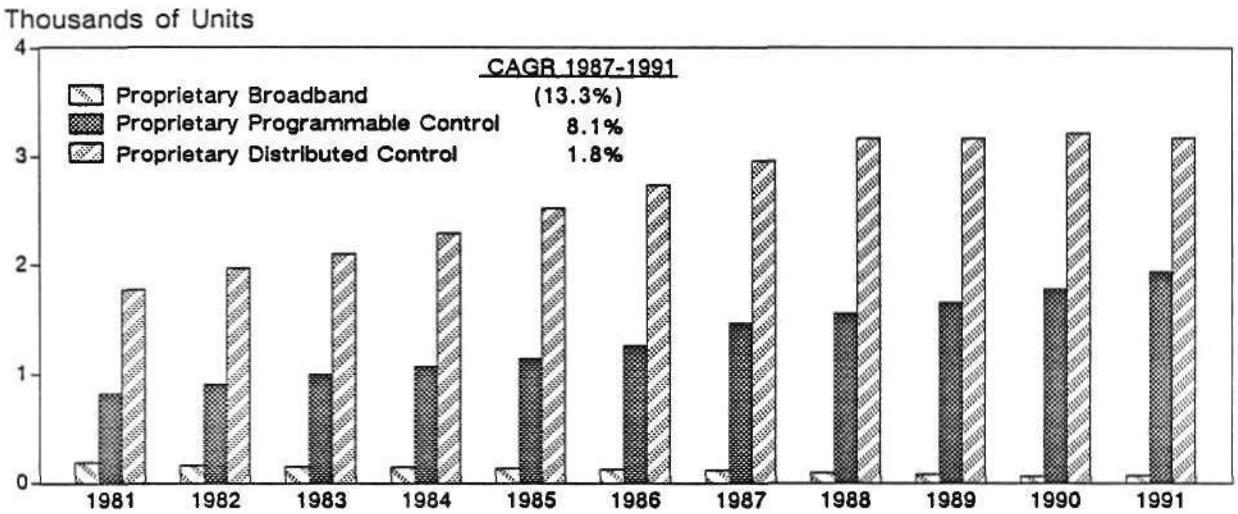
Proprietary LAN Market
Estimated U.S. Revenue
(Millions of Dollars)



Source: Dataquest
April 1988

Figure 43

Proprietary LAN Market
Estimated U.S. Shipments
(Thousands of Units)



Source: Dataquest
April 1988

Companies and Market Share

Dataquest estimates that the total 1986 market for factory LANs was $130 million. This estimate includes both proprietary and public domain LANs, as shown in Table 6.

Digital Equipment Corporation is the leading network vendor, with estimated 1986 factory revenue of $25 million. Digital has products in both the public and proprietary areas. In 1986, the company announced products that enable its minicomputers to communicate using MAP protocols (except layer 6, which is not yet defined). These MAP products reportedly will communicate from minicomputers to numerical controllers, robots, and other factory floor devices. In theory, the MAP products can also link incompatible computers together.

Foxboro is also estimated to have 1986 network factory revenue of $25 million. However, this revenue is from proprietary network products that are primarily used for process control systems by process industry users. Foxboro is broadening its experience in the process industry market to include applications in the discrete-piece industries.

Allen-Bradley ranks third in 1986 network revenue, with an estimated 12.3 percent market share. In addition to its proprietary networks, Allen-Bradley has many cooperative working agreements with computer vendors, such as IBM, Digital Equipment, Hewlett-Packard, Honeywell, and Data General, for links between computers and PLCs and numerical controllers. Both proprietary and public protocols are supported, including MAP. We believe that Allen-Bradley is in a position to be a major participant in expected future growth within the factory LAN market.

Table 6

Top 10 Vendors of LANs Used in Manufacturing by U.S. Factory Revenue (Millions of Dollars) 1986

Vendor	Proprietary LAN	Public LAN	Total Revenue	Market Share
Digital Equipment	$ 7	$18	$ 25	19.2%
Foxboro	25	0	25	19.2
Allen-Bradley	16	0	16	12.3
Bailey Controls	15	0	15	11.5
Gould	8	0	8	6.2
Honeywell	8	0	8	6.2
Ungermann-Bass	0	6	6	4.6
Concord Data Systems	0	4	4	3.1
Industrial Networks	4	0	4	3.1
General Electric	4	0	4	3.1
Other	11	4	15	11.5
Total	$98	$32	$130	100.0%

Source: Dataquest
April 1988

Technology Trends

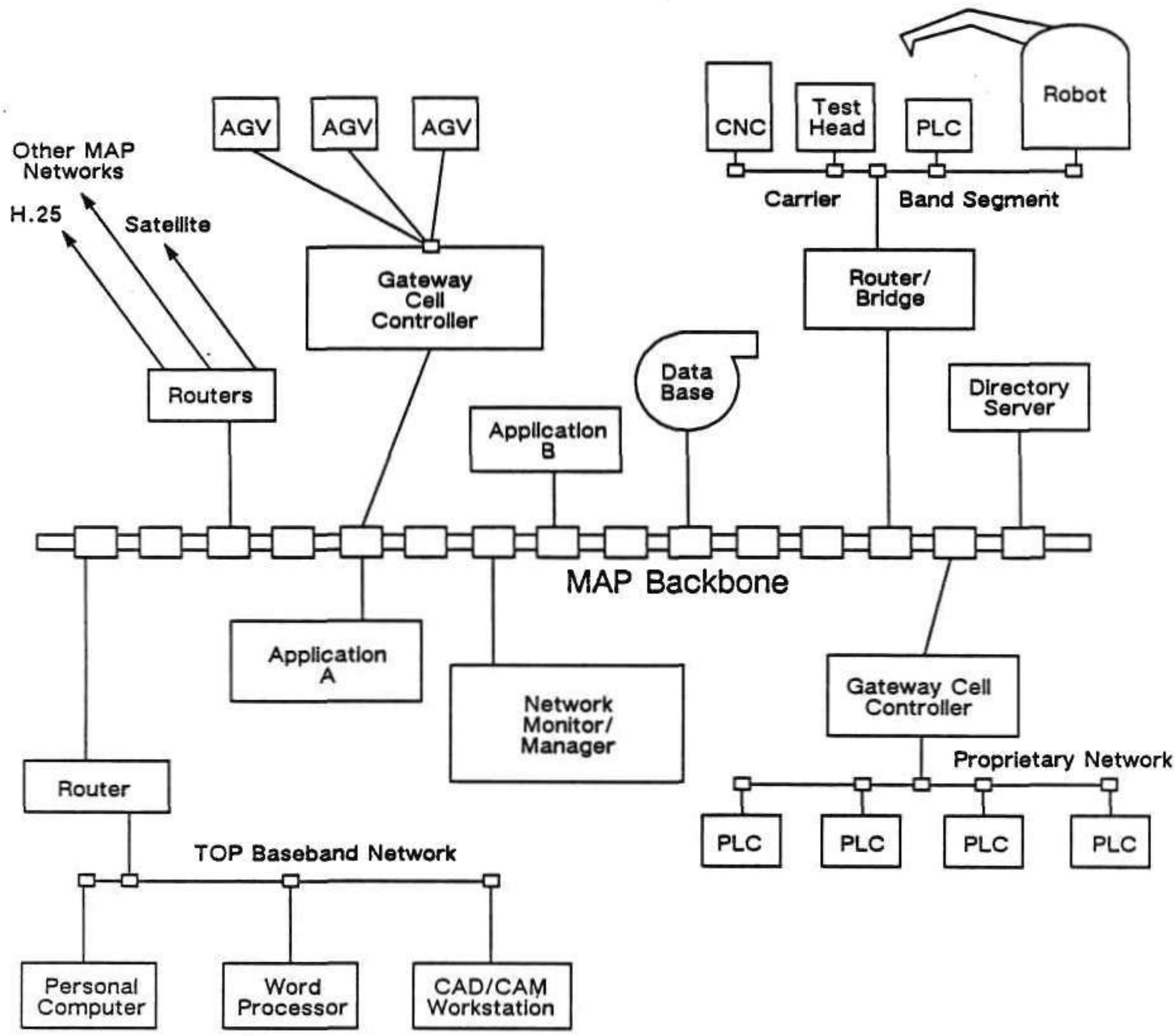
MAP

Manufacturing Automation Protocol (MAP), spearheaded by General Motors, is a highly sophisticated broadband token bus network that connects various pieces of processing equipment. The token bus network connects all nodes to a common bus, with the bandwidth either shared or dedicated. The originating node constructs a message that also contains the address of the destination node. All nodes receive the message, and each must actively decide whether it must be accepted, based on the analysis of the destination address. A failure in any node does not affect others provided that the node is not short-circuited or the node is in a constant transmit condition.

MAP is a seven-layer communication specification designed for the factory floor and based on the OSI model discussed in the previous section. Figure 44 pictorially depicts the functions of a MAP network in a typical factory.

Figure 44

Factory Logical Connections to MAP



Source: ITI, Gateway
MAP Users' Group

Despite the advancements in MAP and TOP standards, much work remains to be done. Not all of the layers of these protocols have been standardized. The MAP standards are not expected to be in place in the market until 1988 or 1989. Although product announcements have been made by several vendors, MAP, nevertheless, continues to evolve slowly as a result of the following:

- The high cost of MAP products—A MAP connection on a network can cost 10 times more than an Ethernet connection.

- The question of MAP product compatibility—To avoid incompatibility, users are attempting to minimize their number of MAP suppliers.

  - Builders of MAP interfaces and software may interpret the standards in different ways.

  - Conformance testing (by the Industrial Technology Institute, Ann Arbor, Michigan, and the National Bureau of Standards) is not performance testing under normal or heavy traffic.

  - Some modems are incompatible when another vendor's modems are on adjacent broadband channels.

  - MAP version 3.0 and 2.1 will have incompatible features.

- A large installed base of proprietary LAN equipment—There is concern with implementing MAP because of the following:

  - Existing networks in a company may become obsolete.

  - Interfaces to MAP at the system level are expensive.

  - Board-level products, although two-thirds the cost of system-level products, will still require at least six months to be integrated by vendors into their equipment.

In addition to the slowly evolving MAP protocol standards, another barrier to implementation is the islands of automation concept. Because of the variety of vendors, different equipment in a factory is automated differently. Each of these operations has its own data base and operating system, resulting in systems that are virtually incompatible with one another. Consolidating islands of automation is a slow process. As more islands are integrated, the communications demands of manufacturing companies will increase rapidly, requiring the flexibility and high capacity of a MAP network.

TOP

TOP, developed by Boeing Computer Services in 1985, is also based on the seven-layer OSI model. Layer 1, the physical layer, however, is specified as a baseband type LAN and IEEE 802.3 carrier sense multiple access with collision detection

(CSMA/CD). This is in contrast with MAP, which specifies a broadband coaxial LAN and the IEEE's 802.4 token bus protocol with access methods. Both TOP and MAP specify the same OSI protocols at layers 2 through 6.

TOP's layer 7, the application layer, has a simpler and more limited file management protocol than MAP has. Because TOP is directed at office environments, this protocol layer covers message handling for electronic mail and covers job transfer and manipulation for remote batch processing. TOP's layer 7 is based on CCITT's X.400 store-and-forward messaging protocol, which forms the basis of OSI office document protocols.

CSMA/CD has the proven capability of handling a wide range of business and engineering applications, including document interchange and graphics processing.

Many issues need to be addressed before TOP is accepted at the same level as MAP, including the following:

- Unlike MAP, TOP is expected to become the LAN standard in an area in which major vendor's proprietary networks are firmly entrenched. The major competition comes from IBM's Systems Network Architecture (SNA).

- TOP involves many office automation functions that MAP does not need. As a result, the establishment of specifications for TOP has become more complex than for MAP. Technical issues that remain unresolved will take time, delaying the acceptance of TOP.

- Lacking a clear-cut identity, TOP needs the support from other industry segments besides manufacturing.

Trends in Technical Workstations

INTRODUCTION

This section provides Dataquest's Technical Computer Systems Industry Service (TCSIS) analysis of the technical workstation market. The information provided includes: vendor market share analysis, industry forecasts, and technology trends.

In the last five years, many companies have emerged, targeting the lucrative engineering and scientific applications market with specially designed graphic workstation computers that Dataquest calls "technical workstations." Several companies have fallen by the wayside, several have emerged as market leaders, and more companies will enter.

The workstation business is shaping into a nearly high-end equivalent of the PC-clone business. In 1987, the number of workstation vendors has almost doubled, with the largest number of new entrants from Japan. It appears that technical workstation technology is a leading indicator of the personal computers and low-end superminicomputers that will be available in a few years; hence, almost every computer company is planning to announce or has announced a technical workstation product. The technical workstation has become the "engineer's personal computer." Table 1 lists the new workstation introductions during 1987.

Table 1

New Workstation Vendors in 1987

Convergent Technologies (United States)
Counterpoint (Japan)
Hitachi (Japan)
Meidensha (Japan)
Mitsubishi (Japan)
NEC (Japan)
Nihon Univac (Japan)
Prime Computers (United States)
Sharp (Japan)
Sony (Japan)
Tektronix (United States)
Toshiba (Japan)
TeleVideo (United States)
UStation (Japan)
Xerox (United States)

Source: Dataquest
September 1988

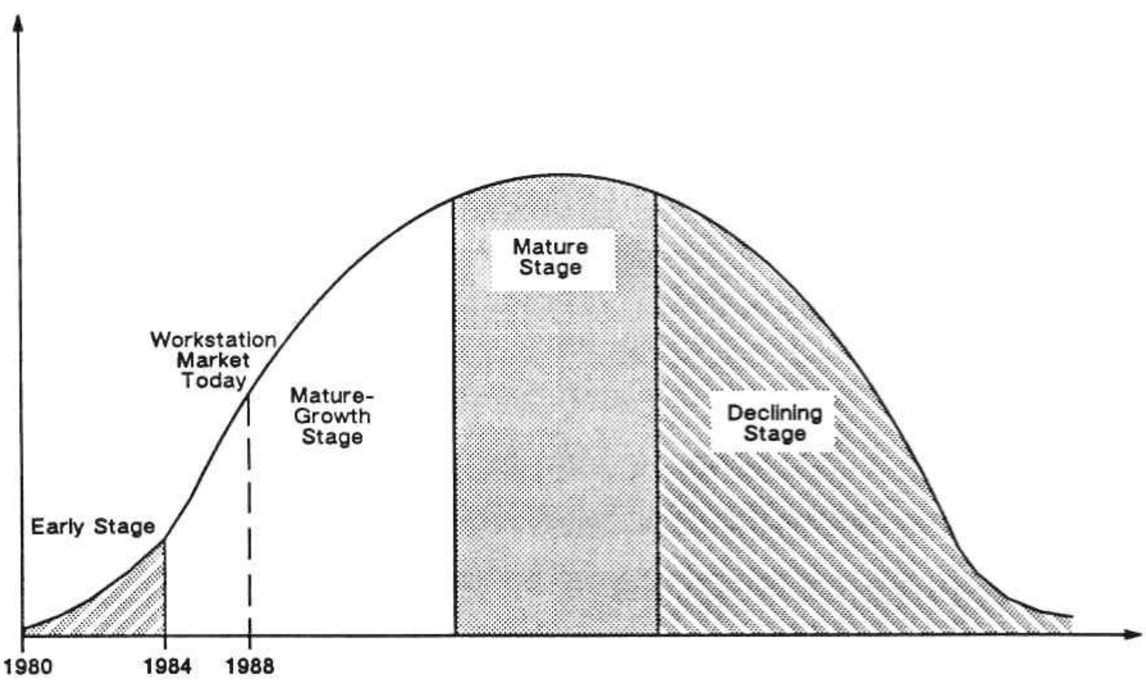
MARKET ANALYSIS

State of the Market

Dataquest believes that the technical workstation market is in a maturing growth phase. Emerging markets typically undergo several phases, as illustrated in Figure 1. This scenario, which occurred with software companies, personal computer companies, and multiuser micro-based systems, is now occurring in the technical workstation market. Sun and Apollo have each shipped more than $1 billion worth of systems since their first shipments. Several start-up companies have come and gone. Companies like Hewlett-Packard, IBM, and Digital have entered the market after it reached significant size. Now we are seeing many Japanese vendors begin their assault. The total installed base of systems beginning in 1980 is valued at more than $5 billion, with shipments totaling 227,000 to date. Technical workstations have evolved from a specialized niche to the mainstay of computing.

Figure 1

Technical Workstation Market Development Cycle



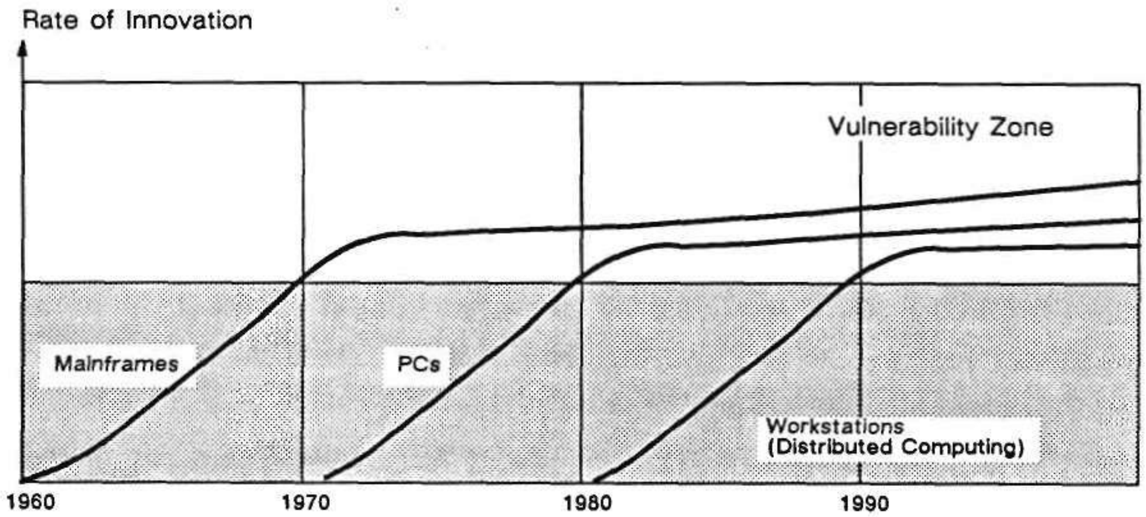
Source: Dataquest
September 1988

Trends in Technical Workstations

Technologies tend to be vulnerable to competition, once the rate of change on technological innovation slows. This is illustrated in Figure 2. Once a rate of computer technology innovation slows, the market is harder to defend and typically becomes flooded with competition, especially from Japanese manufacturers. Unique products can help build a defensible "niche" for a company, but when the technology becomes understood by many, then competition exploits the market niche. However, the technical rate of innovation in the workstation industry has slowed temporarily for the traditional technical workstation segment. Once this happens, the emphasis tends to shift to low-cost manufacturing, and the Japanese enter the market. Last year was the first year Japanese manufacturers entered the workstation market, gaining a 4.6 percent share of the total revenue.

Figure 2

Rate of Technological Innovation



Source: Sun Microsystems Inc.

Why Enter the Market?

With the market dominated by Apollo, HP, and Sun, and the impending threat of Digital and IBM rapidly gaining market share, why would any company enter the market at this point? Computer vendors are realizing:

- The "engineer's PC" is the technical workstation and to play in the engineering computer system market, a vendor must have a workstation to offer.

- The technical workstation market is large, fast-growing, and lucrative.

- Control of the users' interface to the network of personal computers and superminicomputers is a key strategic issue.
- Technical workstation technology is moving into the high-end personal computer area, and vendors want to be well positioned.
- Technical workstations are the leading architectures of future networked-based computing systems.

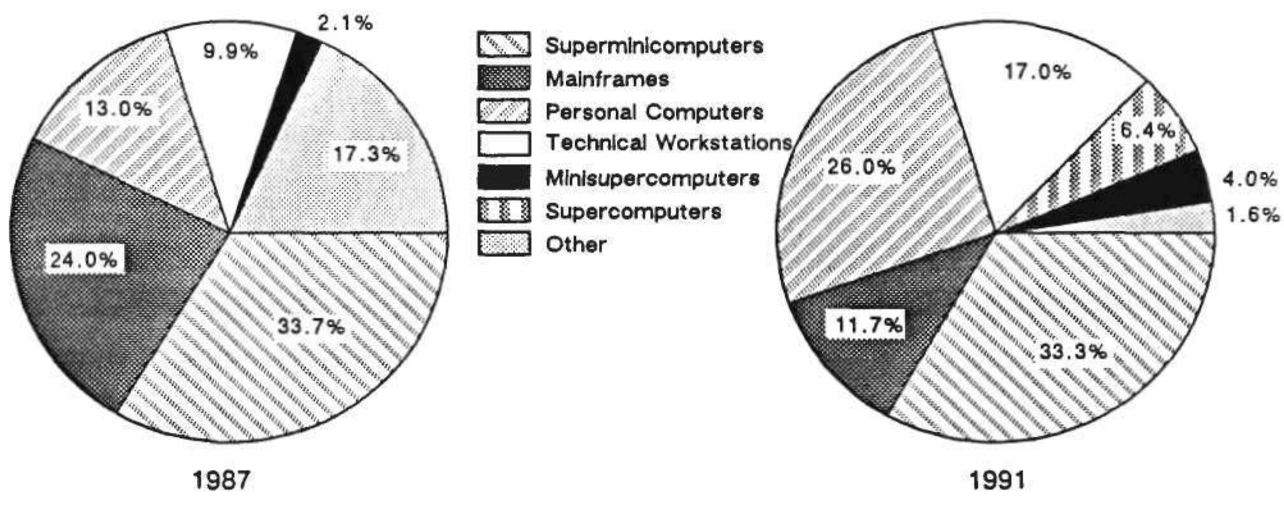
Size of the Market

The technical workstation market began in 1980 and grew to more than $2 billion by 1987. The 1987 vendor ranking by revenue was Sun, Apollo, Digital, and Hewlett-Packard. Dataquest expects the technical workstation market to be more than $6 billion by 1991, growing at a 30 percent compound annual growth rate (CAGR) from 1987 through 1991.

Figure 3 illustrates the size of the technical workstation segment relative to other technical computer product segments. We expect the technical workstation market share to grow from 9.9 percent of the total market revenue in 1987 to 17.0 percent by 1991.

Figure 3

Product Segment Analysis
1987 and 1991



Source: Dataquest
September 1988

Trends in Technical Workstations

While workstation growth rates are still outpacing the other technical computer segments, year-to-year growth rates are slowing, which is expected as the market matures and increases in size. Tables 2 and 3 and Figures 4 and 5 present the technical workstation factory revenue and unit shipment historical data and forecasts for 1982 through 1991.

Table 2

Technical Workstation History
Factory Revenue and Unit Shipments
(1982–1986)

	1982	1983	1984	1985	1986	CAGR 1982-1986
Revenue ($M)*	35	164	471	938	1,563	157.9%
Percent Change	N/M	362.7%	188.1%	99.1%	66.7%	
Shipments (K Units)*	1	6	13	33	61.3	170.9%
Percent Change	N/M	402.4%	125.9%	151.6%	88.6%	
Average Selling Price ($K)	35	27.3	36.2	28.4	25.5	(19.0%)
Total Cumulative Shipments (K Units)	1.5	7.2	20.1	52.6	113.6	195.0%

*All numbers adjusted to calendar year
N/M = Not Meaningful

Source: Dataquest
September 1988

Table 3

Technical Workstation Forecast
Estimated Factory Revenue and Unit Shipments
(1987–1991)

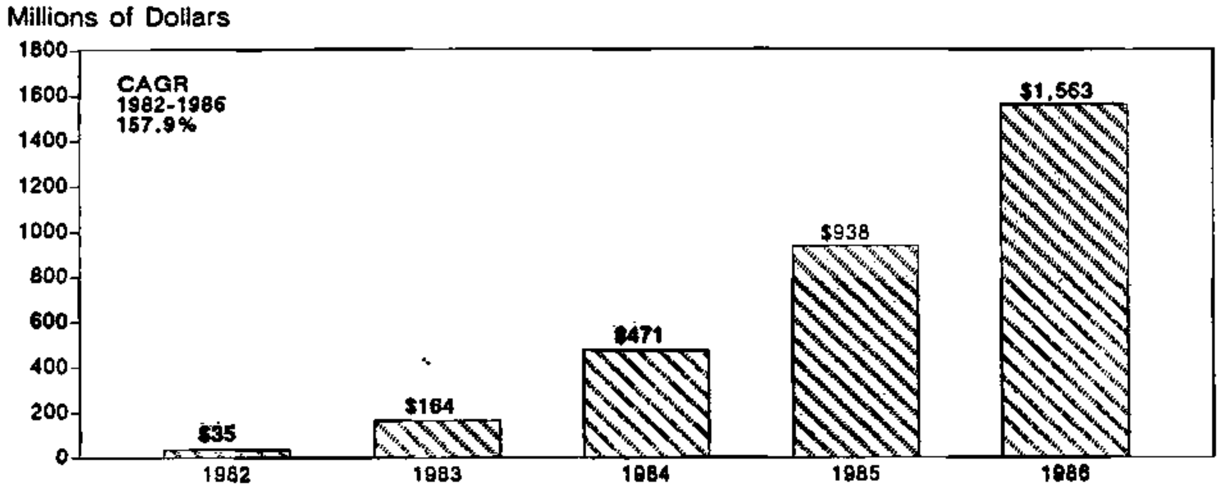
	1987	1988	1989	1990	1991	CAGR 1987-1991
Revenue ($M)*	$2,092	$2,835	$3,781	$ 5,172	$ 6,336	30.0%
Percent Change	38%	35%	30%	27%	28%	
Shipments (K Units)*	95	168	291	455	627	60.4%
Percent Change	55%	78%	72%	56%	38%	
Total Cumulative Shipments (K Units)	208.5	378.0	667.0	1,145.0	1,817.0	71.9%
Average Selling Price ($K)	22.7	17.2	13.0	10.5	9.8	(19.0%)

*All numbers adjusted to calendar year

Source: Dataquest
September 1988

Figure 4

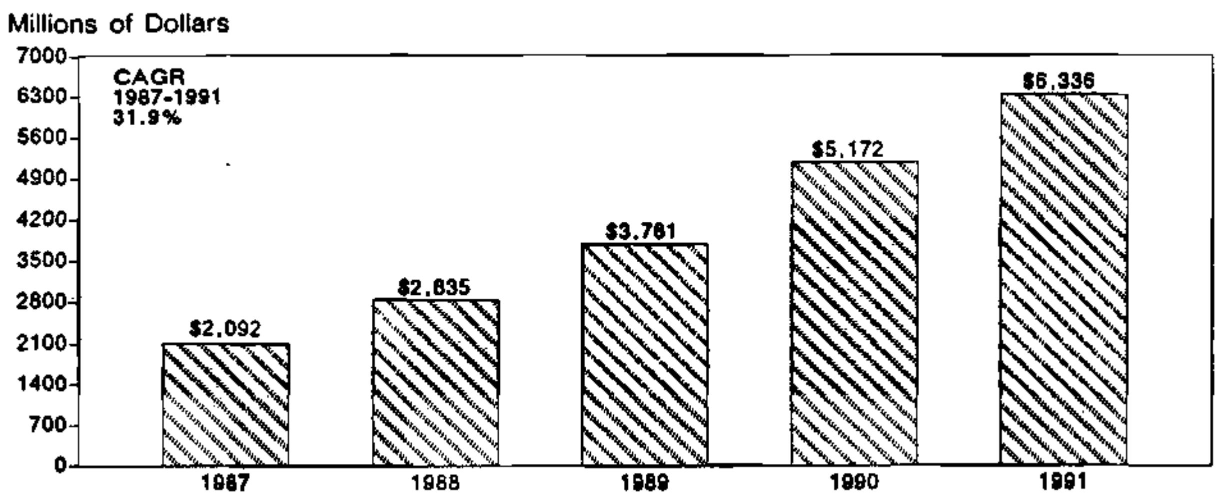
Technical Workstation History
Estimated Vendor Revenue
(1982–1986)



Source: Dataquest
September 1988

Figure 5

Technical Workstation Forecast
Estimated Vendor Revenue
(1987–1991)



Source: Dataquest
September 1988

The vendors 1987 market shares of revenue and units are listed in Table 4 and Figures 6 and 7. The top four companies—Sun, Apollo, Digital, and Hewlett-Packard—hold 79.6 percent of the revenue and 83.8 percent of the unit shipments for the entire workstation segment. We note the following:

- Sun is the biggest market share gainer, with a 4.4 percent increase. Sun is followed by Digital with a 4.2 percent gain. Sony followed with a 1.8 percent gain. (Sony was not in the market prior to 1987.)

- Sun passed Apollo for the number one spot and Digital passed HP for the number three position.

- The biggest market share losers were Apollo, Symbolics, and HP.

- In 1987, Japanese manufacturers shipped a measurable amount of product for the first time. Sony led Japanese manufacturers with 1.8 percent of the market followed by NEC (1.4 percent), Hitachi (1.1 percent), and Fujitsu (0.3 percent). Together, the four Japanese manufacturers accounted for 4.6 percent of the entire workstation market.

Table 4

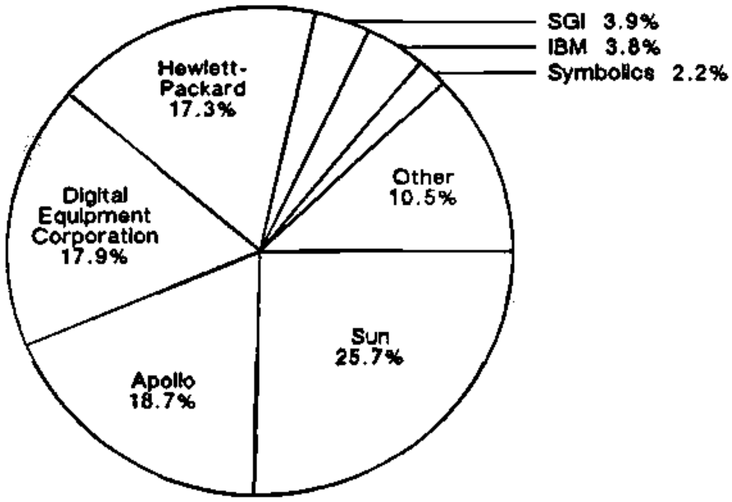
Estimated Technical Workstation
Market Share
(Percent of Total)

	Revenue			Units		
	Market Share		Change	Market Share		Change
	1986	1987	1986-1987	1986	1987	1986-1987
Sun	21.2%	25.7%	4.4%	26.2%	28.2%	2.0%
Apollo	24.3	18.7	(5.6%)	24.6	20.3	(4.3%)
Digital Equipment	13.7	17.9	4.2%	11.5	19.4	7.9%
Hewlett-Packard	20.7	17.3	(3.4%)	24.5	15.9	(8.7%)
SGI	3.4	3.9	0.5%	2.0	2.2	0.2%
IBM	2.6	3.8	1.2%	2.5	3.1	0.6%
Symbolics	6.6	2.2	(4.4%)	2.5	1.1	(1.5%)
Sony	0	1.8	1.8%	0	2.1	2.1%
Xerox	1.9	1.5	(0.4%)	2.0	1.7	(0.3%)
Data General	2.2	1.5	(0.6%)	1.3	1.7	0.4%
NEC	0	1.4	1.4%	0	1.1	1.1%
Texas Instruments	2.0	1.2	(0.8%)	1.5	1.1	(0.4%)
Hitachi	0	1.1	1.1%	0	0.5	0.5%
UStation	0	0.9	0.9%	0	0.6	0.6%
Fujitsu	0	0.3	0.3%	0	0.3	0.3%
MASSCOMP	0.9	0.3	(0.6%)	0.7	0.2	(0.5%)
ISI	0.3	0.4	0	0.4	0.4	0
Other	0.4	0.3	(0.1%)	0.4	0.4	(0.1%)
Total	100.0%	100.0%		100.0%	100.0%	

Source: Dataquest
September 1988

Figure 6

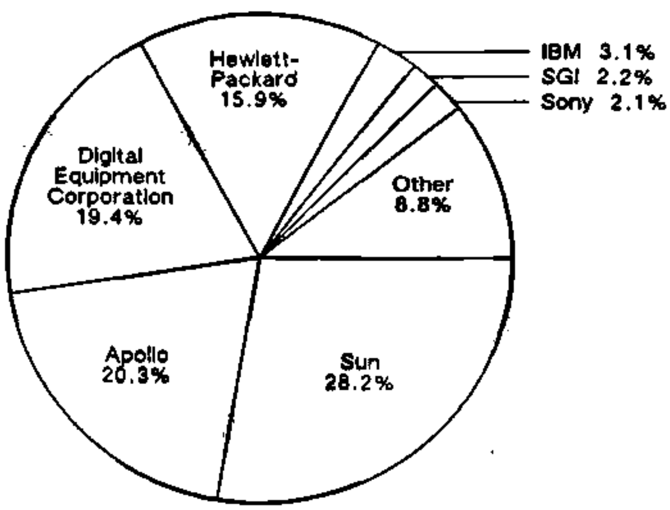
Estimated 1987 Revenue Workstation
Market Share
(Percent of Total)



Source: Dataquest
September 1988

Figure 7

Estimated Unit Workstation
Market Share
(Percent of Total)



Source: Dataquest
September 1988

New Segmentation Expected

Interactive distributed processing is a new way of computing, and we expect it to penetrate more than just the engineering applications. We believe that the users' needs vary with different applications and at different price levels. In the past, workstation-style computing was offered only with systems priced between $15,000 and $60,000. Now, however, we expect the price points to move both downward and upward. We also expect a surge of new vendors to enter the market in the new price bands. Personal computer vendors will have products priced at less than $15,000, and the new companies will sell products for more than $75,000.

We believe that the workstation market is about to split into four distinct segments, as described in Table 5 and illustrated in Figure 8. Figures 9 and 10 illustrate the impact that these new segments will have on the existing market between 1988 and 1991 in terms of revenue and unit shipments, respectively.

This market split will be driven by low-price personal computer technology moving upward and by the emergence of high-performance workstations based on advanced computer, graphics, and VLSI technologies. These two forces will cause many changes in the marketplace over the next few years, creating a major product restructuring. The market strategies and dynamics of selling into each of these product segments will be very different and distinct. Table 6 compares the performance of each of the emerging workstation categories.

Table 5

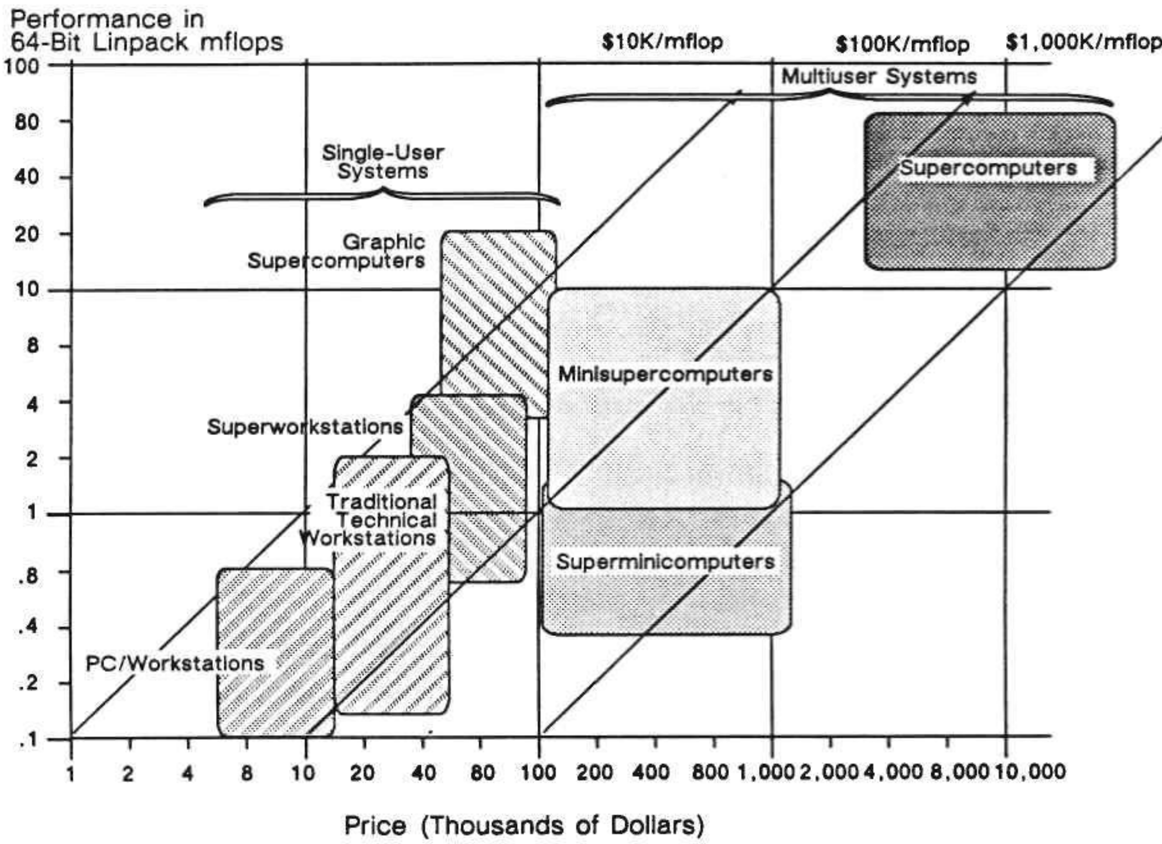
New Workstation Market Segmentation

Segment	Description	Approximate Price Range
Low End	PC/workstations	$5,000 to $15,000
Midrange	Traditional workstations	$15,000 to $50,000
High End	Superworkstations	$40,000 to $80,000
Very High End	Graphic supercomputers	$75,000 to $150,000

Source: Dataquest
September 1988

Figure 8

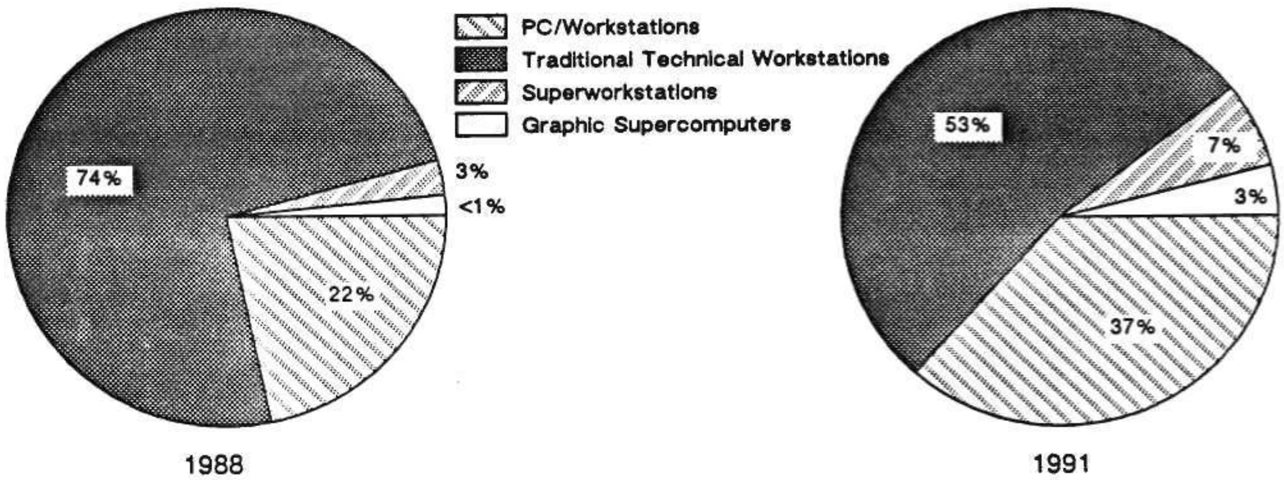
Forecast Workstation Price/Performance Comparison
(Double–Precision LINPACK mflops)



Source: Dataquest
September 1988

Figure 9

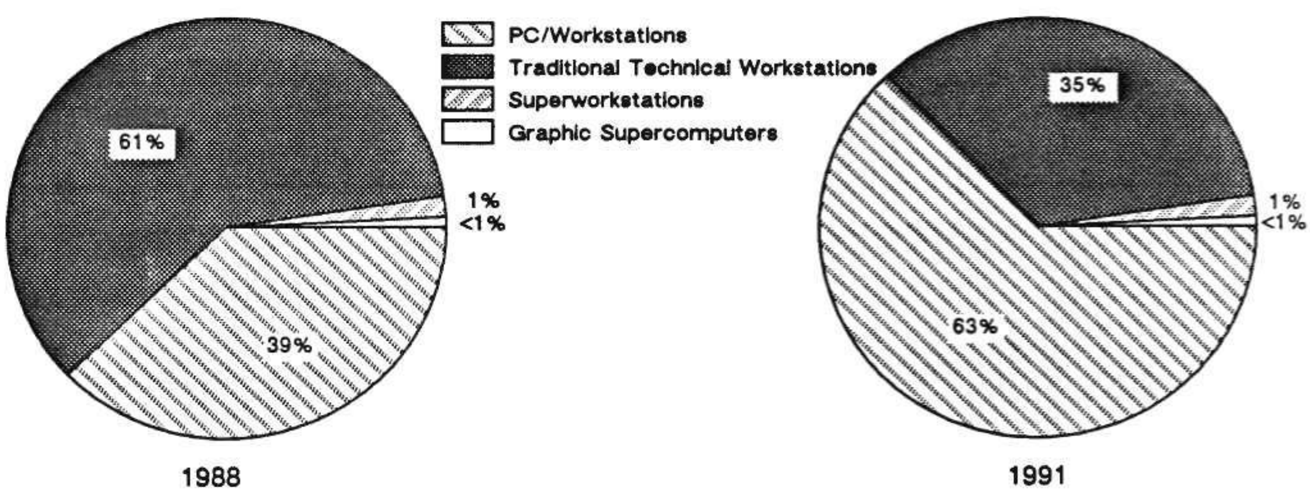
Technical Workstations—All Segments
Estimated Revenue by Segment
1988 and 1991



Source: Dataquest
September 1988

Figure 10

Technical Workstations—All Segments
Estimated Unit Shipments by Segment
1988–1991



Source: Dataquest
September 1988

Table 6

Workstation Price/Performance Comparison

Feature	PC/WS	TWS	SWS	GSC
CPU Performance				
Advertised mips	<4	4-10	8-20	15-40
LINPACK mflops*	<0.8	0.1-2	0.5-4	4-15
Floating-Point Coprocessor	Yes	Yes	Yes	Yes
Cache (Kbytes)	0-4	0-32	32-64	64-128+
Main Memory (Mbytes)	1-16	1-64	8-128	16-1,024
Typical Disk Storage (Mbytes)	20-400	80-600	600-1,024	1,024+
Screen Sizes (Inches)	12-19	12-19	15-19	19
Number of Colors Displayable	256	256-512	512-1,024	1,024-4,096+
Typical Pixel Resolution	0.5M	1M	1.5M	2M
3-D Vector Transforms/Second	2K-20K	5K-100K	100K-400K	300K-1,000K
Gouraud Shaded Polygons/Second	0	0-4K	4K-8K	6K-15K
LAN (Mbits/sec)	10	10	10-125	10-125
Price ($K)	5-15	15-50	40-80	75-150

*Double precision

Source: Dataquest
September 1988

TECHNOLOGY

Technical workstation manufacturers are strongly pursuing the use of the latest technology. Users have computer problems that extend beyond the current technology and are willing to pay for significant improvements in performance. This places unusual pressure on vendors to offer the latest technology. Workstation technology requires large capital investments for companies to stay ahead. Increasing product complexity and decreasing product life cycles are moving many vendors into high risk areas. Any delay in engineering or manufacturing a new workstation product can give competitors an edge and cause the vendor to lose market share.

As the data processing growth rate continues to increase, there is a clear trend in systems architecture to use independent subsystems to off-load the central CPU. These subsystems will, in the future, be based primarily on application-specific integrated circuits (ASICs).

Today, most vendors use standard, off-the-shelf microprocessor technologies, although a few are building their own proprietary processors, hoping to realize a performance edge over the competition. Most of the products using these processors are priced well above standard microprocessor base systems. We expect that the use of standard microprocessors will be the most common approach for most of the products on the market until custom integrated circuits can be designed easily and rapidly. Some vendors are moving to off-the-shelf, high-performance microprocessors (MIPS and AMD) and some vendors are designing their own processor to be a standard platform for the Sun SPARC or for their proprietary platform (Stellar).

Many applications extensively use floating-point calculations, which are CPU-intensive operations. To free the CPU from performing these operations, standard coprocessors and custom VLSI circuits are used. Workstations that offer VLSI-based, floating-point units will have a clear performance edge over their competition, not only in price but in overall system throughput. Weitek, among other application-specific semiconductor vendors, is now offering specialized floating-point VLSI circuits. Automatic vectorizing compilers are expected to become more common in the future.

Users with very large application programs to process require workstation products that will interface closely with existing superminicomputers or mainframe computers at their sites. These systems are being used as batch-compute servers, file servers, and data base servers on networks, leaving the interactive portion of the applications software to run simultaniously on the workstation.

Trends in Technical Workstations

Microprocessors

We expect reduced instruction set computer (RISC) architectures to be introduced by several vendors as the technology becomes better understood. Some examples of RISC-based systems are:

- IBM has introduced the PC RT.
- Silicon Graphics has introduced the IRIS 4D/60
- Prime Computers' new workstation is based on the MIPS R2000 microprocessor.
- Intergraph uses the Fairchild-designed Clipper in its workstations.

Most of the installed base of technical workstations use Motorola 68000 or 68020 microprocessors. Most of the different vendors' product uniqueness has been in the graphics, software, and networking area. We expect many vendors to adopt faster microprocessors to further differentiate their products—such as MIPS Inc. (R2000), Intergraph (Clipper), and National (32532)—or to develop their own microprocessor for high-performance products at the top of their product lines, as Sun has with its SPARC chip. Additionally, we expect a surge in the number of Intel 80386-based workstation running OS/2 and UNIX.

Memories

Video memory and main memory sizes, once a serious limitation due to high memory costs, are rapidly becoming a nonissue with the advent of the 1Mb dynamic random access memory chip (DRAM). A handful of these chips essentially replaces several memory boards used only a few years ago. Four megabytes of memory occupies an area about the size of a credit card on the printed circuit board (PCB). However, no matter how technologically wonderful 1Mb DRAMs are, the transition to the new technology has been more of a hindrance than a savior to the workstation market in 1988. The transition from 256Kb to 1Mb DRAMs has been painful and has caused tremendous availability problems for workstation manufacturers. Sun Microsystems publicly stated that the shortage of DRAMs has cost the company $100 million in lost sales. Sun has not been able to procure enough DRAMs to fill orders, and other manufacturers have delayed new product introductions because of the lack of DRAMs. Dataquest expects this supply problem to ease by the end of 1988 and believes that supply will equal demand during the second quarter of 1989.

Bus Structure Trends

Many vendors offer accepted, industry-standard, I/O bus structures. The dominant buses used are:

- Digital's Q-bus (VAXStation)
- Motorola's VME bus (Apollo's and Sun's main product lines)
- The PC AT bus (Apollo DN3000)

We expect this trend to continue due to the high availability of peripherals in the open market and to the needs of users and OEMs that require specialized hardware that is not available from system vendors. The VME bus and PC AT bus recently replaced most Multibus-I-based products. Multibus-II has not caught on as a workstation bus, probably due to its comparatively late entry into the market.

Graphics Display Trends

Specialized graphics chips off-load the main processor, thereby enhancing total system throughput. The trends are:

- Prices on high-resolution graphics displays are declining 15 to 20 percent per year.
- Systems vendors will be able to offer larger display memories that will enhance graphics system performance as the availability of 1Mb DRAM memories increases and prices decrease.
- Color and monochrome display prices are converging. We believe that the difference will be small enough that most vendors will soon provide color as a standard offering. We estimate that 65 percent of the systems shipped in 1991 will have color displays.
- Specialized graphics coprocessor technology has become a key product differentiator, especially for high-end workstation products and as a primary differentiator of workstations from the new 32-bit personal computers.
- Vendors are scrambling to design and incorporate ASIC engines to process:
  - Shading algorithms (flat, Fong, Garaud, etc.)
  - Rendering
  - Geometric transforming

Networking Trends

Ethernet networking with technical workstations is almost universal now, and Dataquest expects this trend to continue through the forecast period. It is important to note that Ethernet is a very strong, user-driven requirement. Users want to buy workstations that are compatible with their installed networks. Engineering environments usually use Ethernet. Other networking trends are:

- Advanced VLSI circuits will drastically reduce node connect costs, contributing to the decline in total system average prices.

- Fiber–optic technology is expected to gain market acceptance more slowly than many vendors anticipate.
  - Copper–based coax cabling should adequately serve most market applications well into 1989.
  - In–line taps are difficult and costly.
  - A technology is emerging for twisted–pair phone lines to be used at nearly 10–Mbit/second data rates.

Operating Systems

Most workstation vendors are offering the UNIX operating system either as a primary operating system or as a cooperating system of some sort. Vendors that try to sell proprietary operating systems must have a means of interfacing to UNIX to enable file transfers in order to satisfy the demands of the users of the major applications. This is due to the following:

- Users have a high resistance to learning another operating system.
- Universities are teaching UNIX, and students moving into the job market are demanding UNIX.
- Many government and military organizations and aerospace companies that have a need to exchange software are requiring UNIX products from their vendors.
- Proprietary operating systems can be sold successfully; however, buyer resistance is high, unless the operating system has significant technology advantages over UNIX.

UNIX

Only two vendors in the technical workstation business offer operating systems that are not UNIX derivatives: Apollo's AEGIS and Digital's VAX/VMS. Both vendors are continually under strong market pressure to offer and support UNIX, and both have done so or are expected to do so in addition to supporting their own operating systems.

UNIX, specifically the 4.3 bsd version, is the most widely offered operating system for technical workstations. In 1986, 69 percent of the systems shipped (42,700 out of 61,900) used the UNIX operating system. It is not clear how UNIX will evolve in the workstation business. Some vendors are moving to AT&T's System V.3, some are staying with 4.3 bsd, and others are choosing to offer both. We expect that Microsoft's MS–UNIX will become the standard at the low end and for PC/workstations.

MS-DOS and O/S 2

MS-DOS runs on workstation coprocessors and is an important sales item, since much of the users' time is spent running productivity software such as word processing, data base, and spread sheets. The O/S 2 application base will take at least a year to build when it becomes available in 1988. MS-DOS is expected to remain important for several years.

Technology Summary

The technical workstation industry will expand to include many more applications than just those that are now available. New component technologies that are being integrated into technical workstations currently are:

- Advanced 32-bit microprocessors (Motorola M68030, Intel 80386, MIPS R2000, Sun SPARC, etc.)
- Advanced floating-point and vector processing units
- 1-Mbit RAM-based memory systems using surface-mount technology
- Large-capacity disks at low prices (600 Mbyte, 5.25-inch disks)
- Local area network controllers in VLSI silicon
- Fiber-optic networks rated at 80 to 120 Mbits/second
- VLSI graphic controllers
- High-resolution monitors
- Higher-density ASICs

Product performance will expand upward into the minisupercomputer and supercomputer areas where price is no object to buyers and downward in price into the personal computer area where price is the dominant selection criteria. Networking will include fiber-optic technology, and graphics will include real-time, three-dimensional modeling that the average person may view as a photograph.

Today's technical workstation is the leading indicator of personal computer technology in the next three to five years. The challenge to workstation manufacturers is to continually innovate.

SAM-1987

Consumption by Application Market

Table 1

North American Semiconductor Consumption
by Application Market
(Millions of Dollars)

	1984	1985	1986	1987	1991	CAGR 1987-1991
Total Semiconductor	$13,139.0	$9,607.0	$10,201.0	$12,344.0	$19,229.0	11.7%
Data Processing	6,031.0	3,715.0	3,953.0	4,993.0	8,122.0	12.9%
Communications	2,057.0	1,357.0	1,507.0	1,777.0	2,984.0	13.8%
Industrial	2,107.0	1,561.0	1,600.0	1,946.0	3,183.0	13.1%
Consumer	970.0	698.0	732.0	867.0	1,264.0	9.9%
Military	1,276.0	1,488.0	1,561.0	1,777.0	2,194.0	5.4%
Transportation	698.0	788.0	848.0	984.0	1,482.0	10.8%

Source: Dataquest
December 1987

Table 2

North American Semiconductor Consumption
by Application Market
(Percent)

	1984	1985	1986	1987	1991
Total Semiconductor	100.0%	100.0%	100.0%	100.0%	100.0%
Data Processing	45.9	38.7	38.8	40.4	42.2
Communications	15.7	14.1	14.8	14.4	15.5
Industrial	16.0	16.2	15.7	15.8	16.6
Consumer	7.4	7.3	7.2	7.0	6.6
Military	9.7	15.5	15.3	14.4	11.4
Transportation	5.3	8.2	8.3	8.0	7.7

Source: Dataquest
December 1987

Consumption by Application Market

Table 3

North American IC Consumption by Application Market (Millions of Dollars)

	1984	1985	1986	1987	1991	CAGR 1987-1991
Total IC	$10,941.3	$7,710.0	$8,136.0	$10,124.1	$16,467.2	12.9%
Data Processing	5,234.2	3,226.2	3,419.9	4,457.0	7,484.6	13.8%
Communications	1,656.5	1,042.6	1,149.7	1,411.6	2,543.3	15.9%
Industrial	1,655.0	1,141.1	1,157.4	1,446.6	2,468.3	14.3%
Consumer	822.5	567.9	576.3	690.5	1,028.0	10.5%
Military	1,038.5	1,159.0	1,228.1	1,419.8	1,829.3	6.5%
Transportation	534.7	573.1	604.6	698.6	1,113.6	12.4%

Source: Dataquest
December 1987

Table 4

North American IC Consumption by Application Market (Percent)

	1984	1985	1986	1987	1991
Total IC	100.0%	100.0%	100.0%	100.0%	100.0%
Data Processing	47.8	41.8	42.0	44.0	45.5
Communications	15.1	13.5	14.1	13.9	15.4
Industrial	15.1	14.8	14.2	14.3	15.0
Consumer	7.5	7.4	7.1	6.8	6.2
Military	9.5	15.0	15.1	14.0	11.1
Transportation	4.9	7.4	7.4	6.9	6.8

Source: Dataquest
December 1987

Consumption by Application Market

Table 5

North American Bipolar Digital IC Consumption by Application Market (Millions of Dollars)

	1984	1985	1986	1987	1991	CAGR 1987-1991
Total Bipolar Digital	$2,843.2	$2,006.0	$2,021.0	$2,310.8	$3,536.6	11.2%
Data Processing	1,332.7	897.0	853.4	1,011.2	1,656.5	13.1%
Communications	302.3	140.3	162.1	193.7	362.6	17.0%
Industrial	536.2	314.5	311.7	372.5	580.1	11.7%
Consumer	107.7	73.6	82.7	84.8	109.0	6.5%
Military	446.2	469.3	498.0	533.6	663.7	5.6%
Transportation	118.1	111.5	113.0	114.9	164.8	9.4%

Source: Dataquest
December 1987

Table 6

North American Bipolar Digital IC Consumption by Application Market (Percent)

	1984	1985	1986	1987	1991
Total Bipolar Digital	100.0%	99.9%	100.0%	100.0%	100.0%
Data Processing	46.9	41.9	42.2	43.8	46.8
Communications	10.6	9.9	8.0	8.4	10.3
Industrial	18.9	15.6	15.4	16.1	16.4
Consumer	3.8	3.5	4.1	3.7	3.1
Military	15.7	23.6	24.6	23.1	18.8
Transportation	4.2	5.4	5.6	5.0	4.7

Source: Dataquest
December 1987

Table 7

North American Bipolar Memory Consumption
by Application Market
(Millions of Dollars)

	1984	1985	1986	1987	1991	CAGR 1987-1991
Total Bipolar Memory	$431.0	$315.0	$335.0	$370.0	$455.1	5.3%
Data Processing	185.8	122.0	139.3	161.8	240.8	10.4%
Communications	43.1	23.6	23.6	25.4	28.0	2.5%
Industrial	30.0	21.8	25.3	28.9	43.2	10.5%
Consumer	7.4	3.3	6.6	2.9	2.7	(2.2%)
Military	137.6	123.0	118.9	128.0	121.4	(1.3%)
Transportation	27.1	21.3	21.3	22.9	18.9	(4.7%)

Source: Dataquest
December 1987

Table 8

North American Bipolar Memory Consumption
by Application Market
(Percent)

	1984	1985	1986	1987	1991
Total Bipolar Memory	100.0%	100.0%	100.0%	100.0%	100.0%
Data Processing	43.1	38.7	41.6	43.7	52.9
Communications	10.0	7.5	7.0	6.9	6.2
Industrial	7.0	6.9	7.6	7.8	9.5
Consumer	1.7	1.1	2.0	0.8	0.6
Military	31.9	39.0	35.5	34.6	26.7
Transportation	6.3	6.8	6.4	6.2	4.1

Source: Dataquest
December 1987

Table 9

North American Bipolar Logic Consumption
by Application Market
(Millions of Dollars)

	1984	1985	1986	1987	1991	CAGR 1987-1991
Total Bipolar Logic	$2,412.2	$1,691.0	$1,686.0	$1,940.8	$3,081.5	12.3%
Data Processing	1,146.9	775.0	714.1	849.4	1,415.7	13.6%
Communications	259.2	116.6	138.5	168.3	334.5	18.7%
Industrial	506.1	292.7	286.4	343.6	536.9	11.8%
Consumer	100.3	70.2	76.2	81.9	106.3	6.8%
Military	308.6	346.3	379.1	405.6	542.2	7.5%
Transportation	91.0	90.2	91.8	92.0	145.9	12.2%

Source: Dataquest
December 1987

Table 10

North American Bipolar Logic Consumption
by Application Market
(Percent)

	1984	1985	1986	1987	1991
Total Bipolar Logic	100.0%	100.0%	100.0%	100.0%	100.0%
Data Processing	47.5	45.8	42.4	43.8	45.9
Communications	10.7	6.9	8.2	8.7	10.9
Industrial	21.0	17.3	17.0	17.7	17.4
Consumer	4.2	4.2	4.5	4.2	3.5
Military	12.8	20.5	22.5	20.9	17.6
Transportation	3.8	5.3	5.4	4.7	4.7

Source: Dataquest
December 1987

Consumption by Application Market

Table 11

North American MOS Digital IC Consumption
by Application Market
(Millions of Dollars)

	1984	1985	1986	1987	1991	CAGR 1987-1991
Total MOS Digital	$6,356.1	$4,247.0	$4,484.0	$6,055.5	$10,266.4	14.1%
Data Processing	3,338.9	1,922.7	2,037.6	2,887.0	5,031.6	14.9%
Communications	932.6	651.8	721.8	920.9	1,709.3	16.7%
Industrial	775.6	561.5	594.5	799.2	1,430.6	15.7%
Consumer	610.3	386.6	358.2	463.4	583.5	5.9%
Military	402.4	459.5	492.5	636.7	915.2	9.5%
Transportation	296.4	264.9	279.5	348.2	596.3	14.4%

Source: Dataquest
December 1987

Table 12

North American MOS Digital IC Consumption
by Application Market
(Percent)

	1984	1985	1986	1987	1991
Total MOS Digital	100.0%	99.9%	100.0%	100.0%	100.0%
Data Processing	52.5	46.6	45.4	47.7	49.0
Communications	14.7	14.0	16.1	15.2	16.6
Industrial	12.2	13.2	13.3	13.2	13.9
Consumer	9.6	9.2	8.0	7.7	5.7
Military	6.3	10.6	11.0	10.5	8.9
Transportation	4.7	6.3	6.2	5.8	5.8

Source: Dataquest
December 1987

Table 13

North American MOS Memory Consumption
by Application Market
(Millions of Dollars)

	1984	1985	1986	1987	1991	CAGR 1987-1991
Total MOS Memory	$3,248.6	$1,774.0	$1,560.0	$2,049.4	$3,097.3	10.9%
Data Processing	1,789.7	836.0	762.7	1,014.2	1,669.3	13.3%
Communications	492.5	236.9	224.6	291.4	423.7	9.8%
Industrial	288.5	177.9	158.6	220.2	350.1	12.3%
Consumer	417.8	253.1	184.1	238.3	283.1	4.4%
Military	186.5	196.8	169.1	194.0	223.4	3.6%
Transportation	73.5	73.4	60.9	91.3	147.6	12.7%

Source: Dataquest
December 1987

Table 14

North American MOS Memory Consumption
by Application Market
(Percent)

	1984	1985	1986	1987	1991
Total MOS Memory	100.0%	100.0%	100.0%	100.0%	100.0%
Data Processing	55.1	47.1	48.9	49.5	53.9
Communications	15.2	13.4	14.4	14.2	13.7
Industrial	8.9	10.0	10.2	10.7	11.3
Consumer	12.9	14.3	11.8	11.6	9.1
Military	4.8	11.1	10.8	9.5	7.2
Transportation	2.3	4.1	3.9	4.5	4.8

Source: Dataquest
December 1987

Table 15

North American MOS Logic Consumption
by Application Market
(Millions of Dollars)

	1984	1985	1986	1987	1991	CAGR 1987-1991
Total MOS Logic	$1,387.9	$1,278.0	$1,662.0	$2,319.6	$4,196.9	16.0%
Data Processing	695.5	506.0	642.8	960.8	1,796.9	16.9%
Communications	229.4	292.1	371.4	471.7	912.7	17.9%
Industrial	179.5	160.7	209.3	300.8	574.8	17.6%
Consumer	111.3	79.5	107.1	147.8	201.7	8.1%
Military	136.5	194.0	264.8	360.4	587.5	13.0%
Transportation	35.7	45.7	66.5	78.2	123.3	12.1%

Source: Dataquest
December 1987

Table 16

North American MOS Logic Consumption
by Application Market
(Percent)

	1984	1985	1986	1987	1991
Total MOS Logic	100.0%	100.0%	100.0%	100.0%	100.0%
Data Processing	50.1	39.6	38.7	41.4	42.8
Communications	16.5	22.9	22.3	20.3	21.7
Industrial	12.9	12.6	12.6	13.0	13.7
Consumer	8.0	6.2	6.4	6.4	4.8
Military	9.8	15.2	15.9	15.5	14.0
Transportation	2.6	3.6	4.0	3.4	2.9

Source: Dataquest
December 1987

Consumption by Application Market

Table 17

North American MOS Micro Consumption
by Application Market
(Millions of Dollars)

	1984	1985	1986	1987	1991	CAGR 1987-1991
Total MOS Micro	$1,719.7	$1,195.0	$1,262.0	$1,686.5	$2,972.2	15.2%
Data Processing	853.7	580.7	632.0	912.0	1,565.4	14.5%
Communications	210.8	122.8	125.7	157.8	372.9	24.0%
Industrial	307.6	222.9	226.7	278.2	505.7	16.1%
Consumer	81.1	54.0	66.9	77.3	98.7	6.3%
Military	79.4	68.8	58.6	82.3	104.2	6.1%
Transportation	187.1	145.9	152.1	178.8	325.4	16.2%

Source: Dataquest
December 1987

Table 18

North American MOS Micro Consumption
by Application Market
(Percent)

	1984	1985	1986	1987	1991
Total MOS Micro	100.0%	100.0%	100.0%	100.0%	100.0%
Data Processing	49.6	48.6	50.1	54.1	52.7
Communications	12.3	10.3	10.0	9.4	12.5
Industrial	17.9	18.7	18.0	16.5	17.0
Consumer	4.7	4.5	5.0	4.6	3.3
Military	4.6	5.8	4.6	4.9	3.5
Transportation	10.9	12.2	12.1	10.6	10.9

Source: Dataquest
December 1987

Consumption by Application Market

Table 19

North American Linear IC Consumption
by Application Market
(Millions of Dollars)

	1984	1985	1986	1987	1991	CAGR 1987-1991
Total Linear	$1,742.0	$1,457.0	$1,631.0	$1,757.8	$2,664.2	11.0%
Data Processing	562.7	406.5	528.9	558.7	796.5	9.3%
Communications	421.6	250.6	265.9	296.9	471.5	12.3%
Industrial	343.2	265.2	251.2	274.9	457.7	13.6%
Consumer	104.5	107.8	135.4	142.3	335.5	23.9%
Military	189.9	230.2	237.6	249.5	250.4	0.1%
Transportation	120.2	196.7	212.0	235.4	352.6	10.6%

Source: Dataquest
December 1987

Table 20

North American Linear IC Consumption
by Application Market
(Percent)

	1984	1985	1986	1987	1991
Total Linear	100.0%	100.0%	100.0%	100.0%	100.0%
Data Processing	32.3	27.9	32.4	31.8	29.9
Communications	24.2	17.2	16.3	16.9	17.7
Industrial	19.7	18.2	15.4	15.6	17.2
Consumer	6.0	7.4	8.3	8.1	12.6
Military	10.9	15.8	14.6	14.2	9.4
Transportation	6.9	13.5	13.0	13.4	13.2

Source: Dataquest
December 1987

Consumption by Application Market

Table 21

North American Optoelectronic Semiconductor
Consumption by Application Market
(Millions of Dollars)

	1984	1985	1986	1987	1991	CAGR 1987-1991
Total Optoelectronic	$471.8	$369.0	$416.0	$463.2	$522.1	3.0%
Data Processing	194.0	112.9	126.9	129.5	136.8	1.4%
Communications	97.2	66.8	71.6	73.7	81.4	2.5%
Industrial	70.3	63.8	70.7	80.6	93.5	3.8%
Consumer	44.4	33.9	33.3	44.9	59.0	7.1%
Military	32.1	50.2	58.2	66.9	71.0	1.5%
Transportation	33.7	41.3	55.3	67.6	80.4	4.4%

Source: Dataquest
December 1987

Table 22

North American Optoelectronic Semiconductor
Consumption by Application Market
(Percent)

	1984	1985	1986	1987	1991
Total Optoelectronic	100.0%	100.0%	100.0%	100.0%	100.0%
Data Processing	41.1	30.6	30.5	28.0	26.2
Communications	20.6	18.1	17.2	15.9	15.6
Industrial	14.9	17.3	17.0	17.4	17.9
Consumer	9.4	9.2	8.0	9.7	11.3
Military	6.8	13.6	14.0	14.5	13.6
Transportation	7.2	11.2	13.3	14.6	15.4

Source: Dataquest
December 1987

Consumption by Application Market

Table 23

North American Discrete Semiconductor Consumption
by Application Market
(Millions of Dollars)

	1984	1985	1986	1987	1991	CAGR 1987-1991
Total Discrete	$1,727.0	$1,528.0	$1,649.0	$1,757.1	$2,240.5	6.3%
Data Processing	602.7	375.9	407.0	406.1	499.5	5.3%
Communications	304.0	247.5	285.3	291.8	360.6	5.4%
Industrial	381.7	356.0	371.5	420.2	620.9	10.3%
Consumer	103.6	96.3	122.5	130.1	179.2	8.3%
Military	205.5	278.9	274.7	290.9	293.4	0.2%
Transportation	129.5	173.4	188.0	218.0	286.7	7.1%

Source: Dataquest
December 1987

Table 24

North American Discrete Semiconductor Consumption
by Application Market
(Percent)

	1984	1985	1986	1987	1991
Total Discrete	100.0%	100.0%	100.0%	100.0%	100.0%
Data Processing	34.9	24.6	24.7	23.1	22.3
Communications	17.6	16.2	17.3	16.6	16.1
Industrial	22.1	23.3	22.5	23.9	27.7
Consumer	6.0	6.3	7.4	7.4	8.0
Military	11.9	18.3	16.7	16.6	13.1
Transportation	7.5	11.4	11.4	12.4	12.8

Source: Dataquest
December 1987

Semiconductor Consumption--Communications

Table 1

North American Semiconductor Consumption
Communication
Total Semiconductor
(Millions of Dollars)

	1984	1985	1986	1987	1991	CAGR 1987-1991
Total Semiconductor	$2,057.0	$1,357.0	$1,507.0	$1,777.0	$2,984.0	13.8%
IC	1,656.5	1,042.6	1,149.7	1,411.6	2,543.3	15.9%
Bipolar	302.3	140.3	162.1	193.7	362.6	17.0%
MOS	932.6	651.8	721.8	920.9	1,709.3	16.7%
Linear	421.6	250.6	265.9	296.9	471.5	12.3%
Discrete	304.0	247.5	285.3	291.8	360.6	5.4%
Optoelectronic	97.2	66.8	71.6	73.7	81.4	2.5%

Source: Dataquest
December 1987

Table 2

North American Semiconductor Consumption
Communication
Bipolar Logic
(Millions of Dollars)

	1984	1985	1986	1987	1991	CAGR 1987-1991
IC	$1,656.5	$1,042.6	$1,149.7	$1,411.6	$2,543.3	15.9%
Bipolar	302.3	140.3	162.1	193.7	362.6	17.0%
Logic	259.2	116.6	138.5	168.3	334.5	18.7%
Standard	201.7	64.2	80.3	84.8	101.5	4.6%
TTL	193.5	58.2	70.5	73.6	84.6	3.6%
ECL	5.5	3.7	6.9	8.3	16.5	18.7%
Other	2.7	2.3	2.9	3.0	0.4	(41.2%)
ASIC	57.5	52.5	58.2	83.5	233.1	29.3%
Gate Array	40.9	27.8	30.6	43.7	134.3	32.4%
Cell Based	1.1	6.0	6.2	7.1	35.8	49.8%
PLD	7.6	10.5	13.3	24.4	47.6	18.2%
Full Custom	7.9	8.2	8.1	8.3	15.3	16.6%

Source: Dataquest
December 1987

Note: Columns may not add to totals shown because of rounding.

Table 3

North American Semiconductor Consumption
Communication
Bipolar Memory
(Millions of Dollars)

	1984	1985	1986	1987	1991	CAGR 1987-1991
IC	$1,656.5	$1,042.6	$1,149.7	$1,411.6	$2,543.3	15.9%
Bipolar	302.3	140.3	162.1	193.7	362.6	17.0%
Memory	43.1	23.6	23.6	25.4	28.0	2.5%
RAM	10.6	7.7	7.1	7.0	13.2	17.3%
TTL	9.0	5.6	3.9	2.7	1.7	(10.9%)
ECL	1.6	2.1	3.2	4.2	11.5	28.3%
ROM/PROM	28.6	12.3	12.3	13.3	7.5	(13.3%)
Other	3.9	3.6	4.3	5.1	7.3	9.2%

Source: Dataquest
December 1987

Table 4

North American Semiconductor Consumption
Communication
MOS Microprocessors
(Millions of Dollars)

	1984	1985	1986	1987	1991	CAGR 1987-1991
IC	$1,656.5	$1,042.6	$1,149.7	$1,411.6	$2,543.3	15.9%
MOS	932.6	651.8	721.8	920.9	1,709.3	16.7%
Micros	210.8	122.8	125.7	157.8	372.9	24.0%
Microprocessor	50.6	20.8	25.3	27.2	63.3	23.5%
8 Bit	42.1	14.7	17.3	14.6	22.6	11.5%
16 Bit	8.5	5.4	5.7	6.8	23.4	36.2%
32 Bit	0.0	0.7	2.4	5.8	17.4	31.3%
Microcontroller	57.6	35.7	37.4	55.3	107.8	18.2%
4 Bit	9.4	5.7	7.8	7.8	7.7	(0.3%)
8 Bit	48.2	29.5	28.6	44.7	84.3	17.2%
16 Bit	0.1	0.5	0.9	2.8	15.8	53.8%
Microperipherals	102.5	66.2	63.0	75.3	201.7	27.9%

Source: Dataquest
December 1987

Note: Columns may not add to totals shown because of rounding.

Table 5

North American Semiconductor Consumption
Communication
MOS Logic
(Millions of Dollars)

	1984	1985	1986	1987	1991	CAGR 1987-1991
IC	$1,656.5	$1,042.6	$1,149.7	$1,411.6	$2,543.3	15.9%
MOS	932.6	651.8	721.8	920.9	1,709.3	16.7%
Logic	229.4	292.1	371.4	471.7	912.7	17.9%
Standard	68.6	34.3	55.9	73.4	91.3	5.6%
ASIC	160.8	257.7	315.6	398.4	821.4	19.8%
Gate Array	47.0	66.2	97.2	144.4	344.7	24.3%
Cell Based	74.3	174.2	201.8	221.9	413.2	16.8%
PLD	0.1	1.1	3.5	10.3	50.8	49.0%
Full Custom	39.4	16.4	13.0	21.7	12.6	(12.7%)

Source: Dataquest
December 1987

Table 6

North American Semiconductor Consumption
Communication
MOS Memory
(Millions of Dollars)

	1984	1985	1986	1987	1991	CAGR 1987-1991
IC	$1,656.5	$1,042.6	$1,149.7	$1,411.6	$2,543.3	15.9%
MOS	932.6	651.8	721.8	920.9	1,709.3	16.7%
Memory	492.5	236.9	224.6	291.4	423.7	9.8%
DRAM	314.3	111.7	121.5	137.8	222.0	12.7%
SRAM	87.7	58.8	49.4	79.4	109.5	8.4%
EPROM	54.8	40.0	34.2	46.4	50.3	2.0%
ROM	18.4	11.6	6.2	8.4	6.2	(7.3%)
EEPROM/NVRM	14.0	13.3	9.3	15.2	31.0	19.4%
Other	3.3	1.4	4.1	4.0	4.6	4.0%

Source: Dataquest
December 1987

Note: Columns may not add to totals shown because of rounding.

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Segment Overview
North American Electronic Equipment Forecast
(Millions of Dollars)

Segment	1983	1984	1985	1986	1987	1988	1989	1990	1991	CAGR 86-87	CAGR 87-91
Data Processing											
Computers	37,365	49,449	55,484	57,322	65,010	73,210	78,548	84,406	91,094	13.4%	8.8%
Data Storage Subsys.	10,016	11,703	15,365	18,960	21,014	22,392	25,593	26,494	26,837	10.8%	6.3%
Terminals	3,336	3,757	3,391	2,880	2,769	2,840	2,966	3,093	3,181	(3.9%)	3.5%
Input/Output	7,114	7,649	7,062	7,721	8,368	9,019	9,539	9,510	10,172	8.4%	5.0%
Dedicated Systems	4,837	5,546	5,858	5,392	4,711	4,373	4,294	4,400	4,500	(12.6%)	(1.1%)
Subtotal	62,668	78,104	87,160	92,275	101,872	111,834	120,940	127,903	135,784	10.4%	7.4%
Communications											
Customer Premises	7,055	8,286	8,857	9,358	10,074	11,084	12,170	13,114	14,158	7.7%	8.9%
Public Telecom.	4,913	5,649	6,211	6,634	6,834	7,080	7,516	7,881	8,297	3.0%	5.0%
Radio	3,412	4,304	4,740	5,530	6,513	7,608	8,654	9,785	10,556	17.8%	12.8%
Broadcast and Studio	1,464	1,474	1,443	1,494	1,582	1,767	1,892	2,100	2,331	5.9%	10.2%
Other	756	1,175	1,894	1,914	1,958	2,010	2,144	2,346	2,575	2.3%	7.1%
Subtotal	17,600	20,889	23,145	24,930	26,962	29,548	32,376	35,226	37,917	8.1%	8.9%
Industrial											
Security/Energy Mgmt.	1,997	1,960	1,967	2,069	2,211	2,388	2,483	2,678	2,905	6.9%	7.1%
Mfg. Systems	9,248	12,387	12,110	11,748	12,487	13,983	14,586	15,686	17,199	6.3%	8.3%
Instrumentation	5,607	6,461	6,571	6,580	7,235	8,167	8,589	9,197	9,938	9.9%	8.3%
Medical Equipment	4,740	4,880	4,759	5,002	5,345	5,757	6,072	6,432	6,858	6.9%	6.4%
Commercial Aviation	1,764	1,804	1,877	2,104	2,216	2,394	2,582	2,657	2,838	5.3%	6.4%
Other	4,168	4,576	4,831	5,160	5,669	6,394	6,964	7,671	8,466	9.9%	10.5%
Subtotal	27,524	32,068	32,115	32,663	35,162	39,084	41,276	44,321	48,204	7.7%	8.2%
Consumer											
Audio	270	248	254	283	324	332	357	395	407	14.5%	5.9%
Video	3,938	4,520	4,580	4,656	5,127	5,291	5,647	6,254	6,577	10.1%	6.4%
Personal Electron.	1,048	513	600	641	720	756	794	801	816	12.3%	3.2%
Appliances	7,899	9,008	9,792	10,373	11,068	11,522	12,098	12,891	13,691	6.7%	5.5%
Other	634	778	976	1,059	1,116	1,167	1,218	1,270	1,325	5.3%	4.4%
Subtotal	13,789	15,067	16,202	17,011	18,355	19,067	20,114	21,611	22,816	7.9%	5.6%
Military	38,500	43,595	49,300	49,700	47,500	46,900	46,400	46,300	46,700	(4.4%)	(0.4%)
Transportation	5,547	7,441	8,480	9,580	10,809	11,799	13,812	15,050	16,209	12.8%	10.7%
Total Equipment	165,627	197,164	216,401	226,160	240,660	258,232	274,918	290,411	307,630	6.4%	6.3%

Source: Dataquest
November 1987

Segment Detail
North American Data Processing Equipment Forecast
(Millions of Dollars)

Equipment Type	1983	1984	1985	1986	1987	1988	1989	1990	1991	CAGR 86-87	CAGR 87-91
Computers											
Single-User PC											
($1K)	397	111	83	156	355	400	446	504	458	127.6%	6.6%
($1K-$5K)	4,773	9,196	10,792	9,104	13,171	14,831	16,581	18,023	19,339	44.7%	10.1%
($5K-$10K)	1,848	3,855	5,266	5,586	5,648	7,512	6,618	6,598	6,512	1.1%	(3.6%)
Corporate Resource ($1.5M)	11,664	12,956	12,968	13,133	13,555	14,392	15,210	15,855	16,652	3.2%	5.3%
Business Unit ($250K-$1.5M)	5,184	5,682	6,055	6,701	7,429	8,564	9,727	10,944	12,436	10.9%	13.7%
Large Department ($75K-$250K)	6,287	7,030	7,496	8,718	9,427	10,168	10,777	11,490	12,260	8.1%	6.8%
Small Department ($25K-$75K)	3,995	5,151	6,437	6,737	7,237	7,850	8,371	8,837	9,328	7.4%	6.6%
Work Group ($25K)	3,024	4,910	5,271	5,366	5,638	6,050	6,343	6,582	6,833	5.1%	4.9%
Single-User Enhanced ($75K)	193	558	1,116	1,821	2,550	3,443	4,475	5,573	7,276	40.0%	30.0%
Subtotal	37,365	49,449	55,484	57,322	65,010	73,210	78,548	84,406	91,094	13.4%	8.8%
Data Storage Subsystems											
Fixed Disk											
14 Inch	5,148	5,895	6,057	7,228	7,974	8,323	9,216	9,960	9,836	10.3%	5.4%
8-10.5 Inch	1,664	1,958	2,691	2,983	3,403	3,622	4,145	3,173	3,018	14.1%	(3.0%)
5.25 Inch	1,342	2,030	3,403	4,958	4,383	3,910	4,483	4,872	4,960	(11.6%)	3.1%
3-4 Inch	29	156	325	750	1,532	2,403	2,659	2,860	3,365	104.7%	21.7%
Optical Disk											
WORM Optical Disk Drive	0	0	21	56	163	474	1,132	1,339	1,193	191.1%	64.5%
Erasable Optical Disk Drive	0	0	0	0	0	4	93	278	436	N/A	N/A
Tape Drives (1/4", 1/2", 1/8")	1,833	1,664	2,868	2,985	3,559	3,656	3,865	4,012	4,029	19.2%	3.1%
Subtotal	10,016	11,703	15,365	18,960	21,014	22,392	25,593	26,494	26,837	10.8%	6.3%

(Continued)

Segment Detail
North American Data Processing Equipment Forecast (Continued)
(Millions of Dollars)

Equipment Type	1983	1984	1985	1986	1987	1988	1989	1990	1991	CAGR 86-87	CAGR 87-91
Terminals											
Alphanumeric (CRT)											
Minicomputer-Based	1,357	1,490	911	758	646	540	507	467	419	(14.8%)	(11.4%)
Non-IBM, Protocol-Specific	172	202	138	85	69	57	46	35	25	(18.8%)	(22.4%)
IBM 3270	810	909	1,042	873	802	857	852	852	799	(8.1%)	(0.1%)
Host/Vendor-Independent	421	437	431	406	371	362	369	340	297	(8.6%)	(5.4%)
Graphics Terminals	576	719	869	758	881	1,024	1,192	1,399	1,641	16.2%	16.8%
Subtotal	3,336	3,757	3,391	2,880	2,769	2,840	2,966	3,093	3,181	(3.9%)	3.5%
Input/Output											
Remote Batch, Job-Entry, and Output	60	122	214	218	249	270	290	312	335	14.2%	7.7%
Key Entry Equipment	102	80	70	63	57	58	52	47	42	(9.5%)	(7.4%)
Media-to-Media Data Conversion	102	135	143	140	147	154	162	170	179	5.0%	5.0%
Magnetic Ink Recognition	91	79	60	50	41	34	28	23	19	(18.0%)	(17.5%)
Optical Scanning Equipment	195	253	248	276	298	320	347	376	411	8.0%	8.4%
Computer Plotters	232	241	246	253	268	295	330	353	380	5.9%	9.1%
Serial Printers											
Impact, Dot Matrix	2,790	2,299	2,171	2,319	2,259	2,246	2,201	1,792	1,751	(2.6%)	(6.2%)
Impact, Fully Formed	1,044	1,033	381	237	162	115	98	70	59	(31.6%)	(22.3%)
Nonimpact, Direct Thermal	120	175	70	46	32	24	17	11	10	(30.4%)	(25.2%)
Nonimpact, Thermal Transfer	0	33	214	186	309	355	373	423	444	66.1%	9.5%
Nonimpact, Ink Jet	32	109	97	108	154	199	216	269	298	42.6%	17.9%
Line Printers											
Impact, Dot Matrix	332	420	521	611	701	772	803	774	727	14.7%	0.9%
Impact, Fully Formed	1,423	1,471	1,439	1,370	1,254	1,059	946	833	766	(8.5%)	(11.6%)
Nonimpact, Direct Thermal	13	5	2	1	0	0	0	0	0	N/A	N/A
Nonimpact, Thermal Transfer	3	7	12	18	29	44	55	59	58	61.1%	18.9%
Page Printers											
Nonimpact, Plain Paper	573	1,187	1,174	1,825	2,408	3,074	3,621	3,998	4,693	31.9%	18.2%
Subtotal	7,114	7,649	7,062	7,721	8,368	9,019	9,539	9,510	10,172	8.4%	5.0%

(Continued)

Segment Detail
North American Data Processing Equipment Forecast (Continued)
(Millions of Dollars)

Equipment Type	1983	1984	1985	1986	1987	1988	1989	1990	1991	CAGR 86-87	CAGR 87-91
Dedicated Systems											
Office Automation											
Copiers and Duplicators											
PC	0	0	0	0	0	19	22	26	29	N/A	N/A
Segment 1	150	141	90	137	153	165	168	172	175	11.7%	3.4%
Segment 2	20	49	120	86	94	99	104	104	102	9.3%	2.1%
Segment 3	90	173	155	187	207	223	239	256	270	10.7%	6.9%
Segment 4	48	52	22	229	307	344	369	380	396	34.1%	6.6%
Segment 5	836	951	957	498	307	344	369	380	396	(38.4%)	6.6%
Segment 6	199	208	313	924	534	176	88	88	88	(42.2%)	(36.3%)
Electronic Calculators	188	174	151	128	107	98	94	92	89	(16.4%)	(4.5%)
Dictating, Transcribing	33	19	15	12	10	9	9	8	6	(16.7%)	(12.0%)
Electronic Typewriters											
Portable & Compact	0	86	162	398	362	362	325	325	326	(9.0%)	(2.6%)
Low-End, Full-Size	40	85	189	162	175	105	80	60	48	8.0%	(27.6%)
Midrange, Full-Size	36	40	45	44	40	37	32	31	30	(9.1%)	(6.9%)
High-End, Full-Size	141	252	292	355	150	75	25	25	20	(57.7%)	(39.6%)
Display & Modular Display	0	39	64	70	83	114	128	158	158	18.6%	17.5%
Word Processors											
Standalone	515	551	400	137	91	56	39	25	17	(33.6%)	(34.3%)
Shared System	888	963	754	232	182	139	114	88	64	(21.6%)	(23.0%)
WP File Servers	0	0	384	108	88	71	57	47	36	(18.5%)	(20.0%)
Banking Systems											
Check-Handling Systems	58	68	111	102	136	152	169	185	205	33.3%	10.8%
Funds-Transfer Terminals	307	373	307	276	321	343	368	390	415	16.3%	6.6%
Point-of-Sale Terminals	454	491	439	430	442	460	478	497	517	2.8%	4.0%
Cash Registers	77	27	45	44	45	46	47	49	52	2.3%	3.6%
Mailing, Letter Handling, Addressing	508	562	586	574	609	650	684	718	757	6.1%	5.6%
Other Specialized Terminals	248	242	257	259	268	278	286	295	304	3.5%	3.2%
Subtotal	4,837	5,546	5,858	5,392	4,711	4,373	4,294	4,400	4,500	(12.6%)	(1.1%)
Total Data Processing	62,668	78,104	87,160	92,275	101,872	111,834	120,940	127,903	135,784	10.4%	7.4%

N/A = Not Applicable

Source: Dataquest
November 1987

Segment Detail
North American Communications Equipment Forecast
(Millions of Dollars)

Equipment Type	1983	1984	1985	1986	1987	1988	1989	1990	1991	CAGR 86-87	CAGR 87-91
Customer Premises											
Terminal Equipment											
Single-Line Telephones	378	368	285	200	168	126	82	40	30	(16.0%)	(35.0%)
Integrated Voice/Data Workstations											
Asynchronous	25	41	51	55	61	65	74	85	85	10.9%	8.6%
Synchronous	2	2	9	11	14	18	24	31	38	27.3%	28.4%
PC	6	5	44	51	61	69	86	116	151	19.6%	25.4%
Add-On	0	6	17	22	34	50	63	71	91	54.5%	27.9%
Teleprinters	387	294	272	258	245	241	229	218	207	(5.0%)	(4.1%)
Data Communications Equipment											
Modems											
Data Terminal											
300 bps	74	64	52	41	34	30	24	19	15	(17.1%)	(18.5%)
1,200 bps	144	174	186	190	192	195	195	194	193	1.1%	0.1%
2,400 bps	125	141	165	188	211	233	243	252	261	12.1%	5.5%
4,800 bps	250	230	167	118	82	56	37	22	13	(30.6%)	(36.9%)
9,600+ bps	277	303	334	365	425	514	609	615	621	16.4%	9.9%
PC											
300 bps	53	30	17	11	8	6	5	4	3	(27.3%)	(21.7%)
1,200 bps	61	132	163	192	232	215	212	243	279	20.8%	4.7%
2,400 bps	0	0	32	64	130	279	462	629	856	103.1%	60.2%
9,600 bps	0	0	5	28	66	106	161	228	323	135.7%	48.7%
High-Speed											
14.4 Kbps	101	110	116	154	203	261	423	533	672	31.8%	34.9%
16.0/16.8 Kbps	32	47	55	61	61	52	53	47	42	0.0	(8.9%)
19.2 Kbps	0	50	95	133	174	216	265	317	379	30.8%	21.5%
Statistical Multiplexers	209	280	313	331	336	329	301	281	264	1.5%	(5.9%)
T-1 Multiplexers	30	61	158	292	355	518	615	647	626	21.6%	15.2%
Front-End Processors	386	431	552	646	724	816	918	1,026	1,147	12.1%	12.2%
Local Area Networks											
Computer	22	49	99	116	135	150	164	175	187	16.3%	8.4%
Terminal	57	134	190	211	221	222	213	206	199	4.5%	(2.6%)
PC	36	65	182	234	292	360	439	528	635	24.8%	21.4%
Office Workstation	14	23	25	29	30	31	32	33	34	4.8%	2.9%
CAE	18	41	67	86	101	112	123	131	140	17.4%	8.5%
Special	5	9	14	17	22	26	31	36	42	29.4%	17.5%
Business Comm. Systems											
Key Telephone Systems	1,304	1,293	1,101	984	866	836	814	795	778	(12.0%)	(2.6%)

(Continued)

Segment Detail
North American Communications Equipment Forecast (Continued)
(Millions of Dollars)

Equipment Type	1983	1984	1985	1986	1987	1988	1989	1990	1991	CAGR 86-87	CAGR 87-91
Customer Premises (Continued)											
PBX											
1-40 Lines	93	97	97	96	98	99	102	104	106	2.1%	2.0%
41-100 Lines	425	447	461	453	466	478	496	508	520	2.9%	2.8%
101-400 Lines	703	732	727	703	714	731	768	800	833	1.6%	3.9%
401-1,000 Lines	495	548	564	586	617	659	707	743	781	5.3%	6.1%
> 1,000 Lines	643	769	797	825	870	933	1,019	1,107	1,203	5.5%	8.4%
Data PBX	77	119	105	86	87	85	82	79	75	1.6%	(3.6%)
Automatic Call Distributors	207	230	220	254	283	301	313	329	345	11.4%	5.1%
Attached Network Functions											
Protocol Converters	75	140	154	160	161	164	164	153	143	1.1%	(3.0%)
DSU/CSU	47	55	62	62	67	66	58	55	52	8.1%	(6.1%)
Data Network Control Systems											
Response	0	40	48	52	65	75	80	93	108	25.0%	13.5%
Network Management Systems	0	0	0	9	11	13	16	20	25	22.2%	22.8%
Modem Network Management	0	75	85	101	120	145	134	128	122	18.8%	0.4%
Matrix Switch	0	50	61	71	83	90	99	102	105	16.9%	6.1%
Switch/Path	0	117	137	160	173	181	174	158	143	8.1%	(4.6%)
Analyzers	0	125	150	151	149	139	123	117	111	(1.3%)	(7.1%)
Voice Messaging											
Standalone	18	20	20	17	14	11	10	10	9	(13.8%)	(11.1%)
PBX Integrated	18	62	100	150	246	379	483	596	628	64.0%	26.4%
Call Accounting	195	209	231	247	263	281	296	315	325	6.4%	5.4%
Videoteleconferencing	62	69	72	87	103	121	149	175	213	18.4%	19.9%
Subtotal	7,055	8,286	8,857	9,358	10,074	11,084	12,170	13,114	14,158	7.7%	8.9%
Public Telecommunications											
Transmission Equipment											
Multiplex	658	727	812	912	1,015	1,134	1,260	1,311	1,363	11.3%	7.6%
Carrier Systems	1,088	1,217	1,372	1,522	1,692	1,913	2,072	2,205	2,350	11.2%	8.6%
Microwave Radio	399	433	475	515	559	612	675	720	764	8.5%	8.1%
Satellite Earth Station	463	505	580	580	510	638	701	771	830	(12.1%)	12.9%
Switching Equipment											
Central Office											
Analog	1,014	555	437	399	324	109	83	79	78	(18.8%)	(30.0%)
Digital	912	1,690	2,012	2,060	2,085	1,965	1,940	1,934	1,928	1.2%	(1.9%)
Other Common Carrier	290	380	295	368	310	295	281	249	240	(15.7%)	(6.2%)
Private Packet Data Networks											
Nodes	73	117	188	230	280	343	419	511	623	22.0%	22.1%
PADs	16	25	38	45	53	62	74	87	102	17.9%	17.9%
Switch Concentrator	0	1	2	4	6	9	12	15	19	59.5%	34.0%
Subtotal	4,913	5,649	6,211	6,634	6,834	7,080	7,516	7,881	8,297	3.0%	5.0%

(Continued)

Segment Detail
North American Communications Equipment Forecast (Continued)
(Millions of Dollars)

Equipment Type	1983	1984	1985	1986	1987	1988	1989	1990	1991	CAGR 86-87	CAGR 87-91
Radio											
Mobile Radio Systems	214	283	250	255	266	277	284	293	303	4.3%	3.3%
Mobile Base Stations	188	199	217	240	267	274	291	312	335	11.2%	5.8%
Mobile Vehicular	427	612	659	705	754	807	860	920	966	7.0%	6.4%
Cellular Radio/Telephone											
Base Station	106	280	352	714	1,227	1,841	2,421	3,060	3,329	71.8%	28.3%
Radio Telephones	8	46	70	158	218	252	274	320	282	38.0%	6.6%
Broadcast Receivers, Transmitters	1,391	1,678	1,979	2,216	2,482	2,787	3,094	3,403	3,812	12.0%	11.3%
Amateur Radio	6	7	10	9	8	8	7	6	6	(11.1%)	(6.9%)
Citizen's Band; Mobile and Base	1	1	1	1	0	0	0	0	0	0.0	0.0
Portable Receivers, Transmitters	555	676	648	650	670	696	717	715	714	3.1%	1.6%
Checkout, Monitor, Evaluation, etc.	242	252	285	314	356	381	420	463	510	10.2%	10.2%
Comm. Antenna 890 MHz	129	108	105	102	104	105	105	103	101	2.0%	(0.7%)
Microwave Antenna 890 MHz	146	162	164	166	171	180	181	190	198	3.0%	3.7%
Subtotal	3,412	4,304	4,740	5,530	6,513	7,608	8,654	9,785	10,556	17.8%	12.8%
Broadcast and Studio											
Audio Equipment	187	219	211	215	226	244	221	225	241	5.1%	1.6%
Video Equipment	461	496	508	533	562	624	699	804	884	5.4%	12.0%
Transmitters, RF Power Amp.	111	107	114	120	126	139	150	164	180	5.0%	9.3%
Studio Transmitter Links	42	8	19	29	36	53	55	58	68	24.1%	17.2%
Cable TV Equipment	452	410	368	361	379	458	512	584	671	5.0%	15.4%
CCTV	99	109	82	80	82	84	89	96	104	2.5%	6.1%
Broadcast Transmitter Antenna	49	38	53	64	74	68	63	59	68	15.6%	(2.1%)
Other (Studio, Theater)	63	87	88	92	97	97	103	110	115	5.4%	4.3%
Subtotal	1,464	1,474	1,443	1,494	1,582	1,767	1,892	2,100	2,331	5.9%	10.2%
Other											
Intercomm. Equip. Elec. Ampl.	176	213	206	199	198	200	202	204	208	(0.5%)	1.2%
Light Communications Systems											
Fiber Optic	139	254	527	530	530	530	608	697	800	0.0	10.8%
Other (Laser, Infrared)	137	462	807	810	810	810	815	864	916	0.0	3.1%
Telemetering Systems	304	246	354	375	420	470	519	581	651	12.0%	11.6%
Subtotal	756	1,175	1,894	1,914	1,958	2,010	2,144	2,346	2,575	2.3%	7.1%
Total Communications	17,600	20,889	23,145	24,930	26,962	29,548	32,376	35,226	37,917	8.1%	8.9%

Source: Dataquest
November 1987

Segment Detail
North American Industrial Equipment Forecast
(Millions of Dollars)

Equipment Type	1983	1984	1985	1986	1987	1988	1989	1990	1991	CAGR 86-87	CAGR 87-91
Security/Energy Management											
Alarm Systems											
Intrusion Detection	516	568	590	679	781	906	978	1,125	1,288	15.0%	13.3%
Fire Detection	364	477	431	427	436	449	458	472	496	2.1%	3.3%
Discrete Devices	537	548	565	582	599	617	636	655	675	2.9%	3.0%
MPU Load Programmers	26	19	20	23	26	29	32	36	40	13.0%	11.4%
Computerized Energy Control Systems	554	348	361	358	369	387	379	390	406	3.1%	2.4%
Subtotal	1,997	1,960	1,967	2,069	2,211	2,388	2,483	2,678	2,905	6.9%	7.1%
Manufacturing Systems											
Semiconductor Production	1,414	2,717	2,222	2,139	2,266	2,965	2,912	3,397	4,161	5.9%	16.4%
Test Equipment											
ATE	1,188	1,416	1,371	1,255	1,381	1,511	1,718	1,797	1,921	10.0%	8.6%
General	3,654	4,445	4,548	4,503	4,818	5,203	5,359	5,573	5,852	7.0%	5.0%
Process Control Systems	868	1,023	1,092	1,149	1,201	1,256	1,344	1,417	1,449	4.5%	4.8%
Programmable Machine Tools	677	740	790	712	729	735	753	764	796	2.4%	2.2%
Mechanical Assembly Equipment	243	397	391	360	360	401	425	461	500	0.0	8.6%
Plastic Processing Machinery	567	779	604	645	703	748	796	846	913	9.0%	6.8%
Robot Systems											
Assembly	36	67	95	66	70	84	103	123	147	5.6%	20.5%
Material Handling/Loading	51	79	112	81	85	98	114	133	154	5.3%	16.0%
Painting	32	54	60	42	33	38	43	45	49	(21.0%)	10.4%
Spot Welding	33	61	106	85	67	73	83	89	95	(21.9%)	9.4%
Arc Welding	31	57	63	66	70	82	98	122	149	6.0%	20.7%
Machining--Other	49	62	56	37	36	43	48	57	64	(2.7%)	15.4%
Automated Material Handling											
Guided Vehicles	40	70	100	60	66	70	77	85	92	10.0%	8.7%
Programmable Conveyors	194	227	272	300	336	386	406	446	491	12.0%	9.9%
Storage/Retrieval Systems	83	91	104	115	120	130	135	145	160	4.3%	7.5%
Programmable Monorails	10	18	33	43	50	58	63	73	84	16.3%	13.8%
Warehousing	69	73	78	82	88	94	100	105	112	7.3%	6.2%
Other	9	11	13	8	8	9	9	9	10	0.0%	4.4%
Subtotal	9,248	12,387	12,110	11,748	12,487	13,983	14,586	15,686	17,199	6.3%	8.3%

(Continued)

Segment Detail
North American Industrial Equipment Forecast (Continued)
(Millions of Dollars)

Equipment Type	1983	1984	1985	1986	1987	1988	1989	1990	1991	CAGR 86-87	CAGR 87-91
Instrumentation											
Integrating and Totalizing Meters for Gas and Liquids	449	493	547	557	601	649	647	634	708	7.9%	4.2%
Counting Devices	173	209	198	202	222	249	234	253	281	9.9%	6.1%
Digital Panel Meters	27	36	34	33	34	41	41	44	50	3.0%	10.1%
Analog Panel Meters	10	5	6	6	6	5	6	6	5	(8.1%)	(3.2%)
Panel Type	116	128	119	124	141	162	163	196	214	13.7%	11.0%
Elapsed-Time Meters	27	16	12	11	13	14	12	14	15	18.2%	3.6%
Portable Elec. Measuring Instruments	22	23	18	18	23	24	19	20	21	27.8%	(2.2%)
Elec. Recording Instruments	323	418	438	469	517	568	549	602	656	10.2%	6.1%
Physical Property Test, Inspection and Measurement	564	652	678	698	784	845	921	1,000	1,065	12.3%	8.0%
Comm. Meteorological and General-Purpose Instruments	294	381	334	300	354	373	470	447	501	18.0%	9.1%
Nuclear Radiation Detection and Monitoring Instruments	503	495	514	543	526	536	541	550	578	(3.1%)	2.4%
Surveying and Drafting Instruments	246	327	368	390	461	450	479	512	538	18.2%	3.9%
Ultrasonic Cleaners, Drills	107	127	112	110	121	135	146	159	172	10.0%	9.2%
Meteorological	79	86	112	140	163	179	211	243	272	16.4%	13.7%
Geophysical	228	316	313	266	285	386	452	565	712	7.1%	25.7%
Analytical and Scientific Instruments	2,439	2,749	2,768	2,713	2,984	3,551	3,698	3,952	4,150	10.0%	8.6%
Subtotal	5,607	6,461	6,571	6,580	7,235	8,167	8,589	9,197	9,938	9.9%	8.3%
Medical Equipment											
Diagnostic											
Automatic Blood Analyser	744	724	715	787	865	952	1,047	1,152	1,267	9.9%	10.0%
CAT Scanners	510	666	513	457	416	378	344	313	285	(9.0%)	(9.0%)
Digital Radiography	55	60	57	63	71	80	87	97	110	12.7%	11.6%
Electrocardiographs	72	118	96	98	106	114	122	129	135	8.2%	6.2%
Electroencephalographs	15	20	13	15	16	18	20	23	26	6.7%	12.9%
Nuclear Magnetic Resonance	69	81	155	264	385	500	590	649	714	45.8%	16.7%
Respiratory Analysis	16	17	15	15	16	16	16	17	18	6.7%	3.0%
Ultrasonic Scanners	376	294	187	168	186	205	223	243	262	10.7%	8.9%
X-Ray	711	656	685	719	751	793	805	849	896	4.5%	4.5%
Other Diagnostic	291	254	263	276	280	294	303	312	324	1.4%	3.7%
Patient-Monitoring	659	577	640	666	699	741	771	817	882	5.0%	6.0%
Prosthetic											
Hearing Aids	340	363	395	419	444	471	500	534	570	6.1%	6.4%
Surgical Support	104	130	181	217	232	244	249	256	271	6.9%	4.0%
Therapeutic											
Defibrillators	86	91	104	111	117	126	130	135	142	5.4%	5.0%
Dialysis, Diathermy	73	65	71	74	78	85	87	89	92	5.4%	4.2%
Electrosurgical	64	81	80	79	83	89	95	98	105	5.1%	6.1%
Pacemakers	263	371	304	312	320	328	336	345	357	2.6%	2.8%
Ultrasonic Generators	18	32	27	25	27	30	34	36	37	8.0%	8.2%
Other Therapeutic	274	288	258	237	253	293	313	338	365	6.8%	9.6%
Subtotal	4,740	4,880	4,759	5,002	5,345	5,757	6,072	6,432	6,858	6.9%	6.4%

(Continued)

Segment Detail
North American Industrial Equipment Forecast (Continued)
(Millions of Dollars)

Equipment Type	1983	1984	1985	1986	1987	1988	1989	1990	1991	CAGR 86-87	CAGR 87-91
Commercial Aviation											
Aeronautical, Nautical, and Navigational Instrumentation	1,429	1,467	1,508	1,710	1,794	1,942	2,098	2,139	2,284	4.9%	6.2%
Aircraft Engine Instruments Except Flight	335	337	369	394	422	452	484	518	554	7.1%	7.0%
Subtotal	1,764	1,804	1,877	2,104	2,216	2,394	2,582	2,657	2,838	5.3%	6.4%
Other											
Vending Machines	334	394	429	408	386	398	415	421	427	(5.4%)	2.6%
Laser Systems (Excluding Communication)	545	623	621	625	679	760	821	919	1,029	8.6%	11.0%
Power Supplies	755	884	1,029	1,205	1,411	1,764	1,947	2,253	2,607	17.1%	16.6%
Traffic Control	481	474	453	462	485	509	537	562	587	5.0%	4.9%
Particle Accelerator Electronic	34	29	19	17	20	23	25	24	22	17.6%	2.4%
Trainers and Simulators	771	767	831	929	1,040	1,164	1,303	1,460	1,635	11.9%	12.0%
Industr. and Scientific X-Ray	65	53	61	67	75	86	94	98	104	11.9%	8.5%
Lab. and Scientific Apparatus	976	1,101	1,136	1,194	1,290	1,385	1,494	1,576	1,664	8.0%	6.6%
Teaching Machines and Aids	21	64	67	70	77	84	90	97	105	10.0%	8.1%
Scientific Not Elsewhere Classified	185	187	185	183	206	221	238	261	286	12.6%	8.5%
Subtotal	4,168	4,576	4,831	5,160	5,669	6,394	6,964	7,671	8,466	9.9%	10.5%
Total Industrial	27,524	32,068	32,115	32,663	35,162	39,084	41,276	44,321	48,204	7.7%	8.2%

Source: Dataquest
November 1987

Segment Detail
North American Consumer Equipment Forecast
(Millions of Dollars)

Equipment Type	1983	1984	1985	1986	1987	1988	1989	1990	1991	CAGR 86-87	CAGR 87-91
Audio											
Audio Amplifiers	23	16	17	16	14	11	12	12	11	(12.5%)	(5.9%)
Compact Disk Players	0	0	0	0	15	20	30	55	60	N/A	41.4%
Radio	19	23	18	19	21	24	23	22	22	10.5%	1.2%
Stereo (Hi-Fi) Components	202	186	193	215	229	231	246	261	271	6.5%	4.3%
Stereo Headphone	0	2	2	4	7	7	8	8	7	75.0%	0.0
Musical Instruments	11	10	13	15	23	25	27	27	27	53.3%	4.1%
Tape Recorders	15	11	11	14	15	14	11	10	9	7.1%	(12.0%)
Subtotal	270	248	254	283	324	332	357	395	407	14.5%	5.9%
Video											
Video Cameras	5	15	25	41	45	56	60	70	81	9.8%	15.8%
VTRs (VCRs)	20	58	78	105	169	205	230	254	307	61.0%	16.1%
Video Disk Players	0	3	5	6	10	8	8	9	8	66.7%	(5.4%)
Color Televisions	3,582	4,093	4,108	4,165	4,521	4,628	4,937	5,482	5718	8.5%	6.0%
Black-and-White Televisions	331	351	364	339	382	394	412	439	463	12.7%	4.9%
Subtotal	3,938	4,520	4,580	4,656	5,127	5,291	5,647	6,254	6,577	10.1%	6.4%
Personal Electronics											
Games	959	423	505	543	612	647	685	691	705	12.7%	3.6%
Cameras	13	15	18	17	20	23	25	26	26	17.6%	6.8%
Watches	68	62	64	67	72	69	65	61	59	7.5%	(4.9%)
Clocks	8	13	13	14	16	17	19	23	26	14.3%	12.9%
Subtotal	1,048	513	600	641	720	756	794	801	816	12.3%	3.2%
Appliances											
Air Conditioners	873	991	1,022	1,074	1,146	1,231	1,297	1,408	1521	6.7%	7.3%
Microwave Ovens	1,044	1,252	1,467	1,526	1,623	1,679	1,729	1,794	1856	6.3%	3.4%
Washers and Dryers	1,876	2,079	2,168	2,255	2,371	2,451	2,581	2,691	2806	5.1%	4.3%
Refrigerators	2,249	2,573	2,718	2,894	3,082	3,194	3,321	3,517	3672	6.5%	4.5%
Dishwashers, Disposals	885	1,024	1,185	1,236	1,354	1,391	1,467	1,584	1711	9.5%	6.0%
Ranges & Ovens	972	1,090	1,231	1,387	1,492	1,576	1,703	1,897	2125	7.6%	9.2%
Subtotal	7,899	9,008	9,792	10,373	11,068	11,522	12,098	12,891	13,691	6.7%	5.5%
Other											
Antennas (TV, CB, Radio)	125	127	132	137	145	150	156	167	174	5.9%	4.7%
Auto. Garage Door Openers	187	202	218	233	247	257	265	271	282	6.0%	3.3%
Cons. Elec. Equip. N.E.C.	322	449	626	689	723	760	797	832	869	5.0%	4.7%
Subtotal	634	778	976	1,059	1,116	1,167	1,218	1,270	1,325	5.3%	4.4%
Total Consumer	13,789	15,067	16,202	17,011	18,355	19,067	20,114	21,611	22,816	7.9%	5.6%

N/A = Not Applicable
N.E.C. = Not Elsewhere Classified

Source: Dataquest
November 1987

Segment Detail
North American Military Electronic Equipment Forecast
(Millions of Dollars)

Budget Area	1983	1984	1985	1986	1987	1988	1989	1990	1991	CAGR 86-87	CAGR 87-91
Procurement											
Aircraft	9,261	10,372	11,500	10,000	8,300	8,400	8,300	8,300	8,400	(17.0%)	0.3%
Missiles	5,860	6,540	4,900	6,000	6,100	5,900	5,700	5,600	5,600	1.7%	(2.1%)
Space	1,955	2,256	2,600	2,600	2,600	2,700	2,800	2,900	3,200	0.0	5.3%
Ships	3,780	4,045	4,400	3,800	3,200	3,000	3,000	3,000	3,000	(15.8%)	(1.6%)
Ordnance, Weapons, and Vehicles	1,539	1,752	2,400	2,100	2,000	2,000	2,000	2,000	2,000	(4.8%)	0.0
Electronics and Communication	5,130	5,950	6,500	7,200	7,100	7,200	7,200	7,200	7,200	(1.4%)	0.4%
Other	675	730	900	900	900	800	800	800	800	0.0	(2.9%)
Research, Development, Testing, and Evaluation	10,300	11,950	16,100	17,100	17,300	16,900	16,600	16,500	16,500	1.2%	(1.2%)
Total Military	38,500	43,595	49,300	49,700	47,500	46,900	46,400	46,300	46,700	(4.4%)	(0.4%)

Source: Dataquest
November 1987

Segment Detail
North American Transportation Equipment Forecast
(Millions of Dollars)

Equipment Type	1983	1984	1985	1986	1987	1988	1989	1990	1991	CAGR 86-87	CAGR 87-91
Entertainment	1,549	2,142	2,380	2,647	2,893	3,154	3,643	3,959	4,260	9.3%	10.2%
Body Controls	777	1,060	1,261	1,513	1,738	2,067	2,535	2,766	2,976	14.9%	14.4%
Driver Information	798	1,060	1,237	1,458	1,688	1,977	2,415	2,635	2,833	15.8%	13.8%
Power Train	1,933	2,473	2,782	3,007	3,397	3,340	3,709	4,047	4,375	12.9%	6.5%
Safety and Convenience	490	706	820	955	1,093	1,261	1,510	1,642	1,765	14.5%	12.7%
Total Transportation Elec.	5,547	7,441	8,480	9,580	10,809	11,799	13,812	15,050	16,209	12.8%	10.7%

Source: Dataquest
November 1987

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Semiconductor Consumption--Consumer

Table 1

North American Semiconductor Consumption
Consumer
Total Semiconductor
(Millions of Dollars)

	1984	1985	1986	1987	1991	CAGR 1987-1991
Total Semiconductor	$970.0	$698.0	$732.0	$867.0	$1,264.0	9.9%
IC	822.5	567.9	576.3	690.5	1,028.0	10.5%
Bipolar	107.7	73.6	82.7	84.8	109.0	6.5%
MOS	610.3	386.6	358.2	463.4	583.5	5.9%
Linear	104.5	107.8	135.4	142.3	335.5	23.9%
Discrete	103.6	96.3	122.5	130.1	179.2	8.3%
Optoelectronic	44.4	33.9	33.3	44.9	59.0	7.1%

Table 2

North American Semiconductor Consumption
Consumer
Bipolar Logic
(Millions of Dollars)

	1984	1985	1986	1987	1991	CAGR 1987-1991
IC	$822.5	$567.9	$576.3	$690.5	$1,028.0	10.5%
Bipolar	107.7	73.6	82.7	84.8	109.0	6.5%
Logic	100.3	70.2	76.2	81.9	106.3	6.8%
Standard	89.3	55.7	62.1	65.0	68.0	1.1%
TTL	88.6	55.1	61.1	62.5	64.0	0.6%
ECL	0.6	0.5	0.9	2.1	4.0	16.9%
Other	0.2	0.1	0.2	0.4	0.0	(43.3%)
ASIC	11.0	14.5	14.0	16.9	38.3	22.7%
Gate Array	3.9	4.4	3.7	4.0	6.8	14.0%
Cell Based	0.1	0.4	0.5	0.7	6.0	70.3%
PLD	0.0	1.5	2.0	4.2	15.5	38.3%
Full Custom	7.0	8.2	7.8	7.9	10.1	6.3%

Source: Dataquest
December 1987

Note: Columns may not add to totals shown because of rounding.

Table 3

North American Semiconductor Consumption
Consumer
Bipolar Memory
(Millions of Dollars)

	1984	1985	1986	1987	1991	CAGR 1987-1991
IC	$822.5	$567.9	$576.3	$690.5	$1,028.0	10.5%
Bipolar	107.7	73.6	82.7	84.8	109.0	6.5%
Memory	7.4	3.3	6.6	2.9	2.7	(2.2%)
RAM	1.4	1.2	1.1	0.8	0.7	(2.9%)
TTL	1.3	1.0	0.9	0.8	0.3	(22.7%)
ECL	0.2	0.2	0.2	0.0	0.4	N/A
ROM/PROM	5.9	2.1	5.2	2.2	2.0	(1.9%)
Other	0.0	0.0	0.3	0.0	0.0	N/A

Table 4

North American Semiconductor Consumption
Consumer
MOS Microprocessors
(Millions of Dollars)

	1984	1985	1986	1987	1991	CAGR 1987-1991
IC	$822.5	$567.9	$576.3	$690.5	$1,028.0	10.5%
MOS	610.3	386.6	358.2	463.4	583.5	5.9%
Micros	81.1	54.0	66.9	77.3	98.7	6.3%
Microprocessor	7.7	3.2	3.8	3.2	4.7	9.5%
8 Bit	7.7	3.2	3.8	3.2	4.7	9.5%
16 Bit	0.0	0.0	0.0	0.0	0.0	N/A
32 Bit	0.0	0.0	0.0	0.0	0.0	N/A
Microcontroller	59.5	42.7	55.3	64.7	77.3	4.5%
4 Bit	40.8	27.9	41.0	42.2	48.5	3.5%
8 Bit	18.7	14.8	14.3	22.5	28.7	6.3%
16 Bit	0.0	0.0	0.0	0.0	0.0	N/A
Microperipherals	13.9	8.1	7.9	9.3	16.8	15.8%

Source: Dataquest
December 1987

N/A = Not Applicable
Note: Columns may not add to totals shown because of rounding.

Table 5

North American Semiconductor Consumption
Consumer
MOS Logic
(Millions of Dollars)

	1984	1985	1986	1987	1991	CAGR 1987-1991
IC	$822.5	$567.9	$576.3	$690.5	$1,028.0	10.5%
MOS	610.3	386.6	358.2	463.4	583.5	5.9%
Logic	111.3	79.5	107.1	147.8	201.7	8.1%
Standard	28.9	22.7	29.8	35.4	46.4	7.0%
ASIC	82.4	56.9	77.3	112.4	155.3	8.4%
Gate Array	6.7	7.4	11.4	13.8	37.4	28.4%
Cell Based	10.6	11.3	16.1	19.7	62.3	33.3%
PLD	0.0	0.7	1.8	5.1	15.3	31.5%
Full Custom	65.0	37.4	48.0	73.8	40.3	(14.0%)

Table 6

North American Semiconductor Consumption
Consumer
MOS Memory
(Millions of Dollars)

	1984	1985	1986	1987	1991	CAGR 1987-1991
IC	$822.5	$567.9	$576.3	$690.5	$1,028.0	10.5%
MOS	610.3	386.6	358.2	463.4	583.5	5.9%
Memory	417.8	253.1	184.1	238.3	283.1	4.4%
DRAM	130.2	45.6	49.5	66.7	91.8	8.3%
SRAM	4.9	3.6	3.0	4.0	5.8	9.6%
EPROM	164.4	120.0	84.8	105.0	131.7	5.8%
ROM	110.4	77.9	39.6	53.0	38.2	(7.8%)
EEPROM/NVRM	4.7	4.6	3.2	5.6	11.1	18.6%
Other	3.3	1.4	4.1	4.0	4.5	3.2%

Source: Dataquest
December 1987

Note: Columns may not add to totals shown because of rounding.

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Semiconductor Consumption—Industrial

Table 1

North American Semiconductor Consumption
Industrial
Total Semiconductor
(Millions of Dollars)

	1984	1985	1986	1987	1991	CAGR 1987-1991
Total Semiconductor	$2,107.0	$1,561.0	$1,600.0	$1,946.0	$3,183.0	13.1%
IC	1,655.0	1,141.1	1,157.4	1,446.6	2,468.3	14.3%
Bipolar	536.2	314.5	311.7	372.5	580.1	11.7%
MOS	775.6	561.5	594.5	799.2	1,430.6	15.7%
Linear	343.2	265.2	251.2	274.9	457.7	13.6%
Discrete	381.7	356.0	371.5	420.2	620.9	10.3%
Optoelectronic	70.3	63.8	70.7	80.6	93.5	3.8%

Table 2

North American Semiconductor Consumption
Industrial
Bipolar Logic
(Millions of Dollars)

	1984	1985	1986	1987	1991	CAGR 1987-1991
IC	$1,655.0	$1,141.1	$1,157.4	$1,446.6	$2,468.3	14.3%
Bipolar	536.2	314.5	311.7	372.5	580.1	11.7%
Logic	506.1	292.7	286.4	343.6	536.9	11.8%
Standard	479.5	255.2	242.4	270.4	303.8	3.0%
TTL	458.9	235.9	213.4	231.5	238.3	0.7%
ECL	14.3	13.7	21.5	30.6	64.6	20.5%
Other	6.3	5.7	7.5	8.3	0.9	(42.2%)
ASIC	26.6	37.5	44.1	73.2	233.0	33.6%
Gate Array	10.5	21.0	23.1	34.3	129.4	39.4%
Cell Based	0.6	1.1	1.2	1.6	18.8	86.5%
PLD	8.6	8.2	12.7	27.0	60.4	22.3%
Full Custom	6.9	7.1	7.0	10.3	24.3	23.8%

Source: Dataquest
December 1987

Note: Columns may not add to totals shown because of rounding.

Table 3

North American Semiconductor Consumption
Industrial
Bipolar Memory
(Millions of Dollars)

	1984	1985	1986	1987	1991	CAGR 1987-1991
IC	$1,655.0	$1,141.1	$1,157.4	$1,446.6	$2,468.3	14.3%
Bipolar	536.2	314.5	311.7	372.5	580.1	11.7%
Memory	30.0	21.8	25.3	28.9	43.2	10.5%
RAM	16.1	13.5	16.3	18.8	30.2	12.6%
TTL	2.3	2.3	1.5	1.8	0.3	(35.6%)
ECL	13.8	11.2	14.8	17.0	29.9	15.1%
ROM/PROM	10.3	4.6	4.6	4.7	4.9	0.9%
Other	3.6	3.8	4.4	5.4	8.1	10.7%

Table 4

North American Semiconductor Consumption
Industrial
MOS Microprocessors
(Millions of Dollars)

	1984	1985	1986	1987	1991	CAGR 1987-1991
IC	$1,655.0	$1,141.1	$1,157.4	$1,446.6	$2,468.3	14.3%
MOS	775.6	561.5	594.5	799.2	1,430.6	15.7%
Micros	307.6	222.9	226.7	278.2	505.7	16.1%
Microprocessor	50.8	28.9	34.0	44.4	82.2	16.7%
8 Bit	36.1	14.1	16.5	17.2	24.7	9.4%
16 Bit	14.6	13.5	14.1	15.2	31.5	19.9%
32 Bit	0.0	1.4	3.4	11.9	26.1	21.7%
Microcontroller	164.3	112.8	110.5	132.3	224.4	14.1%
4 Bit	3.8	1.7	2.7	5.4	6.2	3.5%
8 Bit	160.5	111.1	107.8	126.5	215.1	14.2%
16 Bit	0.0	0.0	0.0	0.5	3.0	60.8%
Microperipherals	92.5	81.2	82.2	101.5	199.1	18.3%

Source: Dataquest
December 1987

Note: Columns may not add to totals shown because of rounding.

Semiconductor Consumption--Industrial

Table 5

North American Semiconductor Consumption
Industrial
MOS Logic
(Millions of Dollars)

	1984	1985	1986	1987	1991	CAGR 1987-1991
IC	$1,655.0	$1,141.1	$1,157.4	$1,446.6	$2,468.3	14.3%
MOS	775.6	561.5	594.5	799.2	1,430.6	15.7%
Logic	179.5	160.7	209.3	300.8	574.8	17.6%
Standard	84.7	78.2	106.1	137.8	194.9	9.0%
ASIC	94.8	82.5	103.2	163.0	379.9	23.6%
Gate Array	13.4	23.9	34.8	59.7	177.4	31.3%
Cell Based	35.4	32.4	39.6	48.7	146.9	31.8%
PLD	0.7	2.6	4.8	11.1	33.4	31.8%
Full Custom	45.3	23.6	24.0	43.5	22.2	(15.5%)

Table 6

North American Semiconductor Consumption
Industrial
MOS Memory
(Millions of Dollars)

	1984	1985	1986	1987	1991	CAGR 1987-1991
IC	$1,655.0	$1,141.1	$1,157.4	$1,446.6	$2,468.3	14.3%
MOS	775.6	561.5	594.5	799.2	1,430.6	15.7%
Memory	288.5	177.9	158.6	220.2	350.1	12.3%
DRAM	139.5	65.4	63.0	88.0	141.6	12.6%
SRAM	43.8	33.6	28.2	38.1	70.1	16.5%
EPROM	65.2	47.6	37.7	51.6	78.5	11.1%
ROM	11.5	8.7	4.9	7.7	5.4	(8.5%)
EEPROM/NVRM	18.6	18.4	12.8	22.9	39.9	14.9%
Other	9.9	4.2	12.0	12.0	14.7	5.2%

Source: Dataquest
December 1987

Note: Columns may not add to totals shown because of rounding.

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Semiconductor Consumption--Military

Table 1

North American Semiconductor Consumption
Military
Total Semiconductor
(Millions of Dollars)

	1984	1985	1986	1987	1991	CAGR 1987-1991
Total Semiconductor	$1,276.0	$1,488.0	$1,561.0	$1,777.0	$2,194.0	5.4%
IC	1,038.5	1,159.0	1,228.1	1,419.8	1,829.3	6.5%
Bipolar	446.2	469.3	498.0	533.6	663.7	5.6%
MOS	402.4	459.5	492.5	636.7	915.2	9.5%
Linear	189.9	230.2	237.6	249.5	250.4	0.1%
Discrete	205.5	278.9	274.7	290.9	293.4	0.2%
Optoelectronic	32.1	50.2	58.2	66.9	71.0	1.5%

Table 2

North American Semiconductor Consumption
Military
Bipolar Logic
(Millions of Dollars)

	1984	1985	1986	1987	1991	CAGR 1987-1991
IC	$1,038.5	$1,159.0	$1,228.1	$1,419.8	$1,829.3	6.5%
Bipolar	446.2	469.3	498.0	533.6	663.7	5.6%
Logic	308.6	346.3	379.1	405.6	542.2	7.5%
Standard	271.8	257.2	288.3	299.2	307.1	0.7%
TTL	258.0	240.0	262.3	271.7	274.4	0.2%
ECL	8.3	11.6	18.9	19.5	32.0	13.2%
Other	5.6	5.7	7.1	8.0	0.7	(45.4%)
ASIC	36.8	89.1	90.8	106.5	235.1	21.9%
Gate Array	23.1	72.9	72.4	82.0	179.2	21.6%
Cell Based	0.4	1.1	1.2	1.5	8.2	54.0%
PLD	8.6	7.9	10.2	16.5	30.2	16.3%
Full Custom	4.6	7.1	7.0	6.4	17.5	28.4%

Source: Dataquest
December 1987

Note: Columns may not add to totals shown because of rounding.

Table 3

North American Semiconductor Consumption
Military
Bipolar Memory
(Millions of Dollars)

	1984	1985	1986	1987	1991	CAGR 1987-1991
IC	$1,038.5	$1,159.0	$1,228.1	$1,419.8	$1,829.3	6.5%
Bipolar	446.2	469.3	498.0	533.6	663.7	5.6%
Memory	137.6	123.0	118.9	128.0	121.4	(1.3%)
RAM	39.6	38.7	35.9	39.4	30.2	(6.4%)
TTL	37.1	34.2	31.4	31.2	22.0	(8.4%)
ECL	2.4	4.6	4.6	8.3	8.3	0.0%
ROM/PROM	88.0	72.2	69.2	71.2	70.4	(0.3%)
Other	10.1	12.0	13.8	17.3	20.8	4.7%

Table 4

North American Semiconductor Consumption
Military
MOS Microprocessors
(Millions of Dollars)

	1984	1985	1986	1987	1991	CAGR 1987-1991
IC	$1,038.5	$1,159.0	$1,228.1	$1,419.8	$1,829.3	6.5%
MOS	402.4	459.5	492.5	636.7	915.2	9.5%
Micros	79.4	68.8	58.6	82.3	104.2	6.1%
Microprocessor	20.4	13.9	17.2	21.8	29.2	7.5%
8 Bit	11.2	5.1	6.0	5.0	5.6	2.5%
16 Bit	9.2	8.1	8.5	12.2	15.4	6.1%
32 Bit	0.0	0.7	2.7	4.6	8.2	15.5%
Microcontroller	8.1	7.6	7.6	14.6	20.9	9.3%
4 Bit	0.0	0.0	0.0	2.0	2.0	(0.7%)
8 Bit	8.0	7.4	7.2	10.4	14.1	7.9%
16 Bit	0.1	0.2	0.4	2.2	4.8	21.5%
Microperipherals	50.9	47.2	33.8	45.9	54.2	4.2%

Source: Dataquest
December 1987

Note: Columns may not add to totals shown because of rounding.

Semiconductor Consumption--Military

Table 5

North American Semiconductor Consumption
Military
MOS Logic
(Millions of Dollars)

	1984	1985	1986	1987	1991	CAGR 1987-1991
IC	$1,038.5	$1,159.0	$1,228.1	$1,419.8	$1,829.3	6.5%
MOS	402.4	459.5	492.5	636.7	915.2	9.5%
Logic	136.5	194.0	264.8	360.4	587.5	13.0%
Standard	34.3	35.2	51.4	76.3	97.4	6.3%
ASIC	102.2	158.8	213.4	284.1	490.1	14.6%
Gate Array	50.4	110.6	151.8	207.3	358.0	14.6%
Cell Based	23.4	33.2	39.1	44.4	93.1	20.4%
PLD	1.3	1.8	3.8	7.9	22.5	29.8%
Full Custom	27.2	13.2	18.7	24.6	16.5	(9.4%)

Table 6

North American Semiconductor Consumption
Military
MOS Memory
(Millions of Dollars)

	1984	1985	1986	1987	1991	CAGR 1987-1991
IC	$1,038.5	$1,159.0	$1,228.1	$1,419.8	$1,829.3	6.5%
MOS	402.4	459.5	492.5	636.7	915.2	9.5%
Memory	186.5	196.8	169.1	194.0	223.4	3.6%
DRAM	46.5	55.1	56.3	67.6	73.9	2.3%
SRAM	82.8	80.9	67.9	73.8	82.6	2.8%
EPROM	30.1	30.0	25.1	29.6	37.6	6.1%
ROM	13.8	17.3	9.2	9.7	6.3	(10.0%)
EEPROM/NVRM	12.1	12.9	9.0	11.8	21.4	16.1%
Other	1.2	0.6	1.7	1.6	1.6	0.8%

Source: Dataquest
December 1987

Note: Columns may not add to totals shown because of rounding.

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Trends in Consumer Electronics

CONSUMER ELECTRONIC EQUIPMENT MARKETS

Market Characteristics

The unit volume of products shipped from the worldwide consumer market tends to dwarf the volume shipped by other application markets. The size of the consumer market is a function of population, or the number of households, and few other products can claim such a large total available market. In the United States alone, the number of households in 1985 was nearly 87 million.

Electronics Industry Association's (EIA) June 1986 estimates of U.S. household penetration of selected consumer products are shown in Table 1. The television market in the United States is a mature one, with 98 percent penetration. Worldwide, however, the television market is far from mature and remains very active. The consumer market in China is four to five times the size of the U.S. market, and penetration of television in China is reported at a low 15 percent.

Table 1

U.S. HOUSEHOLD PENETRATION OF SELECTED CONSUMER PRODUCTS

	Percent of Households
All Television	98%
Color Television	92%
Color Television with MTS*	3%
VCR	35%
CD Players	3%

*Multichannel television stereo sound

Source: EIA

Trends in Consumer Electronics

Color television, with U.S. household penetration estimated at 92 percent, represents a mature market in relation to VCRs at 35 percent and compact disk (CD) players at 3 percent. Color television has reached a high saturation level in the U.S. market, and unit sales are largely driven by replacement and upgrade activity. As shown in Table 2, unit sales to dealers of color televisions grew at a 9.1 percent compound annual growth rate (CAGR) from 11.2 million units in 1981 to an estimated 17.3 million units in 1986.

Table 2

ESTIMATED U.S. CONSUMPTION OF SELECTED CONSUMER PRODUCTS (Millions of Units)

	1981	1982	1983	1984	1985	1986	CAGR*
Color Television	11.2	11.4	14.00	16.1	17.0	17.3	9.1%
VCR	1.4	2.0	4.10	7.6	11.9	13.2	56.6%
CD Players	0	0	0.04	0.3	1.3	3.2	277.4%

*CAGR for CD players is 1983 to 1986.

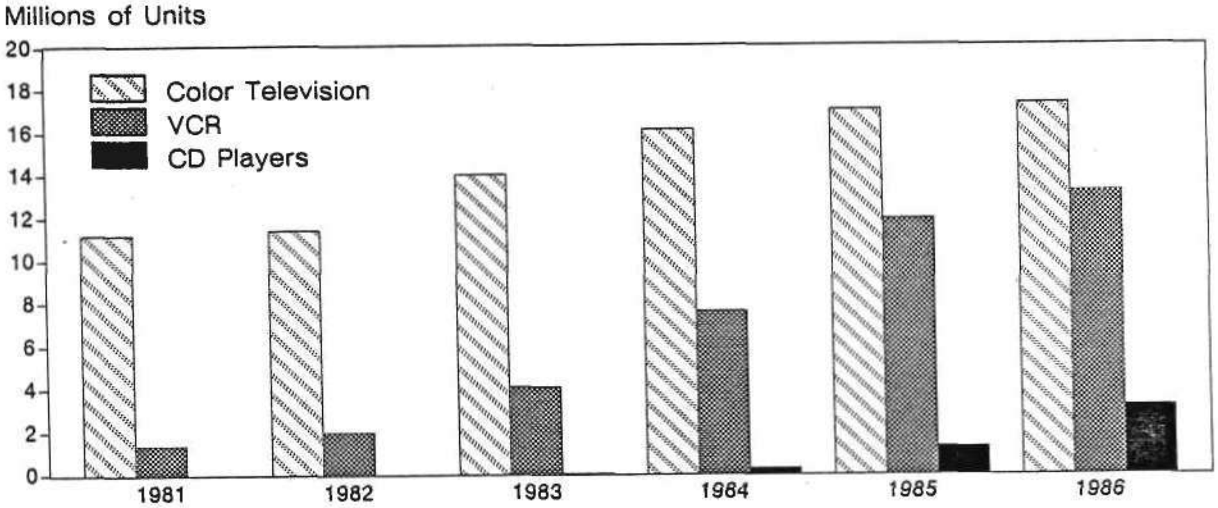
Source: Dataquest
December 1986

While growth of color television sales has slowed, the growth of VCR and CD sales has been exceedingly rapid. U.S. consumption of all three products is shown in Figure 1. Despite the low growth rate of color televisions, these products show a combined CAGR of 21 percent.

The growth potential for new entries into the consumer market is dramatic. VCRs and CD players are relatively new products and exhibit the rapid growth typical of the early stages of consumer product life cycles. In 1981, U.S. VCR sales to dealers were 1.4 million units. Sales reached 11.9 million units in 1985, and sales for 1986 are forecast at 13.2 million units, for a CAGR of 56.6 percent over the five-year period.

Figure 1

U.S. VCR, TV, AND CD PLAYER CONSUMPTION



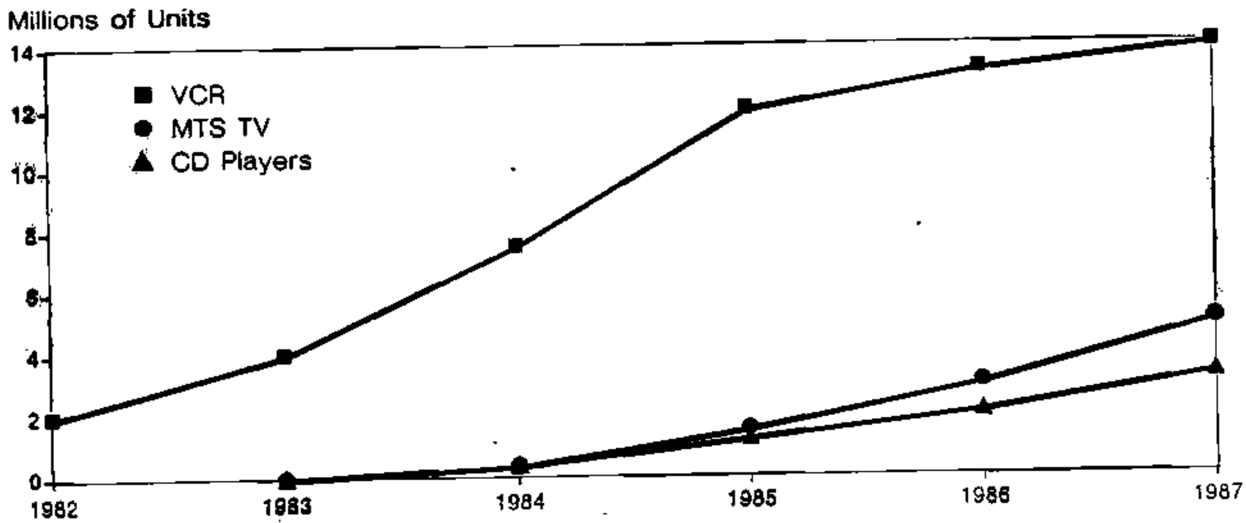
Source: Dataquest
December 1986

CD player consumption illustrates just how steep the growth curve can be in the first five years after product introduction. CD players entered the U.S. market in 1983. By 1985, consumption had risen to 1.3 million units. Consumption is forecast to reach 2.2 million units in 1986, for a CAGR of 277 percent over the period.

Rapid growth early in the life cycle of a new product, such as VCRs, or products enhanced with new technology, such as color televisions with multichannel television stereo sound (MTS), is typical of consumer products. The growth rates of VCRs, CD players, and MTS color televisions are compared in Figure 2. The rapid growth characteristic of VCRs in the early 1980s is being followed by MTS televisions and CD players. Furthermore, in light of the low estimated household penetration of these products, stable overall economic growth should ensure a maintenance of rapid growth in these products over the next five years.

Figure 2

NEW CONSUMER PRODUCTS AND TECHNOLOGY
GROWTH RATES



Source: Dataquest
December 1986

Cost Pressure

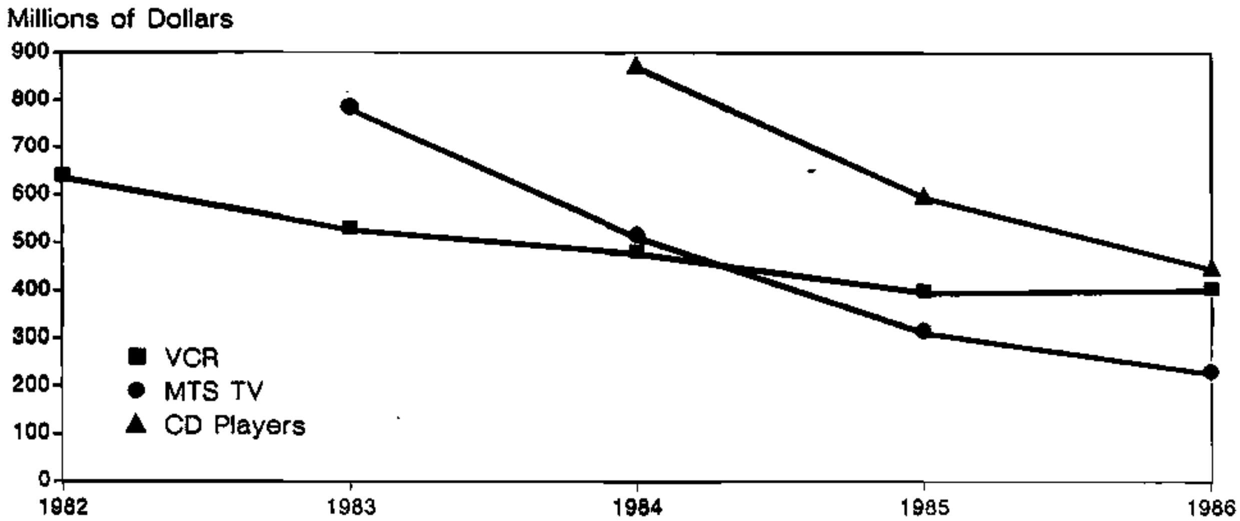
For the major consumer product areas, price is perhaps the single most significant factor affecting success in the marketplace. The electronic products sold to the consumer are generally lower margin than those in the other five application market segments. As a consequence, profitability is dependent on high unit volume sales and stringent management of manufacturing cost.

As unit shipments rise and competition increases, average selling prices (ASPs) drop. Much of the drop in selling prices is accommodated through the economies of scale in high-volume electronics manufacturing. ASPs tend to level as manufacturers pare costs to a minimum and the competitive market settles out. The drop in ASPs of VCRs, CD players, and MTS color televisions is illustrated in Figure 3.

While unit consumption increased dramatically in all three products, CD player ASPs declined by 33 percent, MTS color television ASPs declined by 28 percent, and VCR ASPs declined by 11 percent. VCR prices reached a stable level in 1986, while CD players and MTS televisions still exhibit rapidly falling ASPs.

Figure 3

COMPARISON OF VCR, CD PLAYER, AND MTS TELEVISION ASPs (1982-1986)



Source: Dataquest
December 1986

Much of the pressure for cost control in consumer products affects manufacturing. Because of the economies of high-volume manufacturing, cost falls as unit production increases. Further, the evolution of electronics and manufacturing technology continuously provide opportunities for product enhancement and cost reduction.

Because of the importance of product design in determining manufacturing cost, the emphasis on cost control in consumer products results in highly tailored products. Electronic equipment developed for markets other than consumer tends to have more design flexibility, and can focus on value. Designers of 16-bit PCs can, for example, build a part for future applications, or one that may be underused at the outset, because of the perceived value of future flexibility.

Rigid cost pressure tends to limit extraneous hardware and software in consumer products. Consumer electronic product lifetimes are short, and future flexibility is provided by new generations of equipment.

NORTH AMERICAN CONSUMER MARKETS

Equipment Production

Estimates of North American electronic equipment production are presented behind the Electronic Equipment Forecast tab of this notebook. Tables 3 and 4 recap the consumer electronic market data. As shown in Table 3, consumer electronic equipment is estimated at 17,012 million in 1986 and is forecast to grow at a CAGR of 6.2 percent to reach $21,618 million in 1990.

Table 3

ESTIMATED NORTH AMERICAN CONSUMER EQUIPMENT
(Millions of Dollars)

	1985	1986	1990	1986-1990 CAGR
Audio	$ 255	$ 283	$ 402	9.2%
Video	4,618	4,656	6,254	7.7%
Personal Electronics	600	641	801	5.7%
Appliances	9,792	10,373	12,891	5.6%
Other	976	1,059	1,270	4.8%
Total	$16,241	$17,012	$21,618	6.2%

Source: Dataquest
December 1986

Table 4

NORTH AMERICAN CONSUMER SEMICONDUCTOR
CONSUMPTION FORECAST
(Millions of Dollars)

	1985	1990	CAGR
Audio	$ 22	$ 51	18.9%
Video	417	821	14.5%
Personal Electronics	29	69	19.3%
Appliances	207	331	9.9%
Other	24	38	9.2%
Total	$699	$1,310	13.4%

Source: Dataquest
December 1986

Semiconductor Consumption

Our estimates of North American semiconductor consumption, based on I/O ratio analysis of the consumer electronic equipment market, is shown in Table 4. While consumer electronic production is expected to grow at a CAGR of 6.2 percent, consumption of semiconductors for consumer electronic equipment is forecast to grow at a CAGR of 13.4 percent, from $698.3 million in 1985 to $1,310.1 million in 1990. The higher rate of growth projected for consumer semiconductors is a function of a gradual rise in I/O ratios as functionality and levels of integration are increased.

The growth rate for consumer semiconductor consumption as a whole is exceeded by audio, video, and personal electronics products because the potential for expanded functionality through IC technology is greatest in these products. In contrast, semiconductor consumption by appliance manufacturers is forecast to grow at a slower rate than consumer products as a whole, 9.9 percent CAGR, because opportunities for increasing the level of integration are more limited.

Rising levels of integration and increasing semiconductor content are driven by the need for consumer products to continuously offer more features and functionality for equivalent or lower product cost.

Regional Consumption Comparison

Consumer electronic equipment accounted for an estimated $7 billion of worldwide semiconductor consumption in 1985. We forecast consumer applications to account for $13.8 billion worldwide in 1990. While consumer semiconductors will grow at an estimated CAGR of 14 percent from 1985 to 1990, we believe its share of total worldwide consumption will decline from 28.4 percent in 1985 to 26.6 percent in 1990.

A detailed breakdown of consumer semiconductor consumption by region is given in Table 5. Semiconductors for use in consumer products account for a small percentage of U.S. consumption in relation to other major consumers. Dataquest estimates that 7 percent of U.S. consumption went to consumer applications in 1985 in comparison with 46.3 percent of Japanese consumption. At 76 percent of total consumption, rest-of-world (ROW) countries use the highest proportion of their consumption in consumer applications.

Table 5

REGIONAL CONSUMER SEMICONDUCTOR CONSUMPTION FORECAST (Billions of Dollars)

	1985 Consumption		Consumer Percent	1990 Consumption		Consumer Percent
	Total	Consumer	of Total	Total	Consumer	of Total
United States	$ 9.6	$0.7	7.3%	$15.6	$ 1.1	7.0%
Japan	8.6	4.0	46.3%	20.7	7.0	33.8%
Western Europe	4.6	0.9	19.6%	9.3	1.7	18.3%
Rest of World	1.9	1.4	76.0%	6.1	4.0	65.6%
Total	$24.7	$7.0	28.4%	$51.8	$13.8	26.6%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
December 1986

Trends in Consumer Electronics

Market Characteristics

As mentioned, the consumer semiconductor market is one in which cost pressures are much stronger and volumes higher than generally found in other application market segments. Consumer electronic products are highly tailored and focused on current value in relation to other products. PCs, for example, may be designed with parts that will accommodate additional functionality down the line. This is possible because there is value in future flexibility. An example is the IBM PC AT. Consumer products, on the other hand, are tailored to provide specific functions at the highest possible level of reliability, all at the lowest possible cost.

Like the end equipment, consumer semiconductor devices are usually tailored for a specific product. The investment required to develop a custom design or to fine tune a standard part for use in a consumer product can be justified by the cost economies of high-volume production. In the case of standard products, an example would be modification of a microcontroller design in order to accommodate more I/O than is typical.

Because of the ultimate cost advantages of developing specific circuits for cost-sensitive, high-volume electronic products, consumer equipment manufacturers use a greater number of ASICs in proportion to total semiconductor use than other application market segments.

The continuous drive for higher functionality and lower cost in consumer products is achieved in great part through semiconductor technology. Higher levels of integration serve to make end products smaller, thus lowering cost while providing greater functionality. Also, as a result of cost pressure, high-production volumes, and reliability requirements, semiconductor devices used in consumer products usually do not represent the leading edge of wafer fabrication technology or density.

U.S. CONSUMER EQUIPMENT MANUFACTURERS

Overview

The major shareholders in the worldwide consumer electronic equipment market consist of less than two dozen companies. Consumer product manufacturers who compete in the international consumer marketplace must maintain a relatively narrow profit margin while manipulating tremendous production volume and supporting an international sales and distribution organization.

The total revenue and electronic equipment revenue of seven major U.S. consumer product manufacturers are shown in Table 6. Total revenue for this group was estimated at $56.8 billion in 1985. All companies have electronic equipment revenue of more than $1 billion. Electronic equipment production accounts for more than 50 percent of total revenue for the majority of the companies in this group. General Electric and RCA, with the highest total revenue at $29 billion and $10 billion, respectively, have the lowest percentages of electronic equipment revenue.

Table 6

CONSUMER PRODUCT MANUFACTURERS
1985 REVENUE BY BUSINESS AREA
(Millions of Dollars)

	Total Revenue	Electronic Equipment Revenue	Electronic Equipment Percent of Total
General Electric	$28,936	$10,609	36.7%
Litton	4,591	2,767	60.3%
Raytheon	6,409	3,512	54.8%
RCA	9,992	3,878	28.8%
Singer	2,416	1,496	61.9%
Tandy	2,841	2,316	81.5%
Zenith	1,624	1,467	90.3%
Total	$56,809	$26,045	45.8%

Source: Dataquest
December 1986

Table 7 shows consumer electronic equipment as a percent of electronic equipment revenue. At $9.4 billion, consumer electronics accounts for 35.4 percent of electronic equipment revenue for the seven companies.

Table 7

CONSUMER PRODUCT MANUFACTURERS
1985 ELECTRONIC EQUIPMENT REVENUE
(Millions of Dollars)

		Consumer	
	Total Revenue	1985 Revenue	Percent of Total
General Electric	$10,609	$4,688	44.2%
Litton	2,767	240	8.7%
Raytheon	3,512	157	4.5%
RCA	3,878	1,850	47.7%
Singer	1,496	90	6.0%
Tandy	2,316	1,316	46.3%
Zenith	1,467	1,062	72.4%
Total	$26,045	$9,403	35.4%

Source: Dataquest
December 1986

There are two groups of consumer product manufacturers, and their semiconductor buying patterns can be very different. The first group, represented by the companies mentioned above, accounts for more than half the U.S. consumer equipment production. These companies participate in a range of consumer electronics markets, including the major areas of television and VCRs. Rather than producing end equipment themselves, these companies often purchase equipment manufactured to their specifications by Far Eastern suppliers and sell it under their own label. General Electric, for example, does not manufacture the consumer electronics products sold under its label.

While these companies may not manufacture the products themselves, they often have control of design and parts specifications and, therefore, can have an impact on the associated semiconductor purchases. Other companies, including the manufacturers of large appliances, manufacture products onshore from subassemblies they purchase from a large group of second-tier suppliers. The subassemblies include control units for microwaves and other major household appliances. The second tier suppliers include both U.S.- and offshore-based companies, and the subassembly business is significant. One U.S. supplier of subassemblies for appliances reported revenue in excess of $300 million in 1984.

The second group of U.S. consumer products manufacturers is made up of a large number of companies supplying products in smaller overall markets, such as microwave ovens and other appliances. Although these markets may be considered small in comparison to the volume in the television and VCR markets, they represent substantial revenue to companies whose sales are on the order of millions rather than billions of dollars. For 1985, the security system equipment market is estimated at $1.4 billion in the United States. The home control market is another example. A relatively new product, home control systems, such as those developed by BSR, represented an $11 million market in 1985. Furthermore, 90 percent of this revenue is shared among three companies. These companies typically have direct control of semiconductor purchases for their products and should not be overlooked as major players in the consumer electronics arena.

Purchasing

Dataquest surveyed the 200 largest U.S. electronic equipment manufacturers as indexed by Electronic Business magazine. These companies have more than 500 semiconductor procurement locations and represent a diverse group of buyers. Dataquest believes the surveyed group represents at least 55 percent of the total dollars invested in ICs in the North American market.

Table 8 shows the mix of semiconductor procurement by each application market segment. U.S. manufacturers of consumer equipment report a lower percentage of ICs and a higher percentage of discretes than most other application market segments. ICs represent 71.3 percent of total consumer semiconductor purchases, while other application market segments (with the exception of industrial) report ICs as 75 to 83 percent of purchases. Consumer procurement of discretes as a percentage of the total is reported as 24.9 percent, while the other four segments report 12 to 20 percent discrete procurement.

Procurement is broken down by product area in Table 9. For consumer procurement, micros, ASICs, and linear circuits represent larger percentages of the total than they do for any other application segment. At 23 percent, the consumer procurement figure for micro devices even exceeds the data processing figure for micro devices, 18 percent.

While consumer procurement reports the lowest percentage of standard logic, it has the highest relative use of ASICs, at 14 percent of total IC procurement. ASICs represent one of the areas of rapid growth in consumer circuit consumption. Dataquest estimates that U.S. consumption of ASICs for consumer applications will grow at a CAGR of 39.4 percent from 1985 to 1990, while total U.S. ASIC consumption is expected to grow at 23.5 percent over the same period.

Table 8

1985 SEMICONDUCTOR PROCUREMENT BY APPLICATION MARKET
(Percent of Total Dollars)

	IC	Discrete	Opto	Total
Data Processing	83.0%	12.5%	4.5%	100%
Communications	75.6%	20.3%	4.1%	100%
Industrial	68.4%	24.7%	6.9%	100%
Consumer	71.3%	24.9%	3.8%	100%
Military	78.8%	17.0%	4.2%	100%
Transportation	74.6%	17.5%	7.9%	100%

Source: Dataquest
December 1986

Table 9

1985 SEMICONDUCTOR PROCUREMENT
IC TECHNOLOGY MIX
(Percent of Total IC)

	Memory	Micro	Standard Logic	ASIC	Linear	Total
Data Processing	35%	18%	26%	9%	12%	100%
Communications	39%	9%	35%	8%	9%	100%
Industrial	25%	16%	30%	10%	19%	100%
Consumer	23%	23%	18%	14%	22%	100%
Military	21%	8%	43%	9%	19%	100%
Transportation*	-	-	-	-	-	-

*Sample limited. Detail unavailable at this product level.

Source: Dataquest
December 1986

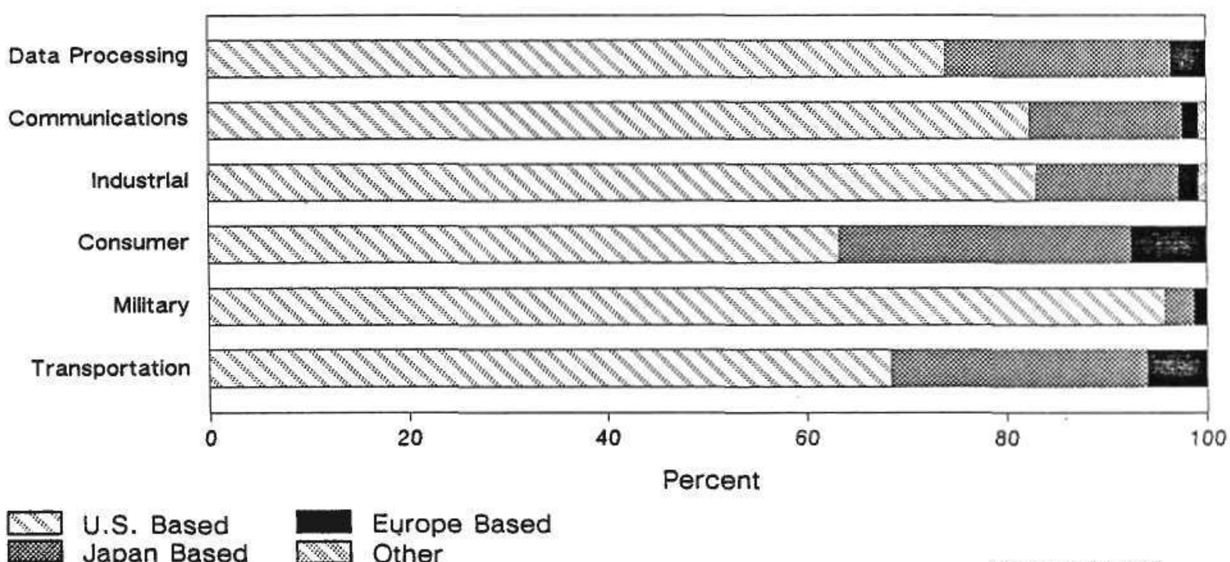
Regional Supplier Base

The regional base of suppliers, as reported by survey respondents, is shown in Figure 4. Consumer equipment manufacturers report a lower percentage of purchases from U.S.-based suppliers than any of the other five application market segments.

The Far East is the major producer of consumer electronic products worldwide, as well as of semiconductors used in consumer equipment. As shown in Figure 5, U.S. consumer equipment respondents reported that 45.8 percent of their semiconductor purchases are made offshore. This is a significantly larger percentage than that reported for other application market segments.

Figure 4

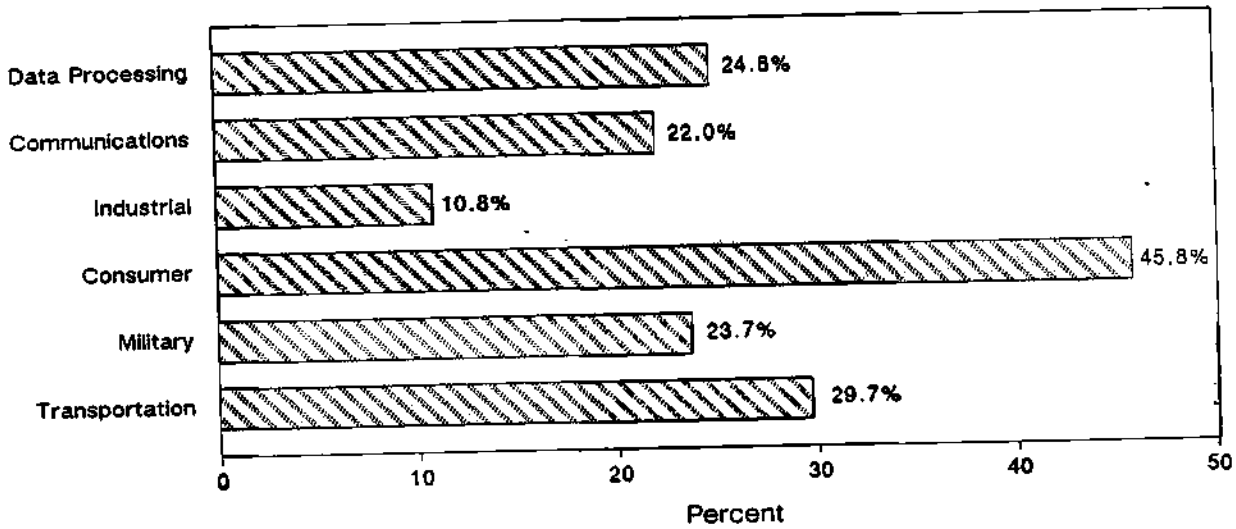
1985 SEMICONDUCTOR PROCUREMENT BY REGIONAL SUPPLIER BASE



Source: Dataquest
December 1986

Figure 5

SEMICONDUCTORS PURCHASED OFFSHORE FOR U.S.-BASED EQUIPMENT PRODUCTION



Source: Dataquest
December 1986

The significance of low-cost, high-volume production to the consumer marketplace is evident in the survey results. While U.S. consumer equipment manufacturers report that 46 percent of total purchases are made offshore, they have also reported that 63.3 percent of their total purchases are from U.S.-based suppliers. Japan-based suppliers accounted for 29 percent of purchases, and Europe-based manufacturers accounted for 7.6 percent, but the total from these two sources still falls short of the 46 percent categorized as offshore purchases. The difference lies in purchases from U.S. manufacturers with offshore production facilities. Because of the cost pressure active in the consumer product arena, U.S. semiconductor companies manufacture high-volume, low-cost consumer IC products offshore in order to maintain cost competitiveness with Far East-based suppliers and equipment manufacturers.

CONSUMER VIDEO

Television

U.S. television sales to dealers and television ASPs are shown in Tables 10 and 11. Total unit sales have increased at an estimated 4.5 percent CAGR from 1981 to 1986. Color television unit sales have grown at 9.1 percent CAGR from 11.2 million units in 1981 to an estimated 17.3 million units in 1986, while sales of black-and-white televisions are declining by 8.8 percent over the same period. While unit television sales do not show dramatic growth, semiconductor use continues to increase as features are added and customer acceptance rises for paying higher prices for products with improved reliability or features.

Table 10

U.S. TELEVISION SALES TO DEALERS
(Millions of Units)

	1981	1982	1983	1984	1985	1986	CAGR
Color TV Total	11.16	11.37	13.99	16.08	17.00	17.30	9.2%
MTS Color TV	0	0	0	0.24	1.50	3.00	253.6%
Black-and-White TV	5.54	5.77	5.70	4.91	3.75	3.50	(8.8%)
Total*	16.70	17.14	19.69	20.99	20.75	20.80	4.5%

*MTS Color TV sales included in Color TV Total sales.

Source: Dataquest
December 1986

Table 11
U.S. TELEVISION ASP

	1981	1982	1983	1984	1985	1986	CAGR
Color TV Total*	$390	$374	$358	$343	$327	$325	(3.6%)
MTS Color TV	0	0	0	$865	$600	$450	(27.9%)
Black-and-White TV	$ 91	$ 88	$ 82	$ 85	$ 82	$ 80	(2.5%)

*MTS Color TV included in Color TV ASP.

Source: Dataquest
December 1986

Features include large 20- and 27-inch screens, remote control, video compatibility, and MTS. Sales of sets with remote control accounted for more than 50 percent of the total sales mix for the first time in 1985, and remote control is expected to reach 60 percent of the total sales mix in 1986. Sales of large-screen televisions (21 inches and over) accounted for 29 percent of sales, up from 25 percent in 1984. More than 200 U.S. television stations have added MTS broadcast capability, and EIA estimates that 75 percent of the viewing audience now has access to MTS programming. As shown in Table 10, sales of MTS color televisions have grown at a CAGR of more than 250 percent since their introduction in 1984.

High-Definition Television

High-definition television (HDTV) yields a picture with more than 1,100 scanning lines. At twice the number of scanning lines specified by the major color television standards in the world, HDTV offers quality rivaling that of 35mm film.

Digital Television

Digital television sets convert analog television signals into digital form, electronically enhance the signal, and then convert it back to analog for a picture that is far superior to the one found on a conventional set. Digital television has twice the scanning lines of conventional analog sets, and the digital signal manipulation will allow split screen viewing of more than one program, freeze-frame, and zooming in on specified elements of the screen.

Trends in Consumer Electronics

Worldwide production of digital televisions is estimated at several hundred thousand sets. While 1985 and 1986 were hailed as the years of acceptance, manufacturers are anticipating quantity production to become a reality in 1987. The market for digital television has been the most active in Asia and Germany, where it is estimated some 10,000 are manufactured each week. Standard Elektrik Lorenz (SEL), part of ITT's Consumer Products Group, was first to produce digital televisions and manufactured an estimated 150,000 units between its initial product introduction in October 1983 and the end of 1985. Matsushita, Sharp, Sony, and Toshiba are making digital televisions in volume, and Samsung of Korea is ramping up production.

Acceptance in the United States has been slow. Toshiba was the first company to bring a digital television to the U.S. market. The price premium for digital television is still high, as much as $300 more per set than conventional color televisions, and the market has not yet reached a stage where a significant proportion of consumers in the United States are willing to pay the difference.

Digital televisions use five to eight ICs in place of several hundred analog devices. The chips are more sophisticated, highly integrated, and perform exponentially more functions on the incoming television signal than the semiconductor complement of conventional analog color television. The higher level of integration eliminates more than 700 solder connections, reducing overall assembly costs and offering reliability improvements on the order of 20 to 30 percent.

ITT produced the first commercially available digital television set that provides processing for picture, sound, and teletext. ITT's Digit 2000 IC system became available in late 1983, and the company lists 20 customers who have either begun production or are currently testing the chip set. Intermetall, ITT's semiconductor operation in Freiburg, West Germany, continues to expand and improve the product. The ITT Digit 2000 system is compatible with all standards, NTSC (United States and Japan), PAL (Europe), and SECAM (France), and incorporates the following functional units:

- Central control unit
- Deflection processor unit
- Video codec unit
- Video processor unit
- Teletext processor

- Audio convertor
- Audio processor
- 1,024-bit EEPROM
- Tuner interface
- Clock generator
- 64K RAM

While ITT is still the major producer of digital televisions, other companies have begun to manufacture some of the digital television circuits. Sony, for example, incorporates some of its own chips in its digital models, although it still depends on ITT for the master chip. Matsushita and Philips have announced plans for joint development of special chips for digital televisions.

CONSUMER AUDIO

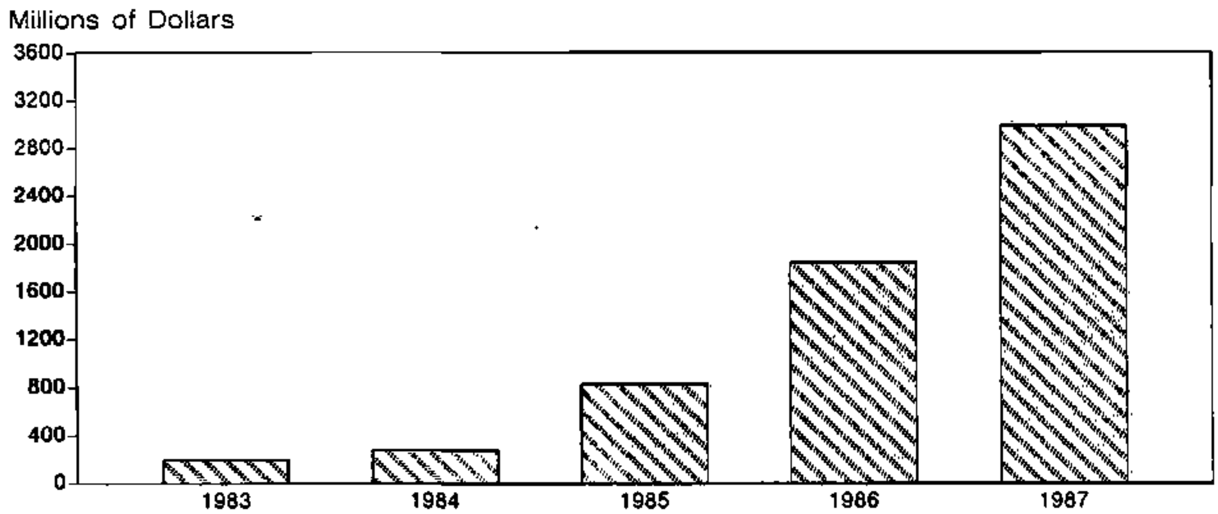
Compact Disk Players

Optical storage has long been hailed as the technology of the future for numerous applications. Finally one product, the CD player, is gaining mass appeal with consumers. CD players are becoming the darling of the audio world, providing a boon to the consumer electronics market and paving the way for other optoelectronic products.

As indicated in Figure 6, Dataquest believes that the 1986 worldwide CD player market will reach $1,847 million, a 123 percent increase over 1985. We estimate that this represented approximately a $323 million semiconductor opportunity for 1986 alone.

Figure 6

ESTIMATED WORLDWIDE COMPACT DISK PLAYER PRODUCTION



Source: Dataquest
December 1986

Background

Developed jointly by Philips, of the Netherlands, and Sony Corporation, of Japan, CD players were the first commercially available digital audio systems offering far greater sound reproduction than conventional analog systems. The first CD systems appeared on Japan's domestic market in October 1982. CD players were introduced to Europe in February 1983 and to North America later in the same year. CD players quickly caught the consumer's attention because of their compact size, easy handling, and superior sound reproduction. Initial sales were slow, however, because of the CD player's high retail price in comparison with that of its analog counterpart.

Compact Disk Player Production

CD player production is dominated by Japanese companies, with the exception of Philips and a few smaller European manufacturers. Table 12 lists the major manufacturers, which we believe account for more than 90 percent of the total CD player production.

Table 12

MAJOR COMPACT DISK PLAYER MANUFACTURERS

Japanese Manufacturers	European Manufacturers
Akai	Akai*
Hitachi	Grundig
JVC	Matsushita*
Matsushita (Panasonic, Technics, Quasar)	Mission
NEC	Philips (Marantz)
Nippon Columbia	Pioneer*
Nippon Gakki (Yamaha)	Revox
Pioneer	Sony*
Sanyo (Fisher)	Toshiba*
Sharp	
Sony	
Toshiba	
Trio-Kenwood	

*Planned production

Source: Dataquest
December 1986

Japanese companies are the most aggressive in terms of increasing production capacity. Sony, the acknowledged leader, boosted capacity 40 percent to 140,000 units per month by the end of 1985. Others, like Matsushita and Sanyo, planned to double their capacity to 100,000 units per month. As shown in Table 13, CD player production is expected to reach 10.5 million units this year, with nearly 84 percent originating in Japan.

Table 13

ESTIMATED PRODUCTION OF COMPACT DISK PLAYERS

	Actual			Forecast	
	1983	1984	1985	1986	1987
Japan					
Volume (K units)	290	769	4,133	8,800	13,650
Production Value ($M)	$138	$185	$634	$1,347	$2,095
Europe					
Volume (K units)	80	210	500	1,725	3,820
Production Value ($M)	$50	$95	$195	$500	$898

Source: Ministry of International Trade & Industry
Dataquest
December 1986

Because of the large demand for CD players, and to avoid the heavy import tariffs (19 percent) placed on these goods going into the European market, Japanese manufacturers are setting up production facilities in Europe. Sony, for example, in a joint venture with CBS, of the United States, has announced plans to manufacture in Europe. Other international ventures include Philips' manufacturing of CD players in Poland and China, JVC's joint agreement in China, and Sanyo's opening of a production plant in Korea.

No major manufacturers are producing CD players in the United States, although software (or disk) production activity is very high. Du Pont and Philips announced a joint venture in North Carolina, joining Sony/CBS (in Indiana) and 3M (in Wisconsin) in disk production.

Market Trends

Three applications--home, portable, and car audio--have emerged for CD players, each with varied market dynamics. In the home environment, unlike VCRs, the audio market is relatively mature. We believe that, today, nearly 75 percent of CD purchases are for replacement of existing (analog) systems. Portable models are rapidly gaining popularity, but with only a few product introductions so far, volumes are still lower than in the home market.

An exciting and potentially large market for CD players is the automobile industry. Despite some early skepticism concerning technical problems, such as heat and vibration (which can hinder CD player performance), many manufacturers are offering CD players as an option in their higher-priced automobiles. Japanese automobile makers expected to sell more than 100,000 cars with CD players in 1986.

With numerous car CD players on the market (Alpine, Hitachi, Kenwood, Pioneer, and Sony), CD players with AM/FM stereo should be a common option in 1987.

Semiconductor Content

Table 14 presents Dataquest's estimates of the component costs of a medium scale CD player. The component values, based on contract-volume prices, result in an input/output ratio (semiconductor value as a percentage of equipment ASP) of 17.5 percent 1985.

In an effort to reduce component costs and improve quality, new chips designed specifically for the CD player are now appearing on the market. Recent examples are an LSI chip YM-3805 introduced by Nippon Gakki, which combines the signal processing and servo circuits, and a Matsushita digital filter LSI chip MN 6618. Other developments include improved lasers, which are used to read the optical disk, an area in which costs will be further reduced.

Table 14

ESTIMATED SEMICONDUCTOR CONTENT OF A COMPACT DISK PLAYER

Components	Quantity	Cost
Integrated Circuits		
Standard Logic (SSI/MSI)	13	
Microcontroller (8-bit)	1	
D/A Converter (12-bit)	1	
Digital Filter	1	
Signal Conditioner	1	
Servo Control Unit	1	
Subtotal	18	$31.24
Optoelectronic		
Laser Diode	1	
Optical Sensor	1	
LED Lamp	1	
Subtotal	3	$22.32
Discrete Components	25	$ 3.75
Total	46	$57.31

$$\frac{\text{Semiconductor Value}}{\text{Retail Value}} = \frac{\$57.31}{\$327} = 0.175 = 17.5\%$$

Source: Dataquest
December 1986

CD Technology as a Catalyst

Consumer acceptance of CD players could help push the development of other optoelectronic products. CD-ROM technology is virtually the same as that found in audio CD players, with the exception of more stringent error correcting demands for data applications. Potential applications for CD technology include the following:

- Computer data storage
- Videodisks
- Publishing
- Road map directories in automobile dashboards
- Medical records
- Laser smart cards

The potential applications for CD technology represent numerous attractive markets, all of which could gain widespread use by the consumer, in part, because of the enthusiastic acceptance of CD players.

As more and more manufacturers expand CD capacity and output, we expect prices to continue to fall while profit margins remain thin. Cutting component cost will become necessary for survival, given the fierce competition in the CD player market.

Perhaps even more important is the advantage the Japanese manufacturers are gaining in optical technology. Because of the potential widespread use of CD-ROMs as data storage devices for computers and because of the shared technology with CD players, another large market is being captured by the Japanese even before it is widely recognized by the industry.

OTHER CONSUMER ELECTRONICS PRODUCTS

Security Alarm Systems

The North American security alarm system market is estimated at $4.5 billion in 1985 and is expected to increase 12 percent to reach $5.1 billion in 1986. As shown in Table 15, during the five-year period from 1983 to 1987, the market is expected to grow at a CAGR of 11.4 percent, from $3.7 billion to $5.7 billion in 1987.

The $4.5 billion 1985 market includes both commercial and residential systems. The commercial market is 50 percent saturated, a function of insurance requirements for businesses. A major area for expansion lies in the residential market, where saturation is at a low 8 percent. Manufacturers recognize the need to promote the product to the public to increase penetration. Home security market penetration is expected to increase as security manufacturers improve marketing techniques, including direct mail advertising, self-developed lead programs, and community awareness. Concentrated investment in product promotion, including the installation of security systems in new construction, is expected to attract increasing amounts of residential business.

Semiconductor Content

Much of the dollar value in the security system market is related to installation and ongoing monitoring services. Table 15 shows the estimated dollar value of equipment at $1.1 billion in 1984. According to a number of manufacturers, more than 90 percent of all systems contain some form of semiconductor technology. Because of the greater market demand for products with the highest level of intelligence, security alarm systems have a relatively high semiconductor content that can approach 60 percent of the cost of the system.

Table 15

NORTH AMERICAN SECURITY ALARM SYSTEM GROWTH
1983 to 1987
(Billions of Dollars)

	1983	1984	1985	1986	1987	CAGR 1983-1987
All Security	$3.7	$4.1	$4.5	$5.1	$5.7	11.4%
Equipment	$1.0	$1.1	$1.2	$1.4	$1.5	10.7%

Source: Security Distribution and Marketing Magazine
Dataquest
December 1986

Security systems vary from something as simple as a motion detector to a variety of complex multilocation monitoring devices. Dataquest estimates that in a typical residential security alarm system costing the consumer $2,000, $400 represents actual hardware. For this type of system, the semiconductor content may be 20 percent of the hardware cost. Devices include 8-bit microprocessors, microcontrollers, RAM, ROM, and EEPROM memory, logic, programmable logic, and discretes. Eight-bit microprocessors are used extensively in the central control units because most systems require the capability to perform a large number of functions at high speeds.

The typical residential alarm system described above consists of a central control panel and a number of remote monitoring locations. The on-site system is connected to a central office, where computers and personnel monitor all the systems in a given area. The central control panel of the security system contains an 8-bit microprocessor to run a real-time clock, monitor up to 134 points of protection, and display statuses alphanumerically 100 times per second. Each remote arm of the system contains a microcontroller, RAM, ROM, or EPROM, standard or programmable logic, and a varying but usually high number of discretes. Memory, logic, and discretes are used in varying arrangements and types, according to the requirements of the specific system and its site.

Semiconductor Suppliers

Although most alarm manufacturers report that U.S. and foreign purchases are evenly split at present, new chips are coming in an increasingly large supply from Far Eastern suppliers. This change is attributed to lower prices and higher reliability. While one manufacturer cited use of a large portion of custom-designed chips from U.S. suppliers, all manufacturers agreed that overall they are increasing purchases from foreign suppliers because system suppliers work to maintain competitiveness by keeping costs down while offering the most advanced technology.

Technological Trends

Technological trends in security alarm systems include the use of digital communicators, derived channels, and short-range wireless equipment. Digital communicators are the most significant of these. In a 1986 survey by Security Distribution and Marketing Magazine, 34 percent of alarm dealers surveyed noted that digital will be the leading area of growth in security monitoring over the next five years. There is also a focus on reducing product size through surface mounting techniques. Relays and switches are out, and manufacturers are moving toward more intelligent systems with higher levels of integration. Customizable features such as user codes placed in EPROM at installation are becoming the rule for residential systems.

APPLIANCES

The North American large appliance industry is a mature marketplace. The sales that occur in most categories are for replacement appliances or for purchases tied to new housing starts. Typically, as long as the economy remains stable, so do the sales of new appliances.

The factory shipments of major home appliances, as shown in Table 16, have risen steadily but unremarkably in most cases. Electric ranges, automatic washers and dryers, disposers, dishwashers, refrigerators, and dehumidifiers reflect a steady replacement market. Trash compactors, freezers, and room air conditioners have shown a decrease in their CAGR. The only large appliance with significantly rapid growth is the microwave oven. Microwave ovens have not yet saturated the market and are in demand both as a desirable amenity in new construction and as an addition to the appliances in existing homes.

Table 16

MAJOR HOME APPLIANCE FACTORY SHIPMENTS
(Millions of Units)

	1981	1982	1983	1984	1985	CAGR 1981-1985
All Major Appliances	30.48	26.68	32.47	39.44	41.80	8.2%
Electric Ranges	2.33	2.04	2.75	3.07	3.14	7.7%
Microwave Ovens	4.42	4.07	5.93	9.13	10.88	25.3%
Automatic Washers	4.37	4.02	4.62	5.05	5.28	4.8%
Automatic Dryers	2.98	2.73	3.29	3.68	3.91	7.0%
Disposers	3.18	2.78	3.54	4.08	4.11	6.6%
Dishwashers	2.48	2.17	3.12	3.49	3.58	9.6%
Compactors	0.19	0.15	0.16	0.18	0.18	(1.3%)
Refrigerators	4.94	4.36	5.48	5.99	6.08	5.3%
Freezers	1.61	1.34	1.34	1.28	1.24	(6.3%)
Room Air Conditioners	3.69	2.76	2.00	3.10	3.02	(4.9%)
Dehumidifiers	0.54	0.44	0.44	0.59	0.59	2.2%

Note: Domestic plus import

Source: AHAM

Microwave Ovens

All microwave ovens contain some semiconductors. There is a wide range in number and type of semiconductors, depending on the complexity of the features in a particular unit. A representative, midrange microwave would contain a microcontroller, memory, comparator logic, transceivers, and a large number of resistors, diodes, and capacitors. Semiconductor parts account for approximately 25 to 40 percent of the cost of materials used in a microwave oven.

As in the case of most large appliances, North American microwave manufacturers such as Amana and Litton assemble the products onshore largely from subassemblies that they purchase from second-tier suppliers. They also purchase their own semiconductor devices directly. Second-tier suppliers of control units and power sources include U.S.- and non-U.S.-based firms. One major U.S. supplier of subassemblies for the appliance market reported sales in excess of $300 million for 1985.

Semiconductor Suppliers

Across the range of large appliance semiconductor purchases, the split is even between foreign and U.S. suppliers. Foreign purchases are much higher for microwave ovens, reaching as much as 90 percent. Lower prices and high quality continue to be the reasons for foreign purchases of circuits for consumer products. The high production volumes for consumer products allows customization of circuits, and the parts best suited to the consumer appliances, in particular microwave ovens, are often available at the lowest price from foreign suppliers.

Semiconductor Market

Despite the availability of semiconductor technology, there is agreement among large appliance manufacturers that there is little consumer demand for the increased capabilities in large appliances that semiconductors supply. The most frequently cited reason for this is that the familiar appliances are required to perform only the functions that they have always performed. A refrigerator, for example, is expected only to keep food cold.

Manufacturers agree that there is always a small segment of the consumer population interested in large appliances with advanced features. While manufacturers offer top-of-the-line items with intelligent features, however, these appliances may represent only the top five percent of the units shipped. Most consumers want the lowest price on a traditional product. When an appliance is replaced, it is often replaced with a unit offering basically the same capabilities as offered by the original. The consumer is receptive to advanced technology if the price is competitive, but will not pay more to receive it. At present, there is a price premium on products with technology-enhanced features.

Appliance manufacturers have little interest in adding semiconductor technology to their products in the face of consumer disinterest. Most manufacturers agree that until semiconductors achieve parity with electromechanical parts, appliances with intelligent features will remain a small, expensive, top-of-the-line percentage of total sales.

Appliance manufacturers also agree that for their purposes, semiconductor technology is still expensive. Adding semiconductors means major changes in existing assembly lines that are not cost-effective in the face of low demand.

Technological Trends

Technological trends in large appliances involve increased use of semiconductors to give the consumer a wider variety of functional capabilities, such as advising of adverse conditions that exist within the unit. There is discussion of possible legislation in Europe that would require freezers to be able to inform the consumer if there has been a power outage for any period of time that would cause food to thaw and refreeze without the consumer being aware of it. Legislation is also being discussed to provide energy-saving features to reduce energy use during times of peak load throughout the community. Any legislation of this kind would promote increased use of semiconductors in appliances in which little or no use of semiconductors currently exists.

Overall, there is surprisingly low interest in the use of available semiconductor technology in large appliances. Manufacturers note that even in microwaves, the most technologically advanced area of large appliances, consumers are not asking for more advanced technology than is currently available. As energy saving becomes increasingly important and the cost of semiconductors continues to fall, however, the use of semiconductors in applications will gradually increase.

Trends in Japanese Semiconductor Application Markets

INTRODUCTION

This section presents an overview of the Japanese electronic equipment industry and the presence of semiconductors within the different equipment segments. As originally proposed, SAM will provide in-depth analysis of North America, with overview information for Western Europe and Japan. The detail for Western Europe and Japan will be left to their respective services, namely the European Semiconductor Industry Service (ESIS) and the Japanese Semiconductor Industry Service (JSIS).

The methodology for compiling these data, as well as the organizational structure, is similar to that used in the North American section. The following areas constitute the scope of this section:

- Overview
- Major Japanese electronic companies
- Electronic equipment overview tables and semiconductor consumption overview tables
- Fast-growing equipment markets

The vast majority of the data used has been collected by Dataquest's Japanese Semiconductor Industry Service, located in Tokyo. Because the information was compiled in Japan, a few important differences must be kept in mind when comparing data from Japan and North America:

- Japanese statistics
- Exchange rate fluctuations
- Absence of Japanese military market

Japanese Statistics

Japanese production statistics use factory value, as opposed to if-sold (retail) value when reporting equipment revenue figures. Hence, distribution and other costs associated with the final product are not included. Therefore, the input/output ratio for equipment manufactured in Japan appears substantially larger than the ratio for North American-produced electronic equipment. All figures for semiconductor consumption will be reconciled with the regional forecasts published by Dataquest's Semiconductor Industry Service (SIS).

The most accurate and detailed data available are reflected in Japanese production statistics, which do not completely concur with our segmentation or definitions. However, to truly provide a worldwide perspective, it is best to consistently use the SAM segmentation across all regions of the world. The original SAM classifications were arrived at after lengthy negotiation and are structured so that alternative reporting schemes can readily be converted into our segmentation.

Exchange Rate Fluctuations

Exchange rate fluctuations can distort a particular growth rate, in dollars, from one year to the next. Thus, the data are presented in both dollars and yen. Unless otherwise stated, the dollar figures were derived using the exchange rate as given in Table 1.

Table 1

ANNUAL JAPANESE YEN TO U.S. DOLLAR EXCHANGE RATE
(Yen per Dollar)

Year	Yen per Dollar
1970	358
1971	343
1972	302
1973	269
1974	292
1975	297
1976	296
1977	269
1978	210
1979	219
1980	227
1981	221
1982	248
1983	235
1984	237
1985	238
1986	167
1987	154*

*Assumed at this rate for 1986-1990.

Source: Wall Street Journal
International Monetary Fund
Dataquest
July 1987

Trends in Japanese Semiconductor Application Markets

No Significant Japanese Military Market

For consistency and ease of comparison, we have used the same equipment segmentation for both the Japanese and North American sections. However, because there is no significant Japanese military market, the military line item has been deleted from the overview tables. Also, two segments--commercial aviation (industrial) and other (consumer)--are not easily extracted from Japanese production statistics, thus making it difficult to identify revenue associated with these items. In the overview tables, these categories have also been deleted. It can be assumed that their small totals have been included elsewhere in the production statistics.

OVERVIEW

The Japanese semiconductor manufacturers' unprecedented commitment to VLSI research and development has helped establish them as leaders in the electronics industry. Over the past twenty years, the electronics industry has evolved from an industry dominated by analog consumer electronics (television and audio products) to the present industry with its emphasis on digital consumer products (compact disk players and digital television), computers, and digital communication networks.

The structure of the Japanese electronics industry differs dramatically from that found in North America or Europe. Their traditional strength has been consumer electronics, which is expected to comprise more than 39.0 percent of their electronic equipment production in 1987. However, the consumer segment is projected to experience substantially slower growth through 1991. Dataquest forecasts a compound annual growth rate (CAGR) of 5.0 percent from 1987 through 1991 for the consumer sector, versus a 7.0 percent CAGR for overall electronic equipment production. Competition from Korea and other low-cost Far Eastern manufacturers and the increasing strength of the yen are the primary reasons for the slowing of consumer electronic equipment production in Japan.

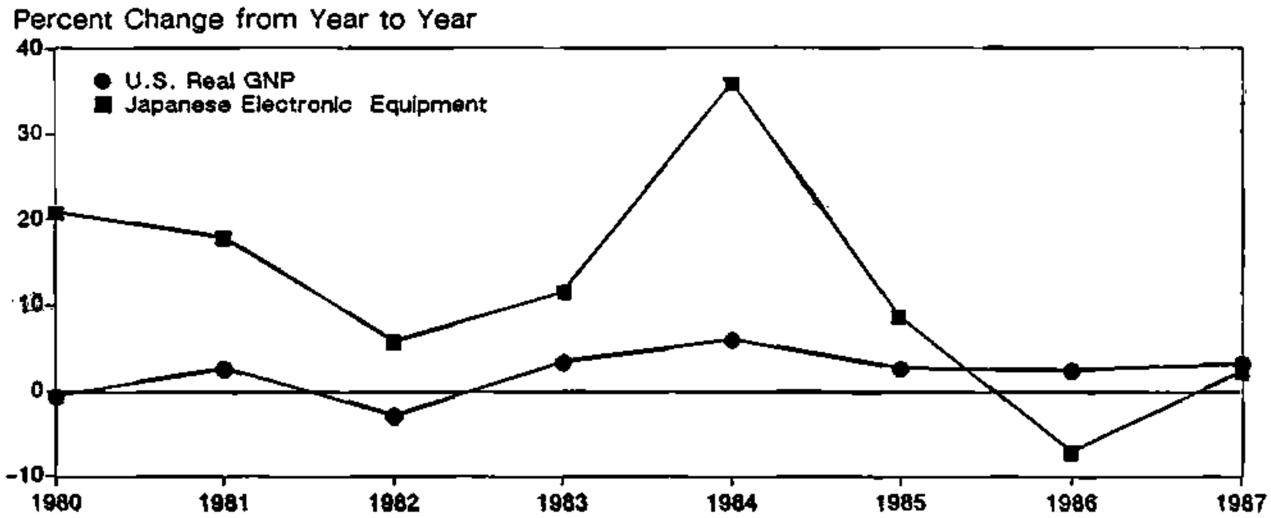
The Japanese industry is becoming increasingly dependent on the export market, leaving itself open to the economic fluctuations and trade friction found especially in the United States. Figure 1 illustrates this point.

While action is currently being considered to promote future economic growth based more heavily on domestic demand, the present forecast for Japanese equipment growth, not surprisingly, parallels the demand found in the North American market.

Trends in Japanese Semiconductor Application Markets

Figure 1

U.S. REAL GNP GROWTH VERSUS JAPANESE ELECTRONIC EQUIPMENT GROWTH (1980-1987)



Source: Dataquest
July 1987

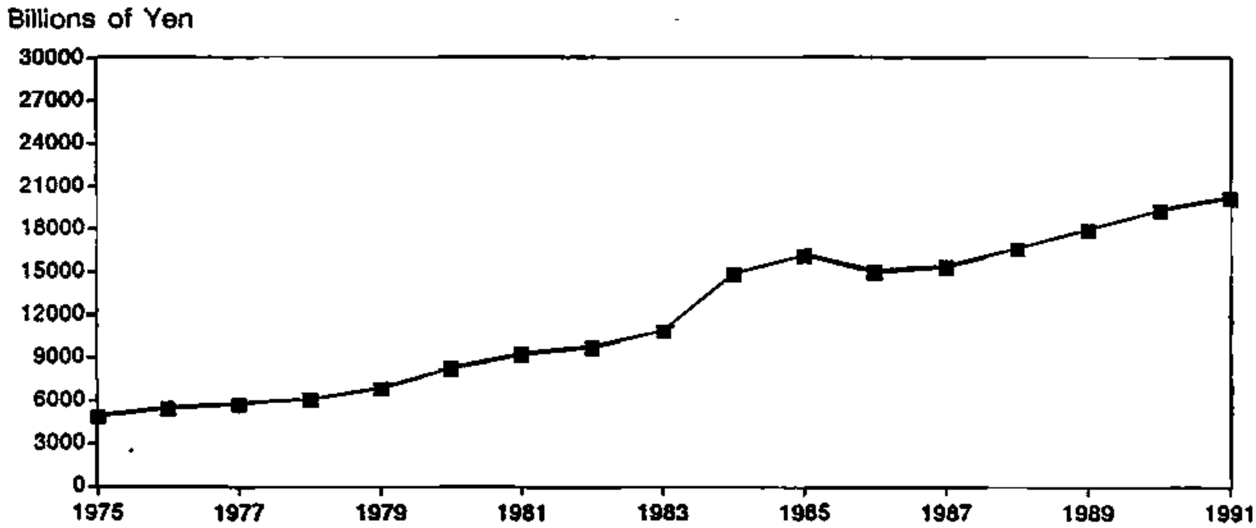
Figure 2 presents a historical look (1975 through 1986) at Japanese electronic equipment production and shows our forecast through 1991. Figure 3 does the same for semiconductor consumption in Japan. Figure 4 ties Figures 2 and 3 together by indicating the percent change in revenue growth from year to year for each figure.

Figures 5 and 6 provide a snapshot for estimated electronic equipment production and semiconductor consumption, by end market, for 1987 and 1991. These are shown in comparison to North American revenues by end market.

Trends in Japanese Semiconductor Application Markets

Figure 2

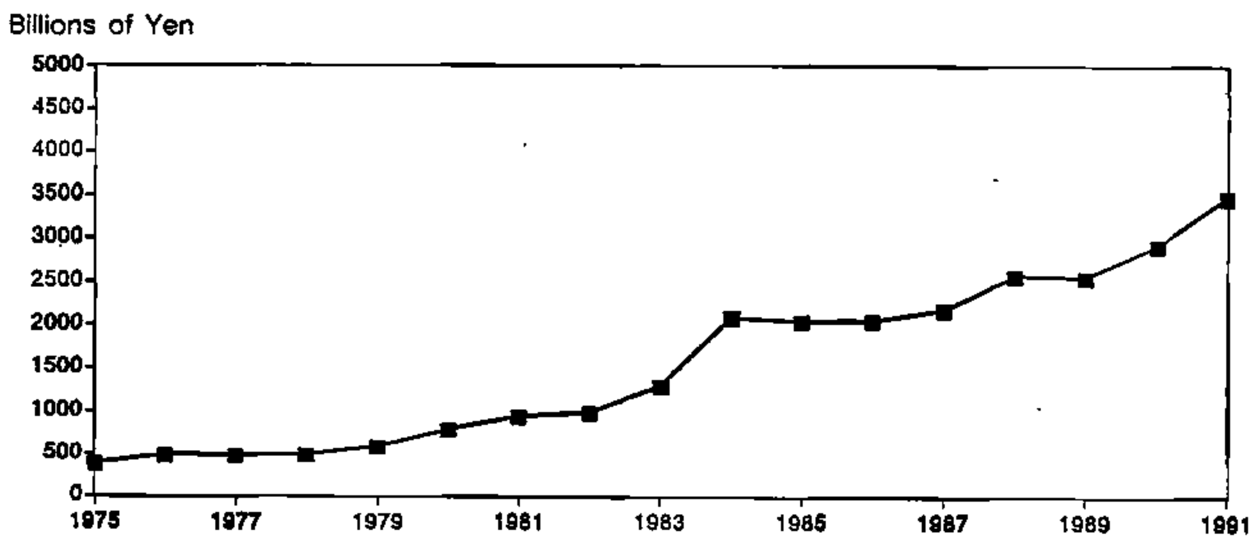
ESTIMATED JAPANESE ELECTRONIC EQUIPMENT PRODUCTION (1975-1991)



Source: Dataquest July 1987

Figure 3

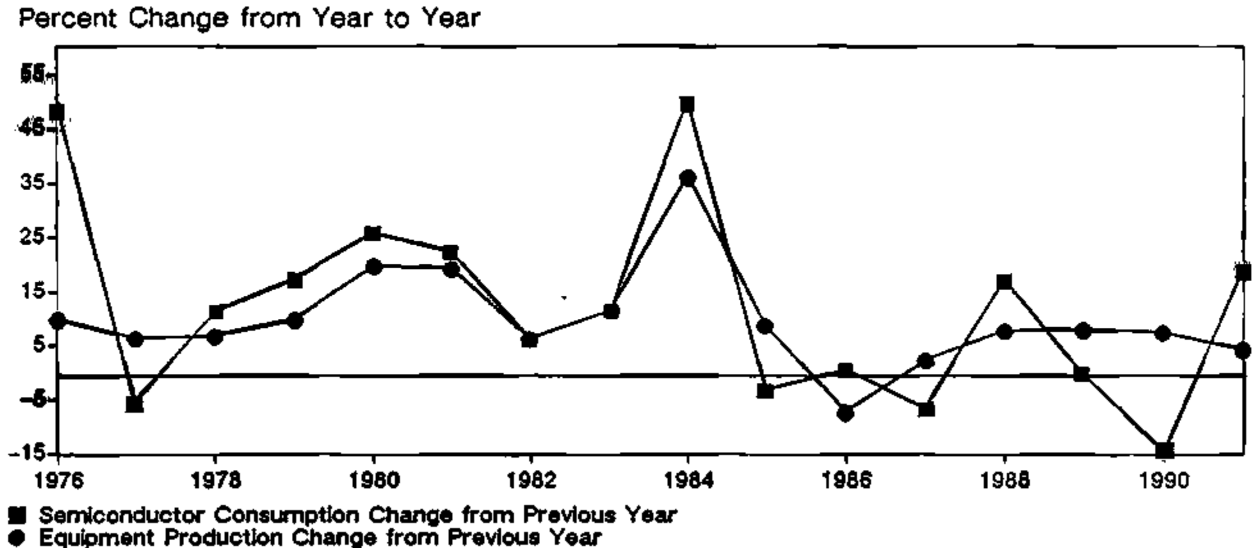
ESTIMATED JAPANESE SEMICONDUCTOR CONSUMPTION (1975-1991)



Source: Dataquest July 1987

Figure 4

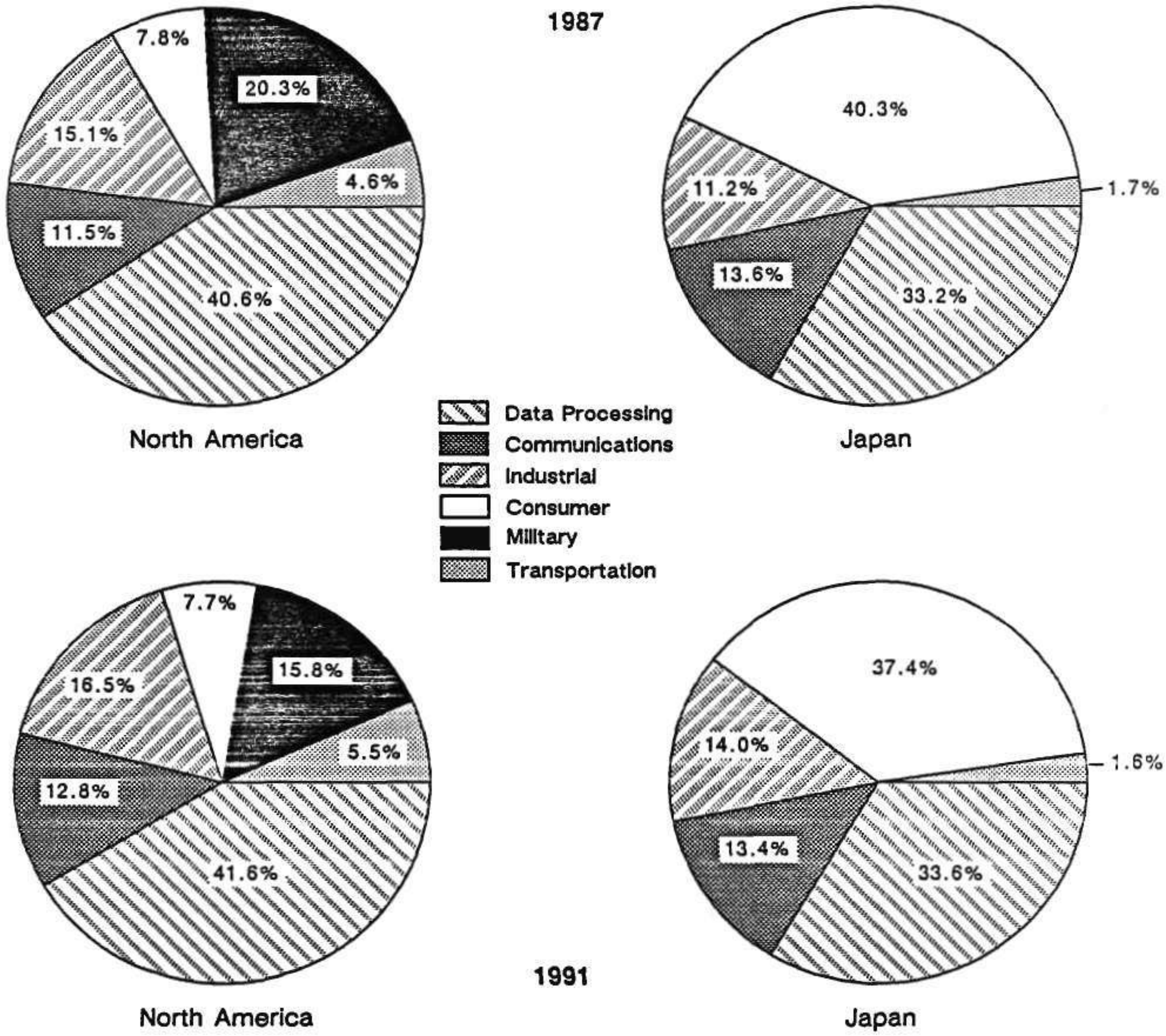
ESTIMATED JAPANESE SEMICONDUCTOR CONSUMPTION VERSUS ELECTRONIC EQUIPMENT GROWTH (1976-1991)



Source: Dataquest July 1987

Figure 5

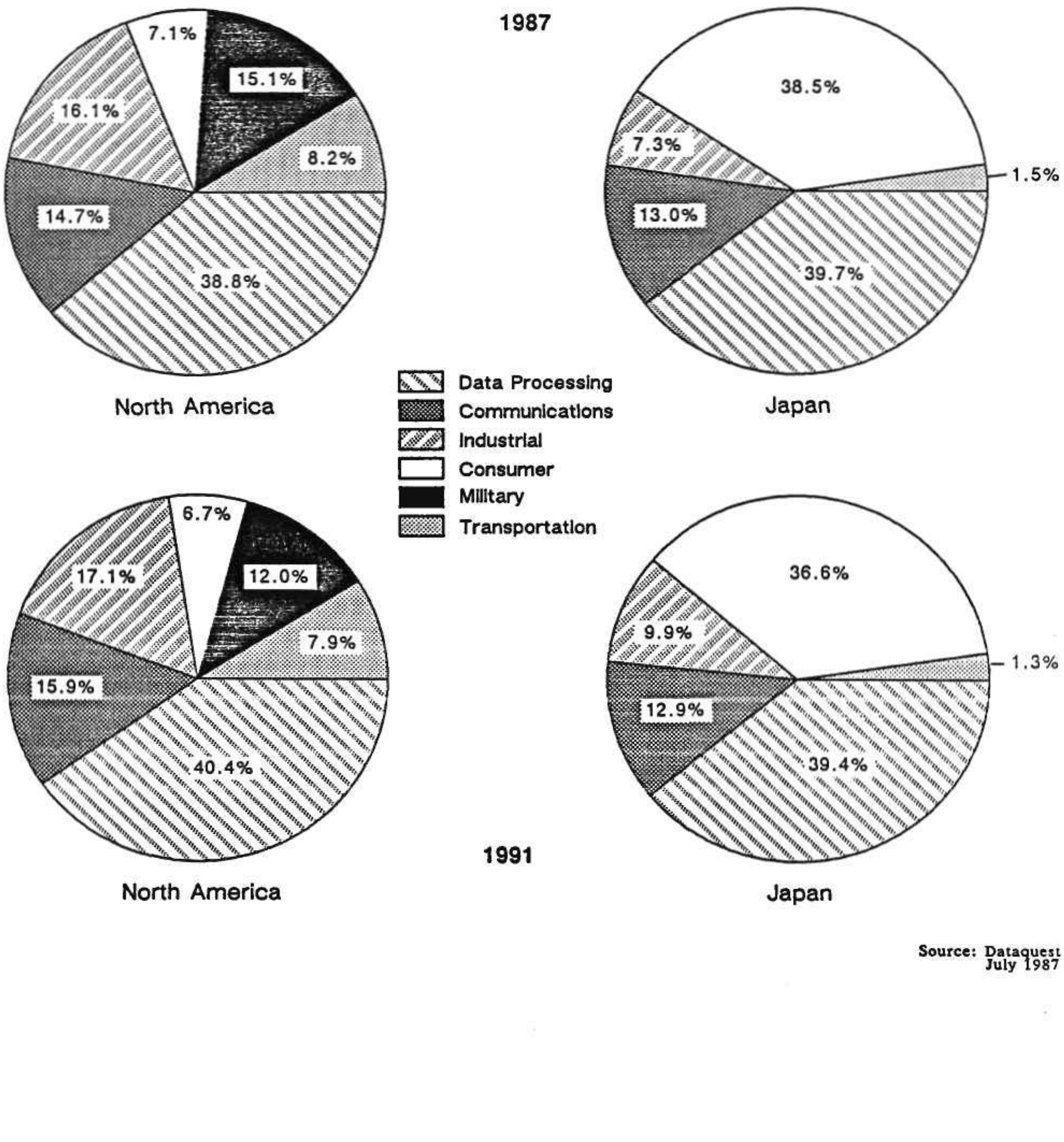
ESTIMATED EQUIPMENT PRODUCTION BY APPLICATION MARKET
(1987 and 1991)



Source: Dataquest
July 1987

Figure 6

ESTIMATED SEMICONDUCTOR CONSUMPTION BY APPLICATION MARKET
(1987 and 1991)



Source: Dataquest
July 1987

Trends in Japanese Semiconductor Application Markets

MAJOR JAPANESE ELECTRONIC COMPANIES

Table 2 lists the 20 largest electronic manufacturers in Japan. The following information is given for each company:

- Rank
- Location of headquarters
- Total revenue (1983-1985)
- Major product areas

The information contained in the table was taken primarily from each company's annual reports. Most Japanese companies end their fiscal years in March; hence, the one-year period ending March 31, 1986, would have revenue figures reported under the year 1986.

Table 2

TOP 20 JAPANESE ELECTRONIC COMPANIES--1986
(Billions of Yen)

Rank	Company	Headquarters	1983	1984	1985	1986
1	Matsushita Electric	Kadoma City, Osaka	¥3,989	¥4,721	¥5,053	¥4,500
2	Hitachi Ltd.	Chiyoda-Ku, Tokyo	¥3,944	¥4,367	¥5,013	¥5,010
3	Toshiba Corporation	Minato-Ku, Tokyo	¥2,401	¥2,707	¥3,342	¥3,400
4	NEC Corporation	Minato-Ku, Tokyo	¥1,443	¥1,762	¥2,258	¥2,335
5	Mitsubishi Electric	Chiyoda-Ku, Tokyo	¥1,588	¥1,740	¥2,035	¥2,109
6	Fujitsu Ltd.	Chiyoda-Ku, Tokyo	¥ 957	¥1,210	¥1,562	¥1,691

(Continued)

Table 2 (Continued)

TOP 20 JAPANESE ELECTRONIC COMPANIES--1986
(Billions of Yen)

Rank	Company	Headquarters	1983	1984	1985	1986
7	Sony	Shinagawa-Ku, Tokyo	¥ 789	¥ 916	¥1,439	¥1,346
8	Sanyo Electric	Moriguchi City, Osaka	¥1,126	¥1,421	¥1,534	¥1,220
9	Sharp	Abeno-Ku, Osaka	¥ 898	¥1,017	¥1,167	¥1,216
10	Nippondenso Co.	Kariya City, Aichi	¥ 689	¥ 829	¥ 955	¥1,000
11	Canon, Inc	Shinjuku-Ku, Tokyo	¥ 657	¥ 830	¥ 956	¥ 890
12	Victor Company of Japan	Chuo-Ku, Tokyo	¥ 497	¥ 553	¥ 765	¥ 700
13	Matsushita Electric Works	Kadoma City, Osaka	¥ 530	¥ 573	¥ 597	¥ 610
14	Ricoh	Ota-Ku, Tokyo	¥ 390	¥ 471	¥ 546	¥ 594
15	Fuji Electric Industry	Kawasaki-Ku, Kawasaki	¥ 342	¥ 355	¥ 508	¥ 526
16	Tokyo Sanyo Electric	Ouragun, Gunma	¥ 347	¥ 483	¥ 570	¥ 454
17	TDK	Chuo-Ku, Tokyo	¥ 310	¥ 416	¥ 427	¥ 400
18	Oki Electric Industry	Minato-Ku, Tokyo	¥ 280	¥ 345	¥ 418	¥ 392
19	Alps Electric	Ota-Ku, Tokyo	¥ 219	¥ 295	¥ 377	¥ 360
20	Matsushita Communication	Kohoku-ku, Yokohama	¥ 291	¥ 301	¥ 326	¥ 317

(Continued)

Table 2 (Continued)

TOP 20 JAPANESE ELECTRONIC COMPANIES--1986
(Billions of Yen)

Rank	Company	Major Products
1	Matsushita Electric	Video equipment, home appliances, communication equipment, audio equipment, electronic components
2	Hitachi Ltd.	Information and communication systems, electronic audio equipment, video equipment, industrial
3	Toshiba Corporation	Computers, industrial equipment, appliances, video equipment, electronic components
4	NEC Corporation	Communications equipment, computers, industrial electronic devices, home electronics
5	Mitsubishi Electric	Video equipment, heavy machinery, industrial
6	Fujitsu Ltd.	Computers, data processing systems, communication semiconductors, electronic components
7	Sony	Computers, industrial equipment, electronic audio equipment, video equipment, appliances
8	Sanyo Electric	Audio equipment, video equipment, home appliances, commercial electric equipment, gas and oil equipment
9	Sharp	Electronic components, industrial equipment, home appliances, solar equipment, audio equipment
10	Nippondenso Co.	Meters, auto electrical equipment, car heaters/ air conditioners
11	Canon, Inc	Cameras, video camera, copiers, business systems, facsimile
12	Victor Company of Japan	Video equipment, audio equipment, instrument

(Continued)

Table 2 (Continued)

**TOP 20 JAPANESE ELECTRONIC COMPANIES--1986
(Billions of Yen)**

Rank	Company	Major Products
13	Matsushita Electric Works	Lighting equipment, appliances, consumer products, electric fixture materials, heavy electrical consumer products
14	Ricoh	Copiers, data processing equipment, facsimile
15	Fuji Electric Industry	Multiuse electric machinery, heavy electric measuring instruments, vending machines/ appliances
16	Tokyo Sanyo Electric	Video equipment, home appliances, industrial
17	TDK	Magnetic tapes, ferrite magnetics, ceramic components, electronic parts
18	Oki Electric Industry	Data processing equipment, communications equipment, electronic components
19	Alps Electric	Switches, tuners, printers, flexible disks
20	Matsushita Communication	IC packages, audio equipment, electronic components

Source: Dempa Shimbun
Toyo Keizai Shinposha
Dataquest
July 1987

ELECTRONIC EQUIPMENT OVERVIEW TABLES

This section presents the overview tables (in both yen and dollars) for Japanese electronic equipment (Tables 3 and 4, respectively), input/output ratios (Table 5), and Japanese semiconductor consumption (Tables 6 and 7, respectively) by end market.

As discussed in the introduction, the segmentation is the same as the North American section, allowing SAM to provide a global and consistent perspective on electronic equipment production.

Table 3

SEGMENT OVERVIEW
JAPANESE ELECTRONIC EQUIPMENT FORECAST
(Billions of Yen)

Segment	1983	1984	1985	1986	1987	1988
Data Processing						
Computers	¥ 722	¥ 1,106	¥ 1,367	¥ 1,551	¥ 1,627	¥ 1,712
Data Storage Subsystems	432	634	787	956	998	1,051
Terminals	417	513	521	598	633	670
Input/Output	290	541	569	630	659	689
Dedicated Systems	996	1,212	1,379	1,215	1,225	1,317
Subtotal	¥ 2,857	¥ 4,006	¥ 4,623	¥ 4,950	¥ 5,142	¥ 5,439
Communications						
Customer Premises	¥ 649	¥ 839	¥ 936	¥ 981	¥ 1,010	¥ 1,066
Public Telecommunications	200	240	336	344	391	412
Radio	475	536	565	597	626	701
Broadcast and Studio	62	63	74	67	66	68
Subtotal	¥ 1,386	¥ 1,678	¥ 1,911	¥ 1,989	¥ 2,093	¥ 2,247
Industrial						
Manu. Systems	¥ 484	¥ 719	¥ 847	¥ 735	¥ 778	¥ 885
Instrumentation	462	555	622	525	560	623
Medical Equipment	107	119	132	139	156	153
Other	130	164	160	168	239	362
Subtotal	¥ 1,183	¥ 1,557	¥ 1,761	¥ 1,567	¥ 1,733	¥ 2,023
Consumer						
Audio	¥ 851	¥ 1,869	¥ 1,717	¥ 800	¥ 822	¥ 843
Video	2,332	3,069	3,209	2,891	2,846	3,166
Personal Electronics	758	809	837	793	773	775
Appliances	1,336	1,687	1,902	1,831	1,782	1,878
Subtotal	¥ 5,277	¥ 7,434	¥ 7,665	¥ 6,315	¥ 6,223	¥ 6,662
Transportation	¥ 202	¥ 255	¥ 265	¥ 262	¥ 256	¥ 297
Total Equipment	¥10,905	¥14,930	¥16,225	¥15,083	¥15,447	¥16,668

(Continued)

Table 3 (Continued)

SEGMENT OVERVIEW
JAPANESE ELECTRONIC EQUIPMENT FORECAST
(Billions of Yen)

Segment	1989	1990	1991	CAGR 1986-1987	CAGR 1987-1991
Data Processing					
Computers	¥ 1,939	¥ 2,117	¥ 2,173	4.9%	7.5%
Data Storage Subsystems	1,156	1,272	1,399	4.4%	8.8%
Terminals	709	750	793	5.9%	5.8%
Input/Output	720	753	788	4.6%	4.6%
Dedicated Systems	1,417	1,527	1,646	0.8%	7.7%
Subtotal	¥ 5,941	¥ 6,419	¥ 6,799	3.9%	7.2%
Communications					
Customer Premises	¥ 1,122	¥ 1,181	¥ 1,225	3.0%	4.9%
Public Telecommunications	488	579	585	2.4%	14.2%
Radio	732	789	840	4.9%	7.6%
Broadcast and Studio	59	63	64	(1.5%)	(0.8%)
Subtotal	¥ 2,401	¥ 2,612	¥ 2,714	5.2%	6.7%
Industrial					
Manufacturing Systems	¥ 1,089	¥ 1,334	¥ 1,388	5.9%	15.6%
Instrumentation	714	793	840	6.7%	10.7%
Medical Equipment	161	169	178	12.2%	3.4%
Other	338	427	431	42.3%	15.9%
Subtotal	¥ 2,302	¥ 2,723	¥ 2,837	10.6%	13.1%
Consumer					
Audio	¥ 1,026	¥ 1,045	¥ 1,078	2.8%	7.0%
Video	3,271	3,378	3,549	(1.6%)	4.0%
Personal Electronics	786	797	799	(2.5%)	0.8%
Appliances	1,984	2,102	2,142	(2.7%)	4.7%
Subtotal	¥ 7,067	¥ 7,322	¥ 7,568	(1.5%)	5.0%
Transportation	¥ 306	¥ 316	¥ 325	3.9%	3.7%
Total Equipment	¥18,017	¥19,392	¥20,243	2.4%	7.0%

Source: Dataquest
July 1987

Table 4

SEGMENT OVERVIEW
JAPANESE ELECTRONIC EQUIPMENT FORECAST
(Millions of Dollars)

Segment	1983	1984	1985	1986	1987	1988
Data Processing						
Computers	$ 3,072	$ 4,667	$ 5,744	$ 9,287	$ 10,565	$ 11,117
Data Storage Subsystems	1,838	2,675	3,307	5,725	6,481	6,825
Terminals	1,774	2,165	2,189	3,581	4,110	4,351
Input/Output	1,234	2,283	2,391	3,772	4,279	4,474
Dedicated Systems	4,238	5,114	5,794	7,275	7,955	8,552
Subtotal	$12,157	$16,903	$19,424	$29,641	$ 33,390	$ 35,318
Communications						
Customer Premises	$ 2,762	$ 3,540	$ 3,933	$ 5,874	$ 6,558	$ 6,922
Public Telecommunications	851	1,013	1,412	2,060	2,539	2,675
Radio	2,021	2,262	2,374	3,575	4,065	4,552
Broadcast and Studio	264	266	311	401	429	442
Subtotal	$ 5,898	$ 7,080	$ 8,029	$11,910	$ 13,591	$ 14,591
Industrial						
Manufacturing Systems	$ 2,060	$ 3,034	$ 3,559	$ 4,401	$ 5,052	$ 5,747
Instrumentation	1,966	2,342	2,613	3,144	3,636	4,045
Medical Equipment	455	502	555	832	1,013	994
Other	553	692	672	1,006	1,552	2,351
Subtotal	$ 5,034	$ 6,570	$ 7,399	$ 9,383	$ 11,253	$ 13,136
Consumer						
Audio	$ 3,621	$ 7,886	$ 7,214	$ 4,790	$ 5,338	$ 5,474
Video	9,923	12,949	13,483	17,311	18,481	20,558
Personal Electronics	3,226	3,414	3,517	4,749	5,019	5,032
Appliances	5,685	7,118	7,992	10,964	11,571	12,195
Subtotal	$22,455	$31,367	$32,206	$37,814	$ 40,409	$ 43,260
Transportation	$ 860	$ 1,076	$ 1,113	$ 1,569	$ 1,662	$ 1,929
Total Equipment	$46,404	$62,996	$68,172	$90,317	$100,305	$108,234

Note: Columns may not add to totals shown because of rounding.

(Continued)

Table 4 (Continued)

SEGMENT OVERVIEW
JAPANESE ELECTRONIC EQUIPMENT FORECAST
(Millions of Dollars)

Segment	1989	1990	1991	CAGR 1986-1987	CAGR 1987-1991
Data Processing					
Computers	$ 12,591	$ 13,747	$ 14,110	13.8%	7.5%
Data Storage Subsystems	7,506	8,260	9,084	13.2%	8.8%
Terminals	4,604	4,870	5,149	14.8%	5.8%
Input/Output	4,675	4,890	5,117	13.4%	4.6%
Dedicated Systems	9,201	9,916	10,688	9.3%	7.7%
Subtotal	$ 38,578	$ 41,682	$ 44,149	12.6%	7.2%
Communications					
Customer Premises	$ 7,286	$ 7,669	$ 7,955	11.6%	4.9%
Public Telecommunications	3,169	3,760	3,799	45.9%	16.5%
Radio	4,753	5,123	5,455	13.7%	7.6%
Broadcast and Studio	383	409	416	6.8%	(0.8%)
Subtotal	$ 15,591	$ 16,961	$ 17,623	14.1%	6.7%
Industrial					
Manufacturing Systems	$ 7,071	$ 8,662	$ 9,013	14.8%	15.6%
Instrumentation	4,636	5,149	5,455	15.7%	10.7%
Medical Equipment	1,045	1,097	1,156	21.7%	3.4%
Other	2,195	2,773	2,799	54.3%	15.9%
Subtotal	$ 14,948	$ 17,682	$ 18,422	19.9%	13.1%
Consumer					
Audio	$ 6,662	$ 6,786	$ 7,000	11.4%	7.0%
Video	21,240	21,935	23,045	6.8%	6.1%
Personal Electronics	5,104	5,175	5,188	5.7%	0.8%
Appliances	12,883	13,649	13,909	5.5%	4.7%
Subtotal	$ 45,890	$ 47,545	$ 49,143	6.9%	5.0%
Transportation	$ 1,987	$ 2,052	$ 2,110	6.0%	6.1%
Total Equipment	$116,994	$125,922	$131,448	11.1%	7.0%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
July 1987

Table 5

SEGMENT OVERVIEW
JAPANESE INPUT/OUTPUT RATIOS BY SEGMENT
(Percent of Total)

Segment	1983	1984	1985	1986	1987
Data Processing					
Computers	19.8%	22.0%	20.5%	22.0%	22.5%
Data Storage Subsystems	9.2%	9.9%	9.0%	9.9%	10.4%
Terminals	14.3%	15.2%	14.3%	15.1%	15.6%
Input/Output	11.9%	14.2%	12.6%	14.1%	14.6%
Dedicated Systems	15.4%	16.4%	15.4%	16.3%	16.8%
Segment I/O	15.0%	16.5%	15.3%	16.4%	16.9%
Communications					
Customer Premises	13.1%	15.3%	13.8%	15.3%	15.8%
Public Telecommunications	9.6%	10.6%	9.7%	10.6%	11.1%
Radio	9.6%	11.2%	9.9%	11.2%	11.8%
Broadcast and Studio	11.5%	13.4%	12.0%	13.4%	13.9%
Segment I/O	11.3%	13.2%	11.8%	13.2%	13.7%
Industrial					
Manufacturing Systems	6.5%	7.9%	6.9%	7.9%	8.4%
Instrumentation	8.6%	9.8%	8.8%	9.7%	10.2%
Medical Equipment	10.1%	10.8%	10.1%	10.7%	11.2%
Other	6.6%	7.9%	6.6%	7.9%	8.4%
Segment I/O	7.7%	8.8%	7.8%	8.8%	9.2%
Consumer					
Audio	16.9%	18.1%	16.5%	18.1%	18.6%
Video	17.2%	19.0%	17.4%	19.0%	19.6%
Personal Electronics	6.7%	9.7%	6.8%	9.6%	10.2%
Appliances	2.3%	2.8%	2.4%	2.7%	3.0%
Segment I/O	11.9%	14.1%	12.3%	13.0%	13.6%
Transportation	12.0%	12.0%	12.0%	12.1%	12.5%
Overall Semiconductor to Equipment I/O Ratio	12.2%	14.0%	12.6%	13.7%	14.2%

(Continued)

Table 5 (Continued)

SEGMENT OVERVIEW
JAPANESE INPUT/OUTPUT RATIOS BY SEGMENT
(Percent of Total)

Segment	1988	1989	1990	1991
Data Processing				
Computers	24.8%	22.6%	24.2%	26.9%
Data Storage Subsystems	11.7%	10.5%	11.4%	13.4%
Terminals	16.9%	15.6%	16.5%	18.5%
Input/Output	15.9%	14.6%	15.4%	17.6%
Dedicated Systems	18.1%	16.8%	17.8%	19.7%
Segment I/O	18.5%	17.1%	18.2%	20.3%
Communications				
Customer Premises	17.2%	15.8%	16.9%	18.9%
Public Telecommunications	12.3%	11.2%	12.1%	14.1%
Radio	13.1%	11.9%	12.9%	15.0%
Broadcast and Studio	15.2%	13.9%	15.0%	17.1%
Segment I/O	15.0%	13.6%	14.6%	16.6%
Industrial				
Manufacturing Systems	9.7%	8.4%	9.5%	11.6%
Instrumentation	11.4%	10.3%	11.2%	13.4%
Medical Equipment	11.4%	10.8%	11.3%	13.5%
Other	9.6%	8.5%	9.3%	11.4%
Segment I/O	10.3%	9.2%	10.1%	12.2%
Consumer				
Audio	19.9%	18.7%	19.7%	22.2%
Video	20.8%	19.6%	20.7%	23.8%
Personal Electronics	11.5%	10.2%	11.4%	13.4%
Appliances	3.7%	3.1%	3.4%	4.3%
Segment I/O	14.8%	13.8%	14.6%	17.0%
Transportation	13.0%	12.6%	12.8%	13.4%
Overall Semiconductor to Equipment I/O Ratio	15.5%	14.2%	15.1%	17.3%

Source: Dataquest
July 1987

Table 6

JAPANESE SEMICONDUCTOR CONSUMPTION BY APPLICATION MARKET
(Billions of Yen)

Segment	1983	1984	1985	1986	1987	1988
Data Processing						
Computers	¥ 143	¥ 243	¥ 280	¥ 341	¥ 367	¥ 425
Data Storage Subsystems	40	63	71	95	104	123
Terminals	60	78	75	90	99	113
Input/Output	35	77	72	89	96	110
Dedicated Systems	153	199	212	198	206	238
Subtotal	¥ 430	¥ 660	¥ 710	¥ 813	¥ 871	¥1,009
Communications						
Customer Premises	¥ 85	¥ 128	¥ 129	¥ 150	¥ 160	¥ 183
Public Telecommunications	19	25	33	36	43	51
Radio	46	60	56	67	74	92
Broadcast and Studio	7	8	9	9	9	10
Subtotal	¥ 157	¥ 222	¥ 226	¥ 262	¥ 286	¥ 336
Industrial						
Manufacturing Systems	¥ 31	¥ 57	¥ 58	¥ 58	¥ 65	¥ 86
Instrumentation	40	54	55	51	57	71
Medical Equipment	11	13	13	15	17	17
Other	9	13	11	13	20	35
Subtotal	¥ 91	¥ 137	¥ 137	¥ 137	¥ 160	¥ 209
Consumer						
Audio	¥ 144	¥ 338	¥ 283	¥ 145	¥ 153	¥ 168
Video	401	583	558	549	558	659
Personal Electronics	51	78	57	76	79	89
Appliances	31	47	46	49	54	69
Subtotal	¥ 626	¥1,047	¥ 944	¥ 820	¥ 844	¥ 985
Transportation	¥ 24	¥ 31	¥ 32	¥ 32	¥ 32	¥ 39
Total Semiconductor	¥1,328	¥2,096	¥2,049	¥2,064	¥2,193	¥2,577

(Continued)

Table 6 (Continued)

JAPANESE SEMICONDUCTOR CONSUMPTION BY APPLICATION MARKET
(Billions of Yen)

Segment	1989	1990	1991	CAGR 1986-1987	CAGR 1987-1991
Data Processing					
Computers	¥ 438	¥ 512	¥ 585	7.4%	12.4%
Data Storage Subsystems	121	145	187	10.0%	15.8%
Terminals	111	124	147	9.4%	10.4%
Input/Output	105	116	139	8.3%	9.6%
Dedicated Systems	238	272	324	3.9%	12.0%
Subtotal	¥1,013	¥1,169	¥1,382	7.2%	12.2%
Communications					
Customer Premises	¥ 177	¥ 200	¥ 232	6.3%	9.8%
Public Telecommunications	55	70	82	19.0%	17.4%
Radio	87	102	126	10.5%	14.3%
Broadcast and Studio	8	9	11	2.2%	4.5%
Subtotal	¥ 327	¥ 381	¥ 451	9.0%	12.1%
Industrial					
Manufacturing Systems	¥ 91	¥ 127	¥ 161	12.4%	25.3%
Instrumentation	74	89	113	12.2%	18.5%
Medical Equipment	17	19	24	17.5%	8.3%
Other	29	40	49	51.3%	25.1%
Subtotal	¥ 211	¥ 274	¥ 347	16.6%	21.3%
Consumer					
Audio	¥ 192	¥ 206	¥ 239	5.6%	11.9%
Video	641	699	845	1.6%	10.9%
Personal Electronics	80	91	107	3.6%	7.9%
Appliances	62	71	92	9.2%	14.3%
Subtotal	¥ 975	¥1,067	¥1,283	2.9%	11.1%
Transportation	¥ 39	¥ 40	¥ 44	0.9%	8.0%
Total Semiconductor	¥2,565	¥2,932	¥3,506	6.3%	12.4%

Source: Dataquest
July 1987

Table 7

JAPANESE SEMICONDUCTOR CONSUMPTION BY APPLICATION MARKET
(Millions of Dollars)

Segment	1983	1984	1985	1986	1987	1988
Data Processing						
Computers	$ 608	$1,027	$1,177	$ 2,043	$ 2,380	$ 2,757
Data Storage Subsystems	169	265	298	567	676	798
Terminals	254	329	313	541	641	735
Input/Output	147	324	301	532	625	711
Dedicated Systems	651	839	892	1,186	1,336	1,548
Subtotal	$1,829	$2,783	$2,982	$ 4,868	$ 5,659	$ 6,550
Communications						
Customer Premises	$ 362	$ 542	$ 542	$ 899	$ 1,036	$ 1,191
Public Telecommunications	82	107	137	218	282	329
Radio	194	253	235	400	480	596
Broadcast and Studio	30	36	37	54	60	67
Subtotal	$ 668	$ 938	$ 951	$ 1,571	$ 1,857	$ 2,183
Industrial						
Manufacturing Systems	$ 134	$ 240	$ 246	$ 348	$ 424	$ 557
Instrumentation	169	228	230	305	371	459
Medical Equipment	46	54	56	89	113	113
Other	37	55	44	79	130	226
Subtotal	$ 385	$ 577	$ 576	$ 822	$ 1,039	$ 1,356
Consumer						
Audio	$ 612	$1,427	$1,190	$ 867	$ 993	$ 1,089
Video	1,707	2,460	2,346	3,289	3,622	4,276
Personal Electronics	216	331	239	456	512	578
Appliances	131	199	192	296	351	451
Subtotal	$2,666	$4,418	$3,967	$ 4,908	$ 5,478	$ 6,394
Transportation	$ 103	$ 129	$ 134	$ 190	$ 208	$ 251
Total Semiconductor	$5,651	$8,845	$8,609	$12,359	$14,240	$16,734

Note: Columns may not add to totals shown because of rounding.

(Continued)

Table 7 (Continued)

JAPANESE SEMICONDUCTOR CONSUMPTION BY APPLICATION MARKET
(Millions of Dollars)

Segment	1989	1990	1991	CAGR 1986-1987	CAGR 1987-1991
Data Processing					
Computers	$ 2,846	$ 3,327	$ 3,796	16.5%	12.4%
Data Storage Subsystems	788	942	1,217	19.3%	15.8%
Terminals	718	804	953	18.6%	10.4%
Input/Output	683	753	901	17.5%	9.6%
Dedicated Systems	1,546	1,765	2,106	12.7%	12.0%
Subtotal	$ 6,580	$ 7,590	$ 8,972	16.2%	12.2%
Communications					
Customer Premises	$ 1,151	$ 1,296	$ 1,503	15.3%	9.8%
Public Telecommunications	355	455	536	29.1%	17.4%
Radio	566	661	818	19.8%	14.3%
Broadcast and Studio	53	61	71	10.8%	4.5%
Subtotal	$ 2,125	$ 2,473	$ 2,928	18.2%	12.1%
Industrial					
Manufacturing Systems	$ 594	$ 823	$ 1,046	21.9%	25.3%
Instrumentation	478	577	731	21.6%	18.5%
Medical Equipment	113	124	156	27.4%	8.3%
Other	187	258	319	64.0%	25.1%
Subtotal	$ 1,371	$ 1,782	$ 2,252	26.5%	21.3%
Consumer					
Audio	$ 1,246	$ 1,337	$ 1,554	14.5%	11.9%
Video	4,163	4,541	5,485	10.1%	10.9%
Personal Electronics	521	590	695	12.3%	7.9%
Appliances	399	464	598	18.4%	14.3%
Subtotal	$ 6,329	$ 6,931	$ 8,332	11.6%	11.1%
Transportation	$ 250	$ 263	$ 283	9.5%	8.0%
Total Semiconductor	$16,656	$19,039	$22,767	15.2%	12.4%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
July 1987

Trends in Japanese Semiconductor Application Markets

FAST-GROWING ELECTRONIC EQUIPMENT MARKETS

In the following sections, each of the five major end markets and the key electronic equipment types within that segment are discussed. These products represent the major consumers of semiconductors as well as the rapidly growing markets.

Data Processing Segment

Computers

The largest computer manufacturers in Japan are, in order of rank: Fujitsu, NEC, IBM-Japan, Hitachi, Toshiba, Oki, Mitsubishi, and NCR-Japan.

The size of the Japanese market for computers is expected to increase at a CAGR of 7.5 percent through 1991, with the demand for microcomputers and peripherals (including printers, displays, and disk drives) leading the way.

While domestic production of personal computers for the home environment has slowed, office automation machines for the business community are enjoying strong growth as these markets expand in Japan.

NEC holds the largest share of the domestic personal computer market, followed by Fujitsu, IBM-Japan, and Sharp. The image of the personal computer as mainly an entertainment machine has changed, as the use of personal computers for business purposes, including Japanese-language word processing, has grown rapidly.

Production of Japanese-language word processors has made this segment one of the fastest growing consumers of semiconductors. There are approximately 30 manufacturers, with NEC, Fujitsu, Sharp, and Canon leading the way.

Copier Machines

Japanese companies continue to dominate the low-end copier market, as personal PPCs (plain paper copiers) enjoy rapid sales growth. Canon triggered the intense competition in the personal copier market by introducing its first models in 1982; since then, other major manufacturers, such as Mita Industrial, Toshiba, Sharp, Ricoh, and Fuji Xerox (a joint venture of Rank Xerox of Great Britain and Fuji Photo Film) have entered this lucrative market.

As the office automation boom continues in Japan, copiers will continue to consume nearly 4.0 percent of all semiconductors produced in Japan.

Trends in Japanese Semiconductor Application Markets

Communications Segment

Facsimile Machines

Facsimile machines represent another rapidly growing market for semiconductors, consuming approximately 2.0 percent of all chips produced in Japan.

The leading manufacturers of facsimile equipment, by rank, are Ricoh, Canon, Panasonic, and NEC.

Dataquest estimates that 1.1 million facsimile units were manufactured in 1986, a 37.5 percent increase over the previous year. Unit production is expected to rise another 27.0 percent in 1987, with a CAGR of 12.5 percent for 1987 through 1991.

Industrial Segment

Robotics

Fanuc, Yaskawa, Kawasaki Heavy Industries, and Hitachi are the leading manufacturers of robots in Japan. Dataquest estimates that Japanese production of robots in 1986 was ¥123 billion, or $799 million. This market is expected to grow at a CAGR of 19.9 percent through 1991.

Most robots use high-performance 16-bit microprocessors, high-precision analog to digital converters, and nonvolatile memory.

Consumer Segment

VCRs

VCRs are the most prevalent application for semiconductors, consuming 10.0 percent of all chips consumed in Japan. With major Japanese companies such as Hitachi, JVC, Matsushita, Sharp, and Sony dominating the worldwide market for these products, the VCR is a vital application for the semiconductor industry. Increased competition from Korea is expected to impact the VCR (and semiconductor) industries in Japan.

The meteoric production rates seen through 1984 have slowed considerably as demand in Japan and Europe (coupled with import quotas) has slackened.

In an effort to ease trade friction, Japanese companies have been rapidly setting up production facilities in Europe and the United States. Hitachi, JVC, Matsushita Electric, Mitsubishi, Sharp, and Toshiba have all been active in foreign production of VCRs.

Trends in Japanese Semiconductor Application Markets

Compact Disk (CD) Players

The most dynamic product to emerge from Japan in 1985 was the CD player. With full-scale production not beginning until 1983, the CD player now ranks as the eighteenth largest consumer of semiconductors in Japan. Leading manufacturers such as Hitachi, JVC, Matsushita, Nippon Gakki, Pioneer, Sanyo, Sony, and Toshiba are estimated to have produced more than 7.3 million units in 1986. Demand for CD players should remain strong as new applications (portable, car environment) help foster the strong growth found in home stereo systems.

For a more detailed analysis of the semiconductor content of CD players, refer to the SAM Research Newsletter, "Compact Disk Players: A Sound Market," published December 17, 1985.

Television Products

While slowly losing market share in terms of semiconductor consumption, color television sets continue to represent a stable application, with potential for strong growth in pocket-size and digital television sets.

Pocket-size color television introductions have increased recently, most of which have an LCD display of less than 3.0 inches. Digital products, which offer numerous additional functions, are being offered by nearly all the major television manufacturers. Along with the high-definition color sets, these products are seen as potentially major consumers of semiconductors in the future.

Transportation Segment

Automobiles

Japanese automobile makers produced a record 12.3 million vehicles in 1986, an 8.0 percent increase over the previous year. With the increasing pervasiveness of semiconductors in automobiles and trucks, this market is expected to remain healthy through 1991. Semiconductor consumption for the automobile industry is expected to increase 9.5 percent (in dollars) in 1987, with a CAGR of 8.0 percent for 1987 through 1991.

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Trends in Smart Cards

INTRODUCTION

Developments in the quick-changing, fast-moving smart card market are continuing to unfold, pushing the market forward. In the nearly three years that we have analyzed smart cards there has been tremendous activity, particularly over the last year; new cards, new participants, and new tests highlight market interest. After many many years of debate, trial, error, and technical achievement the smart card market appears poised for growth.

Dataquest believes that over the rest of this decade, smart card unit volumes, long ago promised, will begin to be achieved. In May 1986, a smart card conference sponsored by Battelle Columbus Laboratories in San Francisco strengthened our stance--we saw a tremendous difference between the 1986 conference and that of 1985. Much of this section discusses Battelle's conference, which is described in more detail below, since it is the premier industry conference on the topic. It is an excellent forum for identifying market developments.

The smart card market issues discussed in this section include applications, manufacturers, regional activity, and overall market trends and developments. The focus is on how these market issues surround the smart card's impact on the semiconductor industry. Smart cards could one day be the single largest market for integrated circuits, making them closely intertwined with the semiconductor industry. Simply put, ICs are what make smart cards smart. They are the reason this market exists.

BACKGROUND

There is no question that applications and solutions to problems are also what drive a market. But we believe that, except in Europe where most smart card activity has been spearheaded, semiconductor manufacturers have only recently placed enough emphasis on this developing market. This interest is occurring most rapidly in Japan, where the surge of activity is focusing on the worldwide scope of the market, particularly U.S. market opportunities. In the United States, where the largest consumption of smart cards is likely to take place over the long term, there is a noticeable lack of participation among domestic IC manufacturers. Motorola is the major exception, and we commend their far-reaching view of the market.

In several of our past analyses, we have noted that it is understandable why IC manufacturers have historically shied away from the smart card market. Several years ago tremendous hype and excitement surrounded the technology, but research and analysis revealed that the smart card was an idea whose time had not yet come. Device manufacturers pulled back resources, saying that the market still had too many "ifs." They awaited further developments, which at that time was the correct assessment of the market.

We believe, however, that this is no longer as true. In the last several years, the smart card market and technology have made great strides. Clearly, domestic semiconductor manufacturers, having studied the market once, are reluctant to get involved. Industry players are still not sure that the market is there. There has been enough activity recently, however, to indicate that waiting to commit resources may mean that it will be too late to participate, and benefit, when growth comes. Historical analyses and findings cannot be applied to today's decisions about this market. The smart card market involves risk; it is not for the fainthearted. It also requires a willingness to accept long-term return on investment. We believe that the smart card market will be large enough in scope that it can be served worldwide; however, by waiting much longer, many U.S. IC manufacturers may find themselves standing by and watching the market as it's won by international counterparts.

THE SMART CARD VERSUS THE MAGNETIC STRIPE

A smart card is typically 85.7 x 54 x 0.76 millimeters--the size of a standard credit card. One or two integrated circuits with processing abilities and nonvolatile memory are incorporated into the card. During transactions, computations and the storage of their results are handled on the card, thus relieving a host computer of those duties. The estimated cost of a smart card typically ranges from $4 to $50; magnetic-stripe cards cost between $0.10 and $1. But an IC has several advantages over the traditional magnetic stripe, the most important being its processing abilities. This processing power provides security--a most important smart card feature for the following reasons:

- It allows the use of smart cards in many new markets.
- It provides more effective card use in already established markets (for example, by reducing credit card misuse and fraud).

These advantages quickly justify the cost of a more expensive card, especially when losses are taken into account--for example, MasterCard and VISA's 1984 combined loss of more than $900 million from fraud and credit abuse.

Trends in Smart Cards

Cards with magnetic stripes do not have the power to execute programming instructions internally, and the cost of putting all card readers on-line is prohibitive. Thus, it is difficult to couple magnetic-stripe storage with computational capability. The smart card combines computing power and storage, thus providing security that only a computing device can. The card's memory can be segmented to hold a personal identification number (PIN), security protocols, and codes. Such data can be used only by the MPU inside the card. The smart card's greatest asset is its ability to interact with a card reader that also has security protocols. Together, they can simultaneously perform complex algorithms; this combination provides sophisticated and virtually impenetrable security. The magnetic stripe does not have the memory capacity to hold user identification, security, and transaction information.

Dataquest believes that other smart card user-ID tests under consideration include matching digital images of signatures, fingerprints, or voiceprints--generally referred to as biometric technology.

Other smart card benefits are as follows:

- Application adaptability
- Increased operational complexity
- Processing at lower cost per transaction

In October 1985, a report on the IC card was published as a result of a joint study conducted by the Groupement Carte Bleue, Bank of America, The Royal Bank of Canada, and VISA International. This study compared smart card technology to mag stripe technology and assessed how smart cards would influence the VISA payment study. Mentioned were several "desirable features" that cannot be implemented with current mag stripe technology:

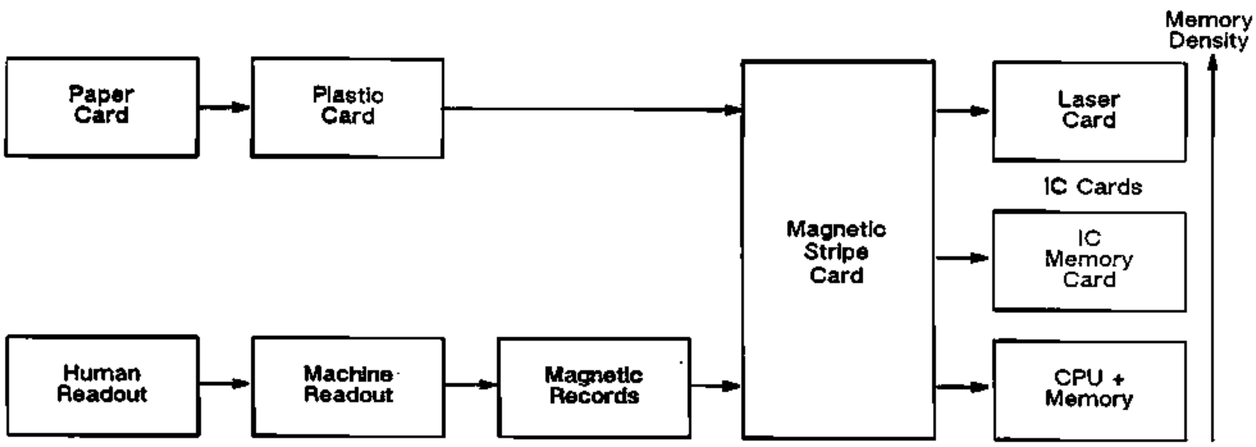
- Selective on-line authorization
- PIN use at the point of sale
- Protection from electronically counterfeited cards
- More reliable electronic media
- New off-line terminal-based services

Trends in Smart Cards

We believe new service offerings will be one of the major reasons VISA justifies future implementation of IC card technology. In fact, as Figure 1 illustrates, we believe the smart card is not an either/or technology when compared with the mag stripe card, but rather an evolutionary step in the plastic card business.

Figure 1

CARD TECHNOLOGICAL EVOLUTION



Source: Dataquest
February 1987

Applications

Overall, smart cards have hundreds of individual applications. Specific areas that we have seen addressed and from which we expect future smart card activity, include the following:

- Gasoline purchasing
- Fleet fuel management
- New auto warranty and service records
- CATV access
- Hospital, medical, or pharmaceutical care

- Insurance policy records, claims, and transactions
- Government programs such as welfare, medicare, and social security
- Film in the next generation of cameras
- Academic records
- Software program cartridges
- Computer storage
- Process control
- Security access and control
- Hotel ID, records, and billing
- Driving licenses
- Commuter passes

Laser Technology

Laser technology, best known as developed by Drexler Technology Corporation in Mountain View, California, is perhaps the most-discussed competitive smart card technology. Drexler's LaserCard™ has between 1 and 4 Mbytes of memory; its primary application is the portability of large amounts of data, such as in a publishing environment. At the Battelle conference, it was stated that the technology has faced setbacks, namely in read/write hardware, which have made it difficult to read and write to the card cost-effectively. The card is fairly difficult to align in the reader, and most application environments are too harsh to provide the "clean-room" environment needed to write to the card without contamination. This can potentially ruin the integrity of the data being transferred. We believe that development activity to address this problem is currently underway. LaserCard™ applications are also fairly different from those of other smart cards. This, combined with the need to overcome current technical limitations, should keep laser technology from being a major competitive factor in the successful development of the smart card market.

Trends in Smart Cards

BATTELLE'S ANNUAL SMART CARD CONFERENCE

On May 19-20, 1986, approximately 200 people gathered in San Francisco to discuss smart card market issues. The emphasis was on smart card applications. Rather than featuring vendors (as was done last year), Battelle's roster of speakers consisted mainly of smart card users. That focus typified the most dramatic change in the market over the last year--the market appears more application driven and likely to grow from a "demand pull." For years the smart card has been a great concept in search of a market--a "technology push." The user focus showed that real problems exist that are in need of real solutions, especially in medical, manufacturing, and military environments. This apparent need for the technology, and the willingness to consider smart card solutions, is the catalyst for our more optimistic view of the market.

SMART CARD ACTIVITY: THE YEAR IN REVIEW

Battelle provided an industry update and overview of the market. It believes that the 1985-1986 time frame for smart cards can be summed up by four major points:

- Continued progress in U.S. market tests
- Continued Japanese thrust
- Market legitimization
- Rapidly evolving products and markets

Table 1 shows the surge in smart card activity in recent years. It is Dataquest's compilation of smart card tests, including both those that have been completed and those that are currently underway. Other activities are past the test phase and have reached commercial viability, as evidenced by Datakey, Incorporated, a company located in Burnsville, Minnesota, that has more than a million smart devices in circulation. Their approach centers around Data Keys and Data Tags, which are molded of thermoplastic and shaped like typical keys and "dog tags." Uninhibited by the packaging constraints of standard credit cards, their products contain ICs that have been used in a myriad of applications, a partial list of which follows:

- Kidney dialysis
- Process control

- Vehicle fleet fuel management
- Security

The backdrop for these tests can be found in France where major point-of-sale (POS) and pay phone programs are being tested. Pilot tests for POS activity were launched in 1982 in Blois, Lyon, and Caen with two major vendors involved: Bull and Philips. Approximately 600 terminals and 60,000 cards have been deployed with the intent of reducing check clearing and communications costs associated with the heavy use of checks that is pervasive in France. Dataquest believes that more than 12 million cards have been ordered there for dissemination by 1988.

Table 1

WORLDWIDE SMART CARD ACTIVITY
(Year-to-Date)

Type	Known Participants	Country	Year Began
Business travelers--pay phones	AT&T	United States	1986
VISA debit cards	Luxembourg's Credit European Bull	Luxembourg	1985
Debit cards	Groupes de Cartes Bancaires Group d'Interet Economique Bull Philips	France	1982
Credit cards	Credito Valtellinese Intelmatique	Italy	1985
Credit cards	MasterCard International Micro Card Technologies Casio Microcard	United States	1985
Pay phones	Telecom Ministry (PTT) Paymatek	France	1982

(Continued)

Table 1 (Continued)

WORLDWIDE SMART CARD ACTIVITY
(Year-to-Date)

Type	Known Participants	Country	Year Began
Pay-per-view debit	Paytel Cable TV Co. Multimil	England	
Record keeping--purchasing	U.S. Navy Smart Card Systems	United States	
Record keeping--academics	University of Paris Bull	France	
Game software	Dai Nippon	Japan	1985
Asset control/consulting	Toyo Trust & Banking	Japan	1984
Capital transfer	Toshiba Credit Mitsui Bank Denney's Japan	Japan	1984
Credit cards	Mitsui Bank Sangin Credit Toshiba	Japan	1985
New media services: home shopping, banking-POS, CATV bill paying	Sumitomo Bank Kyowa Bank Tokai Bank Seiyu Seibu Saison Grp. Matsushita NEC Toppan Moore Dai Nippon et. al.	Japan	1985
"Sezon Gold Card"	Seibu Credit Dai Nippon	Japan	1985

(Continued)

Table 1 (Continued)

WORLDWIDE SMART CARD ACTIVITY
(Year-to-Date)

Type	Known Participants	Country	Year Began
Multipurpose card project	Ministry of Post & Telecommunications NTT Seibu Credit IBM Japan	Japan	1985
Health control card	Tokyo Women's University of Medicine Inabata Industry Dai Nippon	Japan	
Multipurpose	Octo Japan	Japan	1985
Credit card	MasterCard International Credit Agricole Credit Mutuel	France	
Banking	ANZ Bank Commonwealth Bank State Bank of NSW The National Bank Steria (France)	Australia	1987
Personnel ID	U.S. Army Datakey	United States	1982
Corporate cash mgmnt	Royal Bank of Canada Micro Card Technologies	Canada	1985
Peanut buying point automation	U.S. Dept. of Agriculture Micro Card Technologies	United States	1985
Credit/debit cards	VISA International Toshiba Smart Card International General Instruments	United States	1987

(Continued)

Table 1 (Continued)

WORLDWIDE SMART CARD ACTIVITY
(Year-to-Date)

Type	Known Participants	Country	Year Began
Cashless shopping	Daiwa Bank Peacock Supermarket Omron	Japan	1985
Cashless shopping	Kyowa Bank Fujitsu Matsushita Kyodo Printing	Japan	1985
Home banking	J.C. Penney	United States	1984
Encryption security	Tokens & Transactions Consortium U.K. National Physical Lab U.K. British Technology Grp.	England	1982
Banking	Dai Ichi Kangyo Bank Toppan Moore Printing	Japan	
Biometrics security	Identix Micro Card Technologies	United States	1985
Banking	Norwegian Banks	Norway	1984
Credit cards	American Express Bull	Canada	1985
Banking POS	Fuji Bank Tobu Store Oki Electric Dai Nippon	Japan	1985
Banking POS	Mitsubishi Bank Toppan Moore	Japan	1986

(Continued)

Table 1 (Continued)

WORLDWIDE SMART CARD ACTIVITY
(Year-to-Date)

Type	Known Participants	Country	Year Began
Personal medical card	Seibu Marketing Sante System Center Dai Nippon	Japan	1985
Cashless shopping	Sanwa Bank Daiei Group	Japan	1985
Cashless shopping	Taiyo-Kobe Bank	Japan	1986
Cashless shopping	Hokkaido-Takushoku Bank Sapporo Shimin COOP	Japan	1986
Cashless shopping	Nanto Bank	Japan	1986
Banking	Daiichi-Kangyo Bank Taiyo-Kobe Bank Saitama Bank Yokohama Bank Hokuriku Bank Tokyo Bank Kyowa Bank Long-Term Credit Bank of Japan	Japan	1986
Health care	Primary Prevention Program Personal HealthCard Systems, Inc. Micro Card Technologies	United States	1986

Source: Dataquest
February 1987

Their pay phone program was begun as an attempt to reduce the rampant cashbox vandalism that was plaguing the Telecom Ministry's (PTT's) pay phone system. Tests began in 1983 using 200 telephones; Paymatec Schlumberger is the primary vendor. It is believed that by 1990 more than 50 percent of the region's pay phones will use smart cards; approximately 5 million cards already having been issued.

In the programs above three types of cards are involved:

- A prepaid card that contains a preset number of call payment units

- A telephone credit card where charges are billed through the traditional telephone billing system

- A bank card that can function as a debit card or a renewable stored value card

In Western Europe, financial and telecommunication applications have been the primary driving force behind the market.

Many international market participants are setting up U.S.-based operations, established for the primary purpose of developing the U.S. smart card market. Most notable is MicroCard Technologies, Incorporated, a Bull subsidiary located in Dallas, Texas. Its recently opened Dallas manufacturing facility is now in full swing. Acting as a second source to meet Bull's smart card commitments, the facility will also produce cards to meet the needs of its own marketing operation.

The U.S.'s own smart card market has centered around entrepreneurial activity and alternative technologies such as Datakey's that are used in nonfinancial areas. However, recent U.S. trials have involved financial applications and government-sponsored field tests such as the Department of Defense's dog tag program and the Department of Agriculture's test for the smart card as a potential replacement for food stamps. The much-touted financial arena (the most frequently considered application for smart cards) formerly had too many barriers to entry--namely International Standards Organization (ISO) packaging requirements and smart card cost. (Other ISO standards activities for the smart card (for example, communications protocols) are still emerging.) Some mistakenly consider the unclear standards to be a major market barrier. While smart card standards are more complex than mag stripe standards, it is encouraging to note that it took seven years before standards for mag stripe technology were adopted; today, nearly a decade later, more than a billion mag stripe cards are in circulation for financial transactions alone. Table 2 shows the history and technological evolution of plastic cards that led, in 1985, to smart card technology in the financial transaction application area.

Table 2

THE HISTORY OF THE CREDIT CARD

1920s	Credit cards introduced by retailers and gasoline companies
1930s	Embossing on plastic and metal cards begins
1947	The first bank card issued
1950	The first travel and entertainment card issued
1963/1964	The first direct dial point-of-sale (POS) system on the market
1965/1966	Introduction of the magnetic stripe with coded information on paper (cardboard) cards
1968/1969	Introduction of the magnetic stripe on plastic cards
Aug. 1979	MasterCard members permitted to put magnetic stripes on the MasterCard card
June 1981	Introduction of MasterCard's Direct Dial POS support system
1982/1983	All MasterCard and VISA members required to have magnetic stripes placed on their credit cards
1983	Advanced security features added to the cards, including fine line printing, ultraviolet, ink and the hologram
Sep. 1985	MasterCard becomes first global payments systems company to introduce the computer chip card to the United States: testing of the MasterCard Integrated Circuit Card begins

Source: MasterCard International
Dataquest
February 1987

Trends in Smart Cards

Japan's Focus on Smart Cards

Japanese smart card activity has surged over the last year. Dataquest's semiconductor market analysts in Japan have kept abreast of smart card market trends, and we believe that there is no question that this market is being assessed and targeted very seriously by many sectors of the Japanese economy. Much of this activity appears to be orchestrated at the government level. The development of the smart card market is an example of Japanese industrial policy at work; competition is said to be fierce. As many as 50 to 75 small tests are being observed actively; many of these are included in Table 1. Applications are numerous and technologies being used are many. Consensus holds that a large number of small tests provide the best window on market opportunities.

The most striking aspect of Japan's involvement has been the pace with which it has taken an active interest in the market. Smart cards are viewed similarly to both calculator and digital watch markets in terms of manufacturing technology; they lend themselves to the assembly, production, and electronics skills of Japan's large watch and calculator manufacturers.

In Japan, partnerships and alliances appear integral to the market's early development. Manufacturers are aligning themselves with users to secure volume sales that adhere to a worldwide or manufacturer's standard. All this is part of the coordination and cooperation that is being brought to bear on the Japanese focus on this market. Note Table 3 that lists known smart card vendors; the list has tripled in the last several years, with most of the known participants coming from Japan.

In Japan, ongoing tests revolve around applications in:

- Cashless shopping
- Banking (including home banking)
- Medicine
- Software storage
- Media services
- Credit transactions
- Security

Table 3

SMART CARD VENDORS

Vendor	Geographic Region (by Parent Company)
AT&T	United States
Arimiera Giken	Japan
Aster International	Japan
Bull Group	Europe
Casio	Japan
Casio Microcard	Japan
Citizen	Japan
Datakey	United States
DuPont Japan	United States
Dai Nippon Printing	Japan
Enigma Logic	United States
Flonic Schlumberger	Europe
Fuji Advanst	Japan
Fujisoku	Japan
Fujitsu	Japan
General Instrument	United States
GRETAG	Switzerland
Hitachi	Japan
Hitachi Maxell	Japan
IBM	United States
IC Sante	Japan
IHMS	United States
Intellicard International	United States
Japan LSI Card	Japan
Kyodo Printing	Japan
LogicCard	United States
Matsushita	Japan
Micro Card Technologies	Europe
Mitsubishi Electric	Japan
Mitsubishi Plastics	Japan
Mitsui	Japan
Multimel	Europe
NCR Japan	United States
Nippon Coinco	Japan
Oki	Japan
Omron	Japan
Paymatek	Europe

(Continued)

Table 3

SMART CARD VENDORS

Vendor	Geographic Region (by Parent Company)
Philips	Europe
Security Dynamics	United States
Shoei Printing	Japan
Smart Card Systems	United States
SmartCard International	United States
Tohoku Kinzoku	Japan
Tokyo Electric	Japan
Toppan Moore Printing	Japan
Toshiba	Japan

Source: Dataquest
February 1987

U.S. Market Activity

In the past Dataquest has noted that nonfinancial applications would be the driving force behind smart card development, particularly in the United States. Unlike the financial arena, the market would not be restricted by ISO packaging and communication standards for plastic cards, nor would it be limited by the current infrastructure and the manner in which business is currently performed (i.e., having to work around the already heavy investment in automatic teller machines).

MasterCard International and VISA International, with their very different philosophies, strategies, and approaches to the market, have begun to change this. The nonfinancial market legitimized the technology to a certain extent and acted as a proving ground for smart card technology. Just as Dataquest originally expected, these applications appear to have been a catalyst by which the financial community began testing the smart card, analyzing the technology, and forming opinions in order to use the technology within the financial field.

MasterCard: Leading the Way

Things changed in 1985 when MasterCard International formally announced its market test, setting off a flurry of interest and activity, including a smart card approach announced shortly thereafter by VISA International. Both MasterCard and VISA are outspoken about their approach to smart card solutions.

The Battelle conference provided the forum through which MasterCard announced the first public results of its smart card test, currently underway in Maryland and Florida. Its primary reasons for evaluating the technology included:

- Concern over losses
- Belief these losses would continue
- Reducing current systems expenses

Table 4 profiles MasterCard's operating expense distribution. (It states that the combined MasterCard and VISA losses of $902 million in 1984 will total $2.1 billion by 1990.)

Table 4

MASTERCARD'S OPERATING EXPENSES

Activity	Percent of Total Expenses
Marketing	5.0%
New accounts	7.5
Account maintenance	25.5
New merchants	17.0
Merchant servicing	9.0
Credit losses	20.0
Fraud losses	3.5
Authorization	10.0
Operations/administration	2.5
Total	100.0%

Source: MasterCard International
Dataquest
February 1986

The projected major cost savings provided by the technology would be in the following areas:

- A positive impact on counterfeit and fraud losses
- A $200 million savings from the ability to stop under-the-floor-limit transactions from exceeding the cardholder's credit limit
- The elimination of most on-line authorizations, which they projected as $1.4 billion in 1990 for VISA and MasterCard authorization expenses only

These engineering and physical tests of the card made up the first phase of the project:

- Mechanical tests:
  - Flex/bending
  - Torsion
  - Abrasion
  - Drop and impact
  - Concentrated load
  - Imprinting
  - Repeated use
- Environmental tests:
  - Temperature
  - Humidity
  - Ultraviolet light
  - X ray
  - Electromagnetic interference
  - Static electricity

- Chemical tests
  - Perspiration
  - Salt water
  - Alcohol
  - Detergents
  - Gasoline
  - Colas

Several findings resulted with respect to IC technology:

- MasterCard went on record saying that the card system and payment system must use EPROM technology to minimize the alteration of data and breaches of security. It will provide strong recommendations and motivations for vendors to request this technology. MasterCard stated that it also requires a single-chip solution. That technology is available today. We believe that the evolution to a single-chip microcontroller with E2PROM is therefore not needed for the smart card market to take off.

- Stipulations for EPROM use and a three-year life cycle mean that a replacement market is anticipated. This will influence the smart card and IC markets positively.

- In flex or bending tests some chips failed as early as 1,000 test cycles. MasterCard believes that the industry can combine the best technologies to provide a card that meets their specification of no chip failures before 3,000 cycles.

- All cards passed torsion, abrasion, drop and impact, concentrated load, imprinting, and repeated use tests with no problems.

- Temperature tests caused various chip failures; however, it was stated that improved bonding will overcome the sampled problems.

- All cards withstood humidity over various extended periods, and all cards passed ultraviolet light tests, X-ray irradiation, and electromagnetic interference without problems.

- Static electricity tests that exposed the cards to a static discharge between any contact and ground of 1,500 volts through a resistance of 1,000 ohms from a capacitance of 100 picofarads caused poor and erratic performance among current cards. MasterCard specifications will require static resistance of 15,000 volts.

After the successful technological segment of the program, it moved into its second phase, the preparation of functional specifications. MasterCard stated their design criteria and included the following:

- Each manufacturer, each issuer, and each card system must have separate security keys so that a compromise at any one point does not jeopardize an entire system.

- Systems must be capable of changing keys in case they are compromised.

- Of all cards issued, 99.9 percent must be ensured of surviving a three-year life cycle.

- Terminals and cards must be capable of being updated periodically to take advantage of current chip technology.

- All vendors associated with the IC card system must adhere to quality and security standards and undergo a formal certification process.

- The storage area contained within the IC card, as well as the use of the card as an access device, must be completely controlled by the issuing institution.

- The cost of the card and terminal must be below or approaching existing component costs that use mag stripe technology.

- The cost of the processes to support IC card use must also be below or near that of existing mag stripe technology.

MasterCard said its next challenge would be to make the system easier for both the cardholder and the merchant to use, and capable of being extended to many different cultures and consumer environments. It cited three preliminary conclusions from the pilot:

- The smart card has surpassed the magnetic stripe in both durability and security.

- More work is needed to make the card easy for both consumers and merchants to use.

- The design parameters for both the card and the terminals would be distributed to manufacturers for comments so that work on production design prototypes could begin.

We believe that MasterCard has been actively qualifying and discussing vendor participation; we expect an announcement in the first quarter of 1987 as to who the program's major participants will be and how the program will expand. We believe that MasterCard has been working with as many as six IC manufacturers, including NEC and Motorola, whose chips are in the cards currently being tested. We believe Motorola is the only U.S. IC manufacturer among the six or so companies. Possible boons to semiconductor manufacturers are the requirements for multiple sourcing and MasterCard's requirement for state-of-the-art technology. Another potential benefit to semiconductor manufacturers is that, within the overall system that MasterCard proposes, it is considering biometric identification as perhaps a less cumbersome way of identifying cardholders than PIN codes. Possible biometric identification methods include digitized signatures or finger characteristics.

We believe that MasterCard will begin testing and using a production IC card by the second or third quarter of 1987. It views the semiconductor industry as a vital support link necessary to effective implementation of the technology. Unconfirmed estimates place MasterCard IC card use at the low hundreds of thousands by mid-1987, the low millions by 1988, and at a much higher volume in late 1989 to early 1990.

The VISA Approach

VISA International's strategy for smart cards is quite different from that of MasterCard. It believes that the technology is currently needed to improve current bank card services and to provide new services that can produce incremental income. It believes the current system works, that operating costs can be reduced, and so too can fraud losses. It believes that current services are highly profitable and that today's bank card business cannot effectively cost-justify smart card technology. This is in sharp contrast to MasterCard, which justifies smart card implementation to reduce losses and authorization costs, which it believes are inherent in today's system.

VISA believes that, in order to take advantage of new technologies and new services, and to improve existing services, there must be an increase in terminal penetration because different terminals are needed to accept different cards. Therefore, by the card acting as both the card and the terminal, it becomes the delivery system too and eliminates the need for a variety of terminals to be installed before new services can be provided.

For the financial community this is truly forward thinking, because the history of banking holds that authority lies in more than one place--to use the analogy of the safety deposit box, the customer brings his key, the banker does the same, and together they access the box. VISA, however, believes that the key and the lock do not have to be in two different places. MasterCard, on the other hand, approaches the system from a traditional banking operation perspective. In short, VISA views the concept as "pocket banking as compared to controlled banking."

VISA's different perspective, namely its cost justification, its view toward providing new services, and its pocket banking concept, has thrust it toward development of the next generation of smart card technology--namely, a card utilizing E2PROM technology, which it calls a super card and which falls at the most-advanced end of the card evolution spectrum:

- Embossed cards
- Track 2
- Track 1
- IC card or smart card
- Super card or super smart card

VISA is currently testing a small number of cards developed by Smart Card International and manufactured by General Instrument's Microelectronics Division. Its main purpose is to evaluate users' needs and attitudes toward the technology. Meanwhile, VISA has directly commissioned Toshiba to make a production version of the card with the requirement that the technology be on a card that meets the ISO standard of 30 mils in thickness. The time frame for completion is the fall of 1987 to spring of 1988.

We applaud VISA's strategy seeking "a gradual transition to the smarter cards of the future while supporting the coexistence of several technologies," and believe that E2 technology is the long-term answer to many future smart card applications. However, we believe that MasterCard takes a more realistic approach by attempting to use current technology within the present financial infrastructure.

E2 technology for financial applications is still not technically as feasible as for its nonfinancial applications. MasterCard's testing of the technology in a large scale pilot, researching the use and fine-tuning the system, is a manageable approach to making smart card technology realistically meet its needs in today's bank card environment. We believe that smart cards can work in the financial community today, without having to wait for E2 technology in the late 1980s. Testing the system as it exists appears most feasible from a smart card market perspective with respect to its impact on the market for semiconductors and vice versa. MasterCard is chartering U.S. market development in financial applications.

FORECAST

In all, we believe ramp-up in the smart card market is finally beginning. Today, most smart card unit demand comes from Western Europe, namely France. Forecasting the entire market is difficult, however, because of its early stages and because of the tremendous variety of applications, each with potentially huge volumes, each with its own time frame for taking off. Combined with the need to include an element of niche market opportunity, the forecasting challenge becomes even more complicated.

As an example, Table 5 lists the number of major financial cards held in the United States. Estimating how many of these cards might be upgraded to smart cards and by when is risky. Dataquest preferred to begin its assessment by looking at how many cards are currently in the market, and conservatively estimated that by the end of 1986 approximately 9.76 million cards had been distributed overtime, worldwide.

Table 5

U.S. PLASTIC CARD CIRCULATION
(Millions)

MasterCard	68.1
VISA	93.0
American Express	16.3
ATM Mag Stripe Cards	130.0

Source: Smart Card Reports
Dataquest
January 1987

In estimating the short term we chose to analyze known activities and the volume of cards expected to be used for them. We also took card capacity and current capacity utilization into consideration, making some assumptions about the market timing for large scale volumes again based on need that is already projected. In 1987 we expect worldwide production to be 49.4 million smart cards units. Barring unforeseen activity, we do not expect large scale volumes (in the hundreds of millions) until the the early 1990s.

The largest demand for smart cards is from France, with over 98 percent of the cards needed there for financial and telecommunication use. Primary semiconductor suppliers include Thomson, Motorola, and Philips. Depending on MasterCard's activity, and progress in the many Japanese tests, the demand locale could shift quite dramatically. Because of current activity, we believe nearly 51 percent of the cards will be used in financial applications, 44 percent in telecommunication applications, and 5 percent in medical, industrial, and administrative applications.

CONCLUSIONS

We are encouraged by smart card activity overall, particularly in the surge of activity seen in 1986. We believe 1987 will bring continued market opportunities and growth as the market begins its shift into high gear. Market participants should be positioning themselves now; waiting much longer may mean that the market will be closed just as it beings to ramp up. Opportunities exist for many types of IC manufacturers because the market has needs in both large-scale, high-volume applications and in the niches. The smart card market, therefore, will not be restricted to only those who are capable of withstanding the tremendous competition of commodity markets.

Semiconductor Application Markets Newsletters 1987–1988

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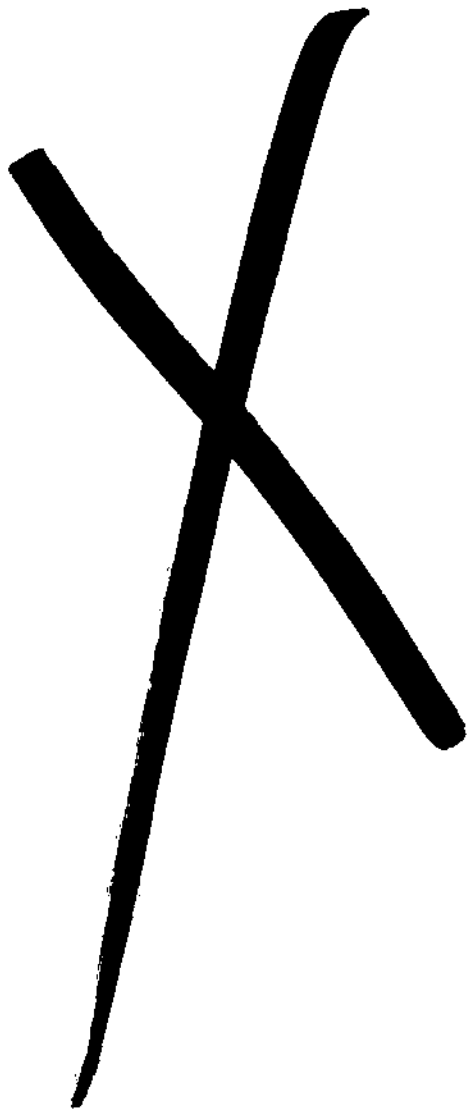

1988 SAM Newsletter Index

The enclosed SAM Newsletter Index is a quick reference guide to the SAM 1988 newsletters. It is structured as follows:

o Titles are organized by both subject and company.

  - The first part is a company list, e.g., LSI Logic.

  - The second part is a subject list, e.g., Memory.

o The newsletter month and year follow each title listing in the index. Refer to the month tab to locate a specific newsletter.

This index is updated quarterly.

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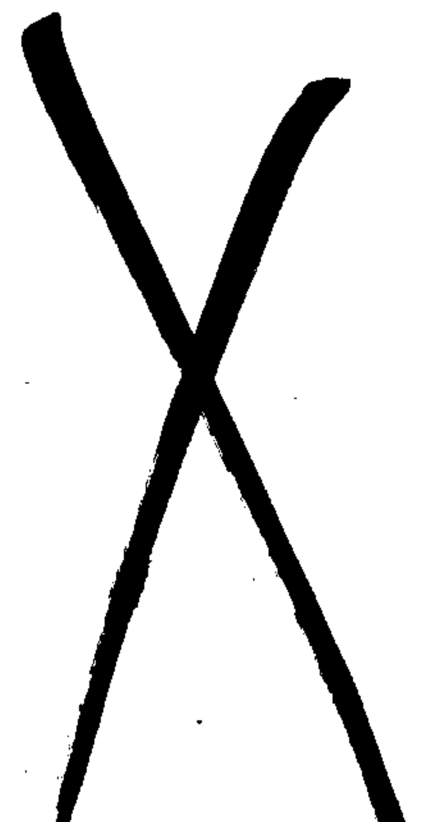

January-March

The following is a list of the newsletters in this section:

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Dataquest
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Research Newsletter

SAM Code: 1987–1988 Newsletters: January–March
1988–15

NAPM ELECTRONICS GROUP SPONSORS FIRST PURCHASING CONFERENCE

INTRODUCTION

The National Association of Purchasing Management's (NAPM's) Electronics Group held its first purchasing conference from March 2 to 4, 1988, in Dallas, Texas. Approximately 125 people from the electronics purchasing community came together to discuss the theme "Purchasing Excellence through Professional Development." Dataquest both participated in and attended the conference; this newsletter presents highlights of the event, which contained an impressive roster of speakers.

SPEAKER HIGHLIGHTS

The first evening's reception and dinner was hosted by Wyle Laboratories, after which Charles M. Clough, Wyle's president and COO, spoke about the driving forces that are changing distribution. He believes that distributors often have the best insight into changing market dynamics because they are affected first and lead the market. He cited the following market forces that will shape distribution in the future:

- Increasingly complex products are being marketed to a large audience. Broad commodity orientations are becoming focused into specially defined segments. He showed the forecast for ASIC technology, which will make up 60 percent of the industry by 1990, to substantiate this change in product mix.
- Regionalization is accelerating, with emphasis on market share growth in individual regions.
- The customer base is expanding, with emphasis on market expansion based on target end markets and meeting specific needs within those markets. He mentioned Wyle's kitting program and support of just-in-time (JIT) programs as examples.
- Partnering and concentration of resources are increasing.
- The massive move toward electronic data interchange will lower transaction costs and inventories.

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Chuck Thompson, senior vice president and director of World Marketing for Motorola's Semiconductor Products Sector, presented an industry update following Mr. Clough's speech. He presented the information from an end, or application, market focus showing the driving forces in the world's semiconductor industry. The military market was the industry's first real market, followed by business and data processing. He also cited newer markets in residential, personal, and transportation electronics, showing the increased pervasiveness of semiconductors and the room for penetration that still exists, because increasing pervasiveness in a greater number of units equals growth. In support of this, he mentioned the growth in the number of customers who now buy "reasonable" quantities of semiconductors. He believes that personal electronics has much room for growth. In all, he forecast a worldwide semiconductor market of $43 billion in 1990, growing to $160 billion in the year 2000.

Following opening remarks by Lisa Martin, Chairman of NAPM's Electronics Group, Robert J. Nahabit, C.P.M. and president of Nahabit & Associates, kicked off the next morning's events. In a motivating speech to the audience of purchasing agents and managers, he discussed the topic, "Does a Buyer Need to Be Technically Trained?" He stated that, while buyers do not necessarily need to be designers or engineers, they should understand the commodity that they are purchasing and the vocabulary of the trade. They should be able to read and understand specs and be involved in design concept meetings and forecast sessions. He stated that buyers should continue to remain active in training, including staying up-to-date on purchasing literature and regular visits to vendors. Buyers should also stay informed and participate in value-added analysis. He said that there were too many part- and order-number placers who viewed their role as picking up the phone, placing orders, and pushing paper.

The premise behind his speech was that the purchasing community members are not merely spenders of company money, but investors of corporate assets whose goal is to obtain the best return on investment. To that end, members of the purchasing community must forge ahead in education and emphasize their key role in their own organizations, Mr. Nahabit emphasized. Companies must be equipped to do the job right the first time and develop the best purchasing department possible, because if they fail to invest up front, they will pay, one way or another.

To reiterate, Mr. Nahabit said that buyers must be poised to change with the industry, although they need not be technically trained. He used ASIC technology as an example, given Mr. Clough's projection that ASICs will constitute more than 50 percent of the industry. He asked the audience if they knew how to pick ASIC vendors and how to second-source, and if they knew the definition of PG tapes and issues surrounding ASICs in surface-mount or SOI packages. Knowledge of these subjects is what differentiates the informed and trained purchasing specialist from the run of the mill, according to Mr. Nahabit.

Wes Sagawa, senior vice president of Product Marketing and Management of Arrow Electronics, spoke next on distribution in 1988. The topic of distribution was important to this audience because, when asked, most of them raised their hands to the question, "How many of you buy more than 75 percent through distribution?" This was a diverse group, coming mostly from small companies.

Mr. Sagawa stated that competition and quality are key issues and that companies must be able to adapt to change. He cited the difference between Penn Central and Chrysler Corporation in their ability to weather their company crises. Companies cannot boast and rest on historical successes, he stated, using the analogy that a person cannot continue to look in a mirror but must be looking out windows.

He also mentioned that the industry will continue to shrink. In 1928, there were 348 auto manufacturers; today there are 3. In 1928, there were 2,547 airlines; today there are 8. Mr. Sagawa thinks the same thing is happening in electronics and distribution. In 1972, the top 5 percent of distributors held 32 percent of distributor resales. Today, the top 5 percent have 48 percent, and he believes that they will have 60 percent by 1992. On that note, he mentioned the major forces challenging distributors:

- Customers want better service, especially quality and reliability.
- Suppliers are pressing for distributors to find new customers.
- Distributors and suppliers no longer receive "warm fuzzies" from Wall Street—the high-tech honeymoon is over.

Mr. Sagawa believes that distributors must take the following steps:

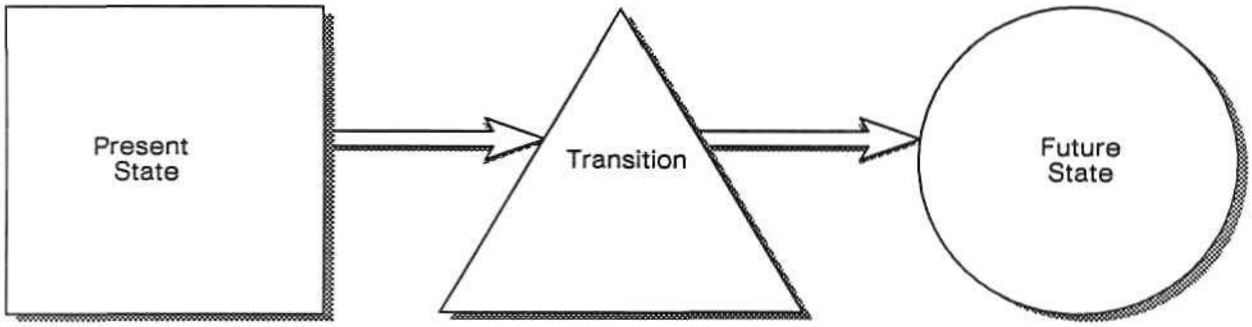
- Carry fewer suppliers
- Expand their markets and emerge into new customer segments
- Form stronger partnerships with customers
- Continue to make on-time delivery a quality issue

Robert P. Ebers, president of Impletec, a consulting and training firm, gave a presentation on adapting to change. He said that the United States has the cultural handicap of not having enough flexibility to allow for change. Old management patterns are no longer working, and the United States is not holding up well under competition. He said that people change before organizations do and discussed the key factors behind change.

People's actions, said Mr. Ebers, are a response to external environments over which they have little control. These environments provide opportunities and problems and also provoke anxiety. If people can take advantage of the opportunities, reduce or solve the problems, and eliminate anxiety, they are successful. But they frequently find themselves repeating the same action, often as a habit, because this is what has been successful for them in the past. When trying to change, however, what needs to change are the very things that have proven successful in the past.

According to Mr. Ebers, Americans think in linear or sequential "left brain" format. This, he said, has created atrophy in the work force because we have created a work force that cannot change, does not take responsibility, and cannot make decisions, especially at the accelerating pace that current markets are dictating.

Mr. Ebers illustrated the three distinct phases of change:



These three distinct stages of change must occur before complete change will happen, he said. They must occur in the above order, and pain or anticipated pain absolutely must exist before any major changes can be made. Pain, he said, is part of the process. Too often, in the United States, we try to reverse the order of the process by deciding what the change should be and then applying it immediately to the current environment—thereby forcing a transition.

Mr. Ebers also stated that during the transitional period preceding a major change, the following phenomena will occur:

- Heightened energy
- Increased struggle to gain control
- Stress
- Increased conflict

These transitions must take place and be managed, however. One way Mr. Ebers suggested increasing flexibility and willingness to change is to introduce trivial (but creative) changes in people's day-to-day life styles. These little variations of routine increase the ability to adapt.

Stan Bruederle, vice president of research for Dataquest's Components Division, provided the audience with an industry update. He said that political and economic uncertainty would prevail in 1988, although growth will occur in electronics. Dataquest's semiconductor market growth projection for 1988 is as follows:

- 21.1 percent in North America
- 20.7 percent in Japan
- 14.0 percent in Western Europe
- 31.5 percent in Rest of World

Mr. Bruederle also predicted that the second half of 1988 will be weaker than the first half, beginning a slowdown that will be present throughout 1989. He discussed the fact that a shortage of capacity exists for state-of-the-art technologies, such as 1Mb DRAMs, 32-bit MPUs, ASICs, and Fast SRAMs.

Gordon Marshall, president, CEO, and chairman of the board of Marshall Industries, discussed the effects of government intervention. He expects the current DRAM shortage to be around for a while and to get worse before it gets better, which will probably affect the overall health of the electronics industry.

Mr. Marshall's view of the progression toward government intervention is as follows:

- The cut in DRAM prices was started by a U.S. company.
- The Japanese semiconductor manufacturers followed suit.
- The United States then cried to the U.S. government.
- FMVs and the trade agreement resulted.
- Japan slowed production because the industry was in a recession.
- Japan slowed capital investments.
- The gray market dried up temporarily.
- 256K capacity was being shifted to 1Mb (no new capacity was being added).
- 1Mb yields have been extremely low.
- Concurrently, American business picked up and demand soared.

The result, he said, has been a "double whammy." He mentioned that 1Mb DRAM demand may outstrip supply by as much as 100 million parts, worldwide, but that it takes an investment of $100 million to build a front end that can make 20 million parts. Therefore, the name of the game is a huge commitment. U.S. companies, however, are small in comparison with the huge size of Japanese conglomerates. A company has to progress through the DRAM manufacturing learning curve—it cannot just back into 1Mb production without going through 64K and 256K. This makes it difficult for U.S. companies to reenter the market.

Mr. Marshall believes that the U.S. government has discouraged Japan from getting too involved, one way or another, and that the result is a vicious cycle. The Japanese, he said, are fiercely competing against one another, and the United States is getting caught in the middle.

John V. Roach, president, CEO, and chairman of the board of Tandy Corporation, spoke about keeping the United States out in front. He said that companies must be low-cost producers and mentioned three key strategies to accomplish this:

- International sourcing—buying wherever it makes the most sense. Tandy has 400 people in the Far East, half of whom are in some form of quality control. They issue all their purchase orders in dollars, and they would rather pay a bit higher price in their contracts and know their costs than take the hit for exchange rate fluctuations.

- Vertical integration—make the make-or-buy decision based on what makes the most sense. Tandy is highly integrated except, for example, with semiconductors. To that effect, Mr. Roach remarked that usually there were more times when he was glad he was not a producer of semiconductors than times when he wished he was—the current situation included.

- Manufacturing facilities location—put manufacturing facilities where it makes the most sense. Manufacturing automation has displaced much of labor cost. This, combined with exchange rates, favors U.S. production in many circumstances. He said that manufacturers should take advantage of the latest technology for quality control and efficient manufacturing.

Mr. Roach thinks that the United States has a unique window of opportunity—a rare time to create a turnaround in U.S. competitiveness. Automation is available, the yen is in our favor, and sentiment has rallied around U.S. support. He said that manufacturers should play on all fronts by being both importers and exporters, and both domestic and international manufacturers.

Jerry Wasserman, vice president of Arthur D. Little, Inc., gave a presentation on Japanese pricing policies. He said that there are several key factors that explain pricing policies:

- Cost of money
- Subsidies
- Profit expectation
- Market scope
- Domestic markets
- Capital intensiveness

The cost of money is much lower in Japan, where the prime rate is about 4 percent compared to 9 percent in the United States. The savings rate is 20 percent of disposable income, compared with the U.S. rate of 5 percent.

Subsidies come in the form of MITI-sponsored programs and trading companies that assume marketing costs, extended payment terms, and accelerated invoice settlement. Profit expectations are low in Japan. Mr. Wasserman used NEC's earnings of $100 million on $17 billion of sales last year as an example. The emphasis in Japan is on revenue growth, which is more important in Japan than profit—market share is paramount. Stockholders have little power.

Japanese companies look to world markets. Here again, market share is key. He said that Japanese companies are worldwide companies that sell domestically; most U.S. companies sell domestically and "just happen to be" international. The emphasis is quite different. Japan's domestic markets are highly protected. Performance expectations are high and government regulation is stringent. Requirements for selling in Japan are complicated.

With respect to capital intensiveness, he said that automation is rampant in Japan and that the focus has been on high-quanlity production and products. Labor-intensive manufacturing has moved offshore.

All combined, pricing in Japan is used as a tool for capturing market share. Japanese companies operate in an environment that permits and encourages aggressive pricing strategies. This focus is quite different than that of U.S. companies.

Tom Temin, editor of Electronics Purchasing magazine gave a speech on proactive purchasing strategies. He said that there were 14 pressures on buyers and sellers of semiconductors in 1988. He explained them accordingly:

- Dealing with mergers and acquisitions
- More danger of government intervention
- Tighter conditions for VLSI—stretching lead times
- Demand exceeding supply of surface-mount components
- Fewer distribution channels carrying fewer lines
- Political instability in Korea
- Uncertain capital equipment markets (shaping trends in available technology)
- Explosion in noncatalog solutions
- Greater demand for zero-defect and reduced incoming inspection
- Shorter product life cycles
- Greater diffusion of purchasing to worldwide markets
- Lead time management by suppliers
- Pressure on military suppliers as resources go to support shortages in the commercial market
- Greater worldwide technological prowess, competition between regions

DATAQUEST CONCLUSIONS

The day ended with a panel of purchasing managers discussing how they would handle tough issues. This created a good forum for audience participation. The last day's event focused on plant tours at Texas Instruments and Boeing Electronics.

The users in the audience had a good opportunity to discuss key issues throughout the conference. Speakers addressed a variety of topics that were interesting and insightful, and we were particularly pleased to gain the perspective of such a unique and qualified list of speakers.

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Research Newsletter

SAM Code: 1987–1988 Newsletters: January–March
1988–14

CHIP SETS: TRENDS AND BENEFITS

SUMMARY

January's announcement of several ICs that would allow PC manufacturers to build 100 percent-compatible clones of IBM's complete new line of personal computers—smaller, faster, and with more features than the originals—stands as continued evidence that there are few areas safe from infiltration by these value-added VLSI parts known as chip sets.

Chip sets are showing up everywhere: in peripherals, in graphics systems, in telecommunications, and in military electronic equipment, among other areas. Dataquest estimates that, in just a few short years, chip sets have grown into a $0.5 billion annual business and will top $1.0 billion by 1990.

While some debate remains over what constitutes a chip set, the following is Dataquest's definition:

> One or several VLSI chips, available off-the-shelf, that integrate (and usually optimize) some or all of the logic, interface, memory, and/or processing functions for a specific system, architecture, or interface protocol.

Regardless of a device's precise categorization, it is clear that ICs that meet this definition are in high demand.

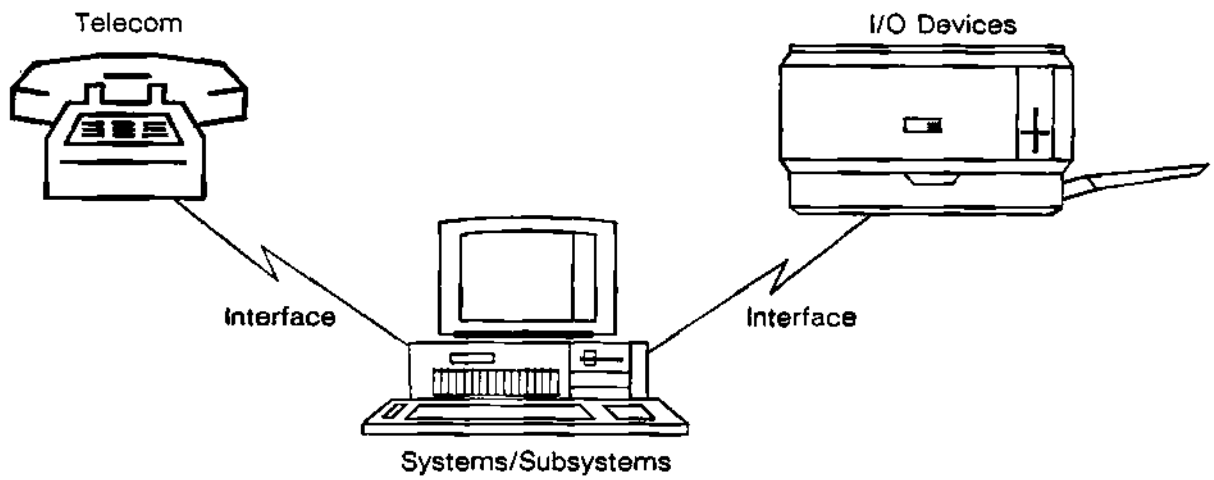
Chip sets were born of the electronic equipment industry's (actually driven by the end user's) seemingly insatiable demand for smaller boxes with higher performance at lower cost. Chip sets can provide these benefits, and more, to OEMs—but, of course, not without some potential pitfalls, as described in the section of this newsletter entitled "Rewards and Risks of Chip Sets."

EXISTING CHIP SET APPLICATIONS AND SUPPLIERS

To date, personal computer system logic, graphics, and disk drive controllers have accounted for the vast majority of chip set revenue. Other applications (see Figure 1) gaining popularity include interface boards (allowing various add-on products or incompatible systems to communicate with the host system), input and output devices (printers, scanners, and facsimile machines), as well as telecommunications products such as local area networks (LANs) and modems. Figure 2 shows Dataquest's preliminary forecasts for system logic, low-end graphics, and disk drive chip sets for the DOS-compatible PC market. Tables 1, 2, 3, 4, and 5 list some of the suppliers for those three categories, as well as some suppliers of several interface and telecommunications chip sets.

Figure 1

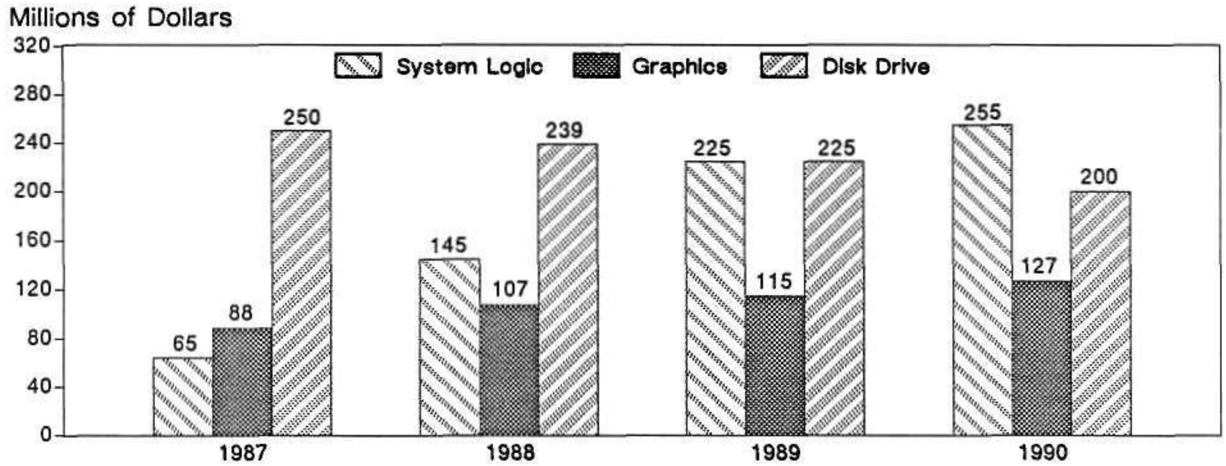
Major Chip Set Applications



Source: Dataquest March 1988

Figure 2

Chip Set Market Forecast
PC System Logic, Graphics, and Disk Drive



Note: A drop in controller board chip revenue is due to a migration to motherboards.
Actual chip usage will increase, but it is not reflected here.

Source: Dataquest
March 1988

Table 1

PC System Logic Chip Suppliers

	PC Bus	AT Bus	Micro Channel
Chips & Technologies	X	X	X
Faraday (Western Digital)		X	X
G2 (LSI Logic)		X	
Intel (Uses Zymos' Chips)		X	
Logic Star		X	
Texas Instruments		X	
UMC		X	
VLSI Technology, Inc.		X	
Zymos	X	X	

Source: Dataquest
March 1988

Table 2

Graphics Chip Set Suppliers

Chips & Technologies	NSI Logic
Cirrus Logic	Paradise
Everex	Tseng Labs
Gemini	Video 7
Genoa	

Source: Dataquest
March 1988

Table 3

Disk Drive Chip Set Suppliers

	ST412 /506	SCSI	Other
Adaptec	X	X	
Advanced Micro Devices		X	
Cirrus Logic	X	X	X
Data Technology	X	X	
Emulex	X	X	
Logic Devices		X	
NCR	X	X	X
SMS	X	X	
Western Digital	X	X	X

Source: Dataquest
March 1988

Table 4

Interface Chip Set Suppliers

	MCA	VME	ISDN	FDDI
Advanced Micro Devices			X	X
Altera	X			
AT&T			X	
Chips & Technologies	X			
DY-4		X		
Force		X		
Intel			X	
Mitel			X	
Motorola		X		
Performance Technologies		X		
Plessey				X
Rockwell			X	
SBE		X		
Siemens			X	
Technology Consortium		X		

Source: Dataquest
March 1988

Table 5

Telecom Chip Set Maket Overview

	LAN/Ethernet	Modem/Fax
Advanced Micro Devices	X	X
Chips & Technologies	X	
Exar		X
Fairchild		X
Fujitsu	X	
GE		X
Gould/AMI		X
Intel	X	X
Mitel		X
Mostek	X	
Motorola	X	X
MPS		X
National Semiconductor	X	X
NEC	X	
Oki		X
Rockwell	X	X
Seeq	X	
SGS/Thomson		X
Sierra Semiconductor		X
Silicon Systems, Inc.		X
Standard Microsystems	X	
Texas Instruments	X	X
VLSI Technology		X
Western Digital	X	X
Xecom, Inc.		X

Source: Dataquest
March 1988

As is evident, many options currently are available, each with unique features and capabilities. But the decision of which products to use, if any, requires careful examination.

REWARDS AND RISKS OF CHIP SETS

The User's Perspective

Chip sets can provide an overall optimum solution for many new system designs. In terms of integration, for example, well-engineered chip sets offer a significant reduction in the number of components needed for a given system. Table 6 illustrates the reduction in ICs required to build an IBM PS/2 Model 80 clone, using the chip set offering from Chips & Technologies, Inc.

Table 6

PS/2 Model 80: IBM ICs versus Chip Sets

	IBM PS/2 Model 80	Chips/280 Implementation
Standard Logic	144	43
Microdevices	8	4
ASICs	19	0
Memory Devices	13	12
Chip Set Devices	0	7
Total*	184	66

*Does not include system RAM

Source: Dataquest
March 1988

Along with integration come benefits of optimized performance and system reliability. Higher functionality and lower power consumption, of course, are typical by-products of chip count reduction, due to the lessening of on- and off-chip and package delays. In addition, chip set designs usually integrate as many related functions as possible onto each device. Fewer devices on a board and, hence, fewer solder joints and package connections can offer greatly enhanced reliability.

Another benefit of using chip sets is that they are available immediately, almost as off-the-shelf commodity parts and, thus, can speed time to market. This is particularly important to OEMs building products with short product life cycles. (Personal computer manufacturers, for example, must cycle new designs every 6 to 18 months to remain competitive.)

For many OEMs lacking their own IC design and manufacturing capabilities, chip sets may provide the only viable path to entry into a given market. Most systems can be built around standard logic devices. However, with the cost of most chip sets near that of the components that they are replacing and with their inherent advantages, chip sets may be the commodity of choice.

Using chip sets, however, is not for everyone. Product differential is often more difficult, because every OEM using the same off-the-shelf parts ends up with basically the same system. And while most chip sets are designed using ASIC methodologies and CAD tools enabling modification of parts for a given buyer, adding proprietary features to a chip set has an impact on time to market as well as component cost.

In general, most chip sets are sole-supplied. That is, only one vendor actually offers the part, although each supplier usually has several manufacturing foundries available for its own use.

A final concern in the use of chip sets is that of legality, especially with parts that enable the unauthorized cloning of another company's system. For example, OEMs that are currently examining the building of IBM PS/2-compatible systems are being directed by chip set suppliers to obtain licensing through IBM before using the seller's chips. Certainly, much uncertainty still clouds this area. Thus, it behooves potential users to do their homework on these types of systems first.

The Supplier's Perspective

A silicon supplier's ability to provide the systems solutions available through chip sets truly adds value to the product. Thus, vendors are generally able to realize much higher margins on chip sets than on other parts. Interestingly, many chip set suppliers do not own their own fabs and are able to shop around for the best technologies at the lowest prices while avoiding the internal cost of constantly developing leading-edge processes themselves. Of course, such practices are not without obvious supply risks.

For silicon vendors that sell into markets already seeing penetration by chip sets, the absence of similar offerings in their product portfolios may result in substantial loss of business. Take, for example, Intel, which, without its own chip set, essentially lost $40 million worth of microperipherals business to Chips & Technologies last year. In a case such as this, a vendor cannot afford to stay out of the chip set business. (Intel has, in fact, signed an agreement with chip set supplier Zymos for AT-compatible parts and reportedly is developing its own PS/2-compatible devices.)

Many additional chip set applications remain to be uncovered in the data processing, communications, industrial/instrumentation, consumer, automotive, as well as military markets. Silicon manufacturers with system expertise can serve as market drivers and reap the rewards by introducing innovative products.

But developing and supporting chip sets are not trivial tasks. They require a comprehensive understanding of an OEM's system as well as the needs of the intended final users. And just as the end products experience short product life cycles, so (and even more so) do the ICs going into those systems.

Heavy support, including technical assistance and extensive documentation, is demanded from users, and herein lies a major differentiating feature among various chip set suppliers. As a result, many companies are not well equipped to become significant players in the chip set business.

STRATEGIES FOR SELECTING (OR BECOMING) A VENDOR

Price and performance are obvious key considerations in deciding whether or not to use chip sets, but in selecting a supplier, the following issues are equally, if not more, critical:

- System expertise
  - It is important to know whether a potential supplier is merely copying parts from another company's data book or truly understands your system requirements. This can make the difference between fully compatible parts and almost compatible parts.

- Track record
  - Has the potential vendor been delivering parts in a consistent, timely manner?
  - Have the parts always performed to specifications?
  - Has the supplier locked in some other solid, loyal customers, or have they switched vendors after one or two transactions?
- Foundry/second sourcing
  - More often these days, rumors are spreading about upcoming foundry capacity shortages, particularly in sub-2-micron CMOS technologies. The recent earthquake in Japan that debilitated the Hitachi fab and the current big shortage of memory chips throughout the world have the potential to shrink capacity further for nonmemory products, including chip sets. Now, more than ever, multiple-sourcing and long-term contracts for capacity from a vendor's foundry are essential.
- Growth path
  - How committed and capable is a supplier to fulfill product migration needs?
  - How well resourced is a supplier in terms of cash, capital, and personnel?
  - Having access to a product line that can be upgraded and expanded easily may provide the edge needed in remaining competitive.
- Flexibility
  - Many OEMs will need proprietary or specialized features incorporated within their parts. While many of the suppliers can accommodate these needs, not all can provide turnkey services or deliver CAD tools to the OEM to perform its own modifications. Timing, pricing, and level of customization are all important factors here.
- Service, service, and more service
  - Although this term is almost trite these days, the use of chip sets necessitates a rekindling and revamping of the concept. A user of chip sets has a lot at stake: with them, the entire heart of an OEM's system essentially has been turned over to a third party. For this reason, it is imperative that the supplier truly act as part of the team. A chip supplier must be willing and able to go to any lengths to ensure that the OEM's system gets to market on time and according to specifications.

Without a doubt, chip sets show promise of many benefits to users and suppliers alike. New architectures and applications are emerging for a variety of electronic equipment, including digital televisions, VCRs, and flight and automotive control systems, to name a few. The challenges put forth, then, are these:

- How will each OEM optimize the use of chip sets?
- How will each IC supplier be a player in the chip set market?

Nanci Magoun

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Research *Bulletin*

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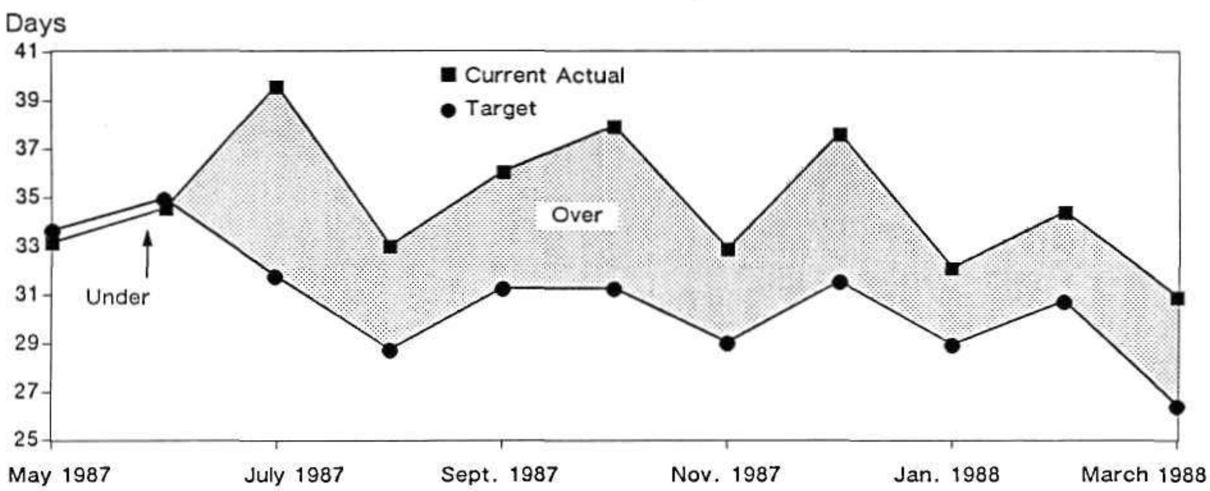
1988–13

MARCH PROCUREMENT SURVEY: AVAILABILITY TURNS INTO ALLOCATION

The availability crunch of high-density DRAMs and 32-bit microprocessors that we highlighted in February has continued unabated, and in many cases, DRAMs are on allocation. Overall targeted and actual inventory levels declined this month, as shown in Figure 1, while 60 percent of the respondents reported that their sales have risen. This outcome reinforces how end-use demand affects procurement practices—end-use demand decreases inventories while key raw material supplies remain tight. As shown in Figure 2, the computer segment of the survey showed actual inventory levels rising slightly (up 3 percent over target), but anything within this range reflects good inventory control. Except for DRAMs, lead times have remained stable at around 12 weeks, reflecting adherence to contractual delivery schedules.

Figure 1

Current Actual versus Target Inventory Levels
(All OEMs)



Source: Dataquest
March 1988

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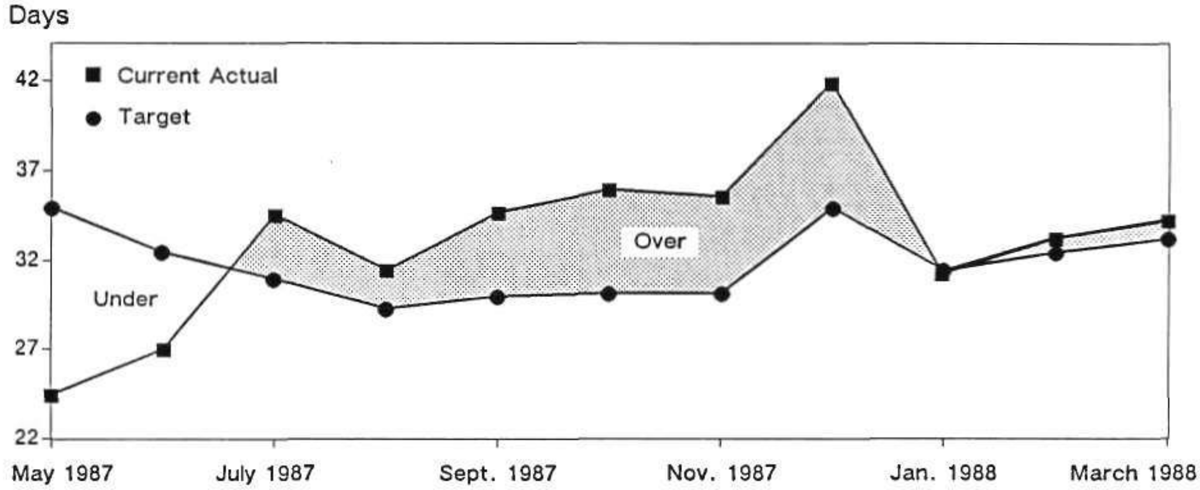
Figure 2

Current Actual versus Target Inventory Levels (Computer OEMs)



Source: Dataquest March 1988

Overall pricing (except for DRAMs) has remained relatively unchanged since last month, while orders to distributors have continued at the same elevated levels of last month.

DATAQUEST OBSERVATIONS

The current availability problems affecting DRAMs and high-end microprocessors are not as severe for users who have in place long-term procurement arrangements. Granted, most users want more of these parts and improved lead times, but it appears that those who have good relationships with vendors are faring better than those who do not. As mentioned in last month's report, the balance of supply with demand for DRAMs and 32-bit MPUs will begin to be seen by mid- to late summer (third quarter 1988) as production volumes come into the market. The rest of the market appears fairly well balanced as supplies continue to meet demand forecasts.

Mark Giudici

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Research *Newsletter*

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1988-12

THIRD ANNUAL PROCUREMENT SURVEY—MAJOR ISSUES SHIFT IN 1988

SUMMARY

Results of our third annual procurement survey were announced at Dataquest's Semiconductor User and Applications Conference held in San Francisco, California, in late February. This year, the most important issue raised by major electronic equipment manufacturers was that of component availability, stretching lead times, and shortages.

Semiconductor users also stated that their plans to shift electronic equipment production offshore were slowing—a trend that for now reverses a major move seen in the last two years. Although the issue of cost and cost reduction is still paramount, the overall frenzy has calmed somewhat during the last twelve months.

The manufacturers that make up the Electronic Business 200 participated in our annual data and trends-gathering project, which takes a look at what semiconductor buyers are saying. This year, the 44 percent overall survey response rate indicates that users expect to increase their 1988 purchases by more than 13 percent. In our 1987 survey, users projected growth for the year at just over 13 percent, while the actual industry growth was 21.4 percent. We believe that users continue to be cautious in their projections despite the general consensus that demand is robust. Dataquest believes that North American semiconductor consumption will grow 21.1 percent this year.

Survey Structure

Each year, Dataquest's Semiconductor Application Markets service gathers information for semiconductor manufacturers about their customers and markets in the United States. Users who receive this information use it as a sounding board to compare their business perspective with that of their peers. In all, both sides get a better understanding of the business issues facing semiconductor buyers and sellers in the coming year.

For our surveys, the original list of 200 companies was pared to eliminate component, semiconductor, and software companies that do not buy semiconductors for use in their electronic systems and subassemblies. We also eliminated distributors from the survey audience. About 150 companies remain. Using this list, we then identify and

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survey by telephone each procurement location within the 150 companies. Our interviews are held with buyers, purchasing managers, or individuals who are in material or corporate contract management. Nearly 600 individual locations make up the total audience. Figure 1 shows the geographical locations of these major customers.

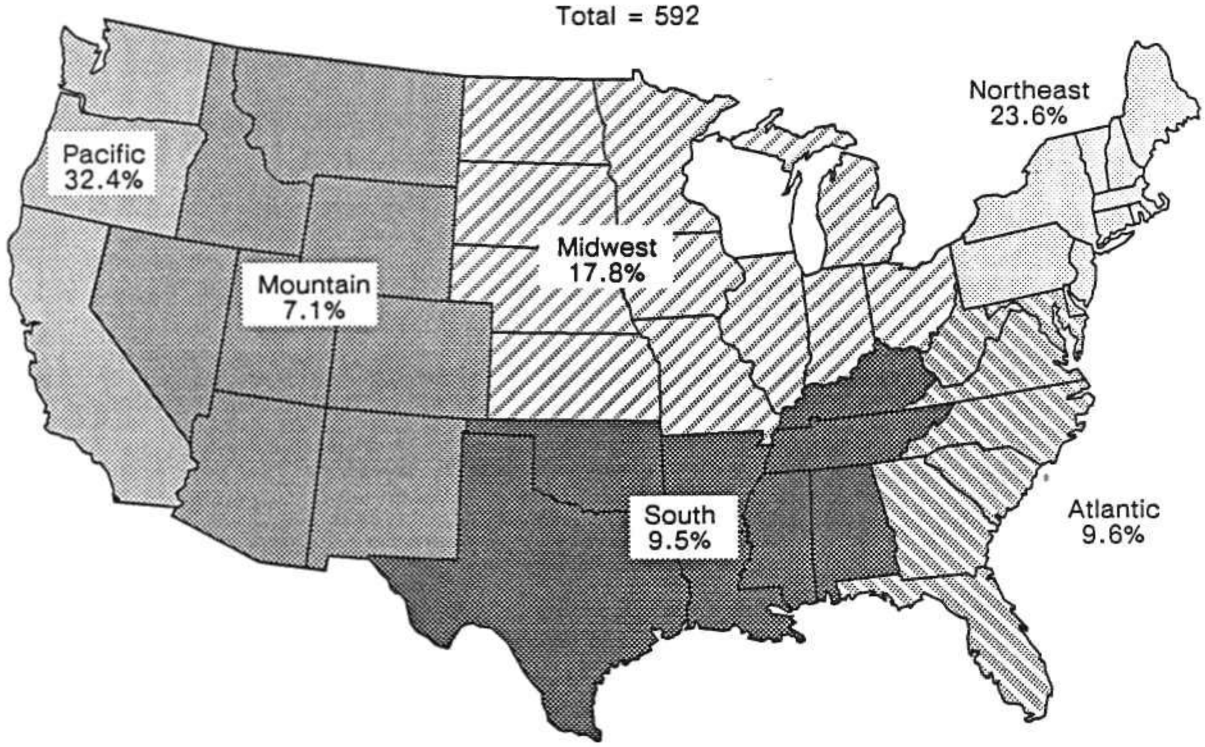
We estimate that these users account for $260 billion in electronics revenue and 60 to 65 percent of North American semiconductor consumption. Obviously, when it comes to purchasing, many of them carry clout.

Figure 2 reflects the audience in terms of their major line of business. There are fewer data processing and communications participants than their purchases would indicate, since these are the two largest markets for semiconductors in the United States. The industrial base, much larger in number, is actually more diverse and fragmented, thus it accounts for a much smaller percentage of total purchases.

Figure 1

Procurement Survey Audience

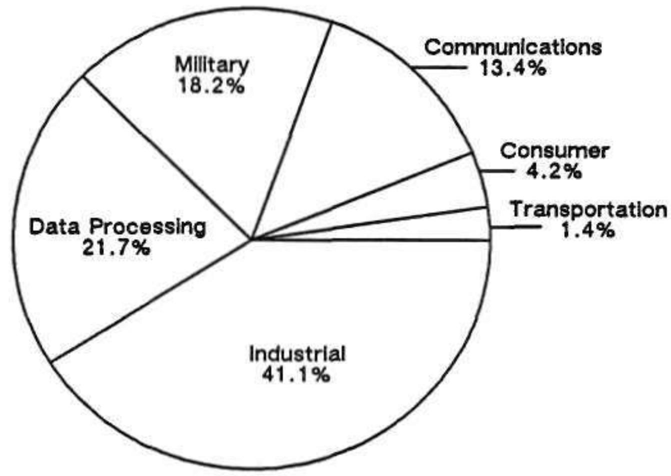
Total = 592



Source: Dataquest
March 1988

Figure 2

Survey Audience by Major Line of Business



Source: Dataquest
March 1988

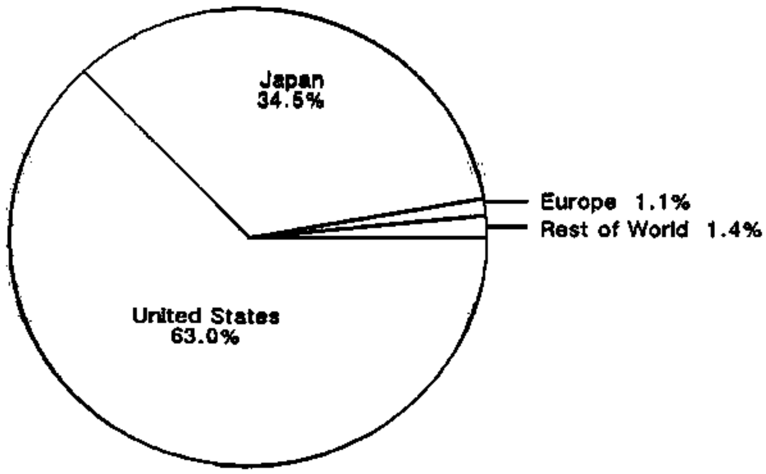
ASSESSING GLOBAL IMPACT

Once again, statistics were gathered about the regional base of semiconductor suppliers. We defined the regional base as the semiconductor company's country of origin and found that not too much has changed since last year. In this year's survey, 80.5 percent of purchases were made from U.S.-based semiconductor manufacturers, down slightly from 83.0 percent the previous year. Japan and Europe came in at 17.1 and 1.0 percent respectively; the Japanese portion was up from last year's 14.0 percent, while the European portion remained flat. This coincides with the 1987 market rebound that was driven by data processing—particularly PCs and related peripherals, which are memory intensive. ROW suppliers dropped slightly from 1.8 percent last year to 1.4 percent this year.

It's interesting to note that the value of components bought from non-U.S. suppliers was directly related to the type of equipment the electronic equipment manufacturer produced. As mentioned earlier, data processing manufacturers rely on MOS memory. This tendency can be seen in Figure 3, which shows the regional supplier base of users in the data processing arena.

Figure 3

Regional Supplies Base of Data Processing User



Source: Dataquest
March 1988

Shifts Offshore

Table 1 shows the response to our question about anticipated shifts to offshore production. The good news is that far fewer companies will shift a great deal of production. However, about the same number of users as last year still expected some shift. More users said that no movement was likely. Even more noteworthy was that for some, the word "shift" meant going to Western Europe or coming back to the United States. The respondents cited currency exchange rates and advances in automated manufacturing for their no longer having the need to move. The users said that labor costs are becoming a less significant portion of total cost and that many hidden costs associated with offshore production have become apparent over the last two years—including shipment costs, language barriers, and overall communication difficulties.

Users who believed that some move would occur stated the following as the reasons for their decision:

- Lower assembly costs
- Falling dollar, high price of yen, and other exchange-related reasons
- Buying and producing in local markets (where products are sold)
- Better quality

Table 1

Anticipated Shift to Offshore Production

Response	1986	1987	1988
A Great Deal	84.0%	10.1%	3.3%
Some	35.9%	33.2%	34.0%
Not at All	55.7%	56.7%	62.7%

Source: Dataquest
March 1988

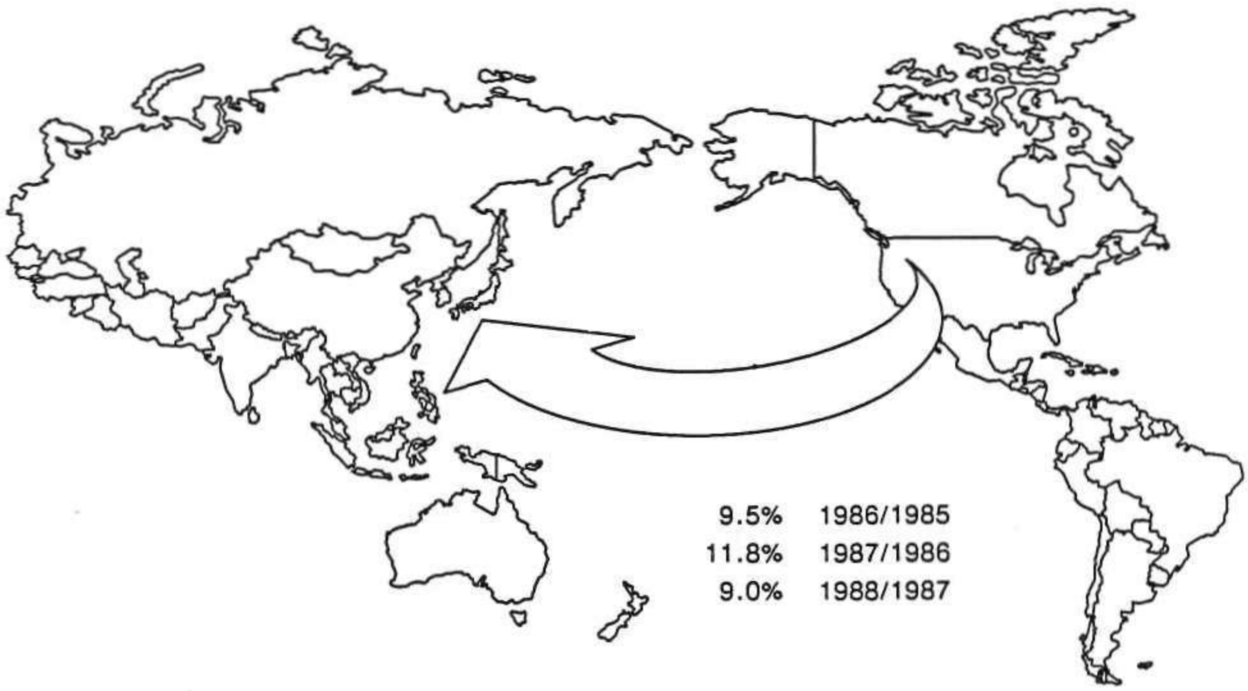
We believe that for the most part, the companies that had plans to move their facilities have already done so. Two years ago, we were the first to see this trend and said that it was primarily the data processing manufacturers who planned to move. This was a serious indicator for the U.S. market because of its reliance on data processing for a healthy semiconductor market. As a result, we saw dramatic increases in ROW semiconductor consumption. Today, ROW semiconductor consumption is 41 percent data processing and 45 percent consumer (a reflection of Japan's shift of low-end consumer goods). The third largest semiconductor market in the ROW is communications at 9 percent.

For the most part, users said that any further shifts would not significantly impact their domestic semiconductor consumption. While Dataquest's Asian Semiconductor and Electronics Technology Service still forecasts high growth in ROW consumption, projections are for a more moderate 32 percent growth in 1988 compared with the 62 percent and 54 percent seen in 1987 and 1986, respectively. Figure 4 shows the estimated U.S. consumption that, according to our audience, may still move abroad. This pattern coincides with historical growth rates in ROW and again indicates a slowing.

Once again, the message to semiconductor manufacturers is clear: Be a worldwide participant or lose position in the global market.

Figure 4

Estimated U.S. Semiconductor Consumption Moving Offshore
(Percent of Total Dollars)



Source: Dataquest
March 1988

ASSESSING INVENTORY LEVELS

Dataquest believes that fundamental industry transitions are still occurring that are significantly changing manufacturing operations. Offshore production is one, but streamlined operations, automation, and an overall concern about competitiveness are affecting the way that manufacturers are doing business with their suppliers. Many users mentioned "becoming world class" as a major goal and concern.

To this end, inventory strategies put in place over the last two years appear to be holding, despite the severity of the current DRAM crisis. This may be because many larger, more "sophisticated" companies implemented these programs, and they are the companies that established the partnerships that were required to make these programs successful. The partnerships, coupled with purchasing power, may mean that supply, though lean, is available, thus keeping inventory programs from crashing. Many companies that we have spoken with since the survey have indicated complete commitment to their inventory programs.

Over the past nine months, in our monthly surveys of a smaller audience, Dataquest has been is seeing an absolute resolution on the part of users to keep their inventories in line. Any month-to-month shifts are remedied in subsequent months. Right now, users are carrying about five to six weeks of inventory. Our annual survey statistics indicate the same thing. More users said that they were planning small increases in their inventories, but about the same number said they are planning decreases. Still, 40 percent said that target levels were in sync with current levels. Overall, we are not seeing any major changes or hiccups in inventory levels or management. We believe that this is quite promising, given the current industry environment.

WHAT ARE THE USERS SAYING ABOUT ASICs?

The adoption of ASIC technology continues to be of great interest. Although the procurement community is often unprepared to comment on a company's ASIC plans, we believe that their answers are revealing nonetheless. Users who do not know about ASIC use are an indication that ASIC adoption is still not far enough down a company's learning curve. Buyers who are aware and provide us with insight are an indication that more and more companies are integrating the knowledge of purchasing, design, and marketing, up front in system development—a trend we continue to see.

Answers to our survey continue to show that companies are relying on internal versus external design teams at a rate of three to one. This finding has been consistent over the past three years. Last year, 60 percent of our audience were nonusers of ASIC technology and 45 percent of them planned to adopt the technology. This year, only 50 percent did not use the technology, and of those, 59 percent believed that their companies were on the move to adopt the technology. This shows that the move to ASICs is continuing at a rapid pace.

Table 2 shows the nonusers and their major line of business for the past three years. Clearly, the data processing community has led the way and has been largely behind the ASIC industry's phenomenal growth. The last bastion is the industrial market. Reaching this multifaceted, highly fragmented, and somewhat conservative audience has been a real challenge. Geographically, they are widely distributed and their systems usually have stringent requirements and are produced in smaller volume, making the design costs associated with ASIC technology not as cost effective as a traditional solution. Price pressure on the ASIC market and supplier awareness of unique needs in this diverse but remaining marketplace should promote ASIC awareness and adoption in these companies.

Table 2

Who Are the ASIC Nonusers?

	Percent of Total Responses		
	1985	1986	1987
Data Processing	22%	18%	13%
Communications	16	11	15
Industrial	45	49	55
Consumer	2	6	2
Military	15	14	15
Transportation	0	2	0
Total	100%	100%	100%

Source: Dataquest
March 1988

We asked the nonusers what ASIC design methodology would be their technology of choice. Once again, we found that preferences varied by the major line of business of the respondents. They answered accordingly, with the technologies ranked by level of interest, as follows:

- Data Processing
  - Cell-based ICs
  - Gate arrays
- Communications
  - Cell-based ICs
  - Programmable logic devices
- Industrial
  - Programmable logic devices
  - Cell-based ICs
  - Gate arrays
- Military
  - Cell-based ICs

THE MAJOR ISSUES

In each of our surveys, we have asked the users an open-ended question about the major issues that they are facing in the coming year. Table 3 shows a comparative look at the main issues over the last three years.

In 1987, the top concerns involved the traditional pricing, availability, and quality. Yet, all of the issues also involved cost and cost reduction, including concerns about offshore manufacturing and procurement, which first appeared last year. User concerns about surface mount, ASICs, and product obsolescence also related to cost. Our analysts read each survey individually and the tone of last year's survey was much more frenetic than ever, with heated comments about competitiveness, international markets, and "buying American." Clearly, concern about the U.S. market position was rampant, and cries about government intervention and FMVs rang out loud and clear.

This year, the tone is much calmer, even though many of the issues are similar. At present, the major concern is availability. A myriad of concerns about memory components have replaced last year's concern about FMVs. Cost control is still a major concern, but offshore procurement and manufacturing have moved off the list. Even more startling is the lessening concern over quality. We believe that for many customers, Japanese and U.S. component quality has finally reached parity. The importance of quality has not dropped, but concern because of lack of quality has. Users are still working on inventory management, which is evidenced by the continuing concern about vendor reduction and just-in-time delivery (JIT). Concern over currency exchange rates has increased dramatically.

Table 3

The Major Issues

1986	1987	1988
Pricing	Pricing	Availability/lead times/ shortages
Quality/reliability	Availability/lead times	Pricing
On-time delivery	Quality/reliability	On-time delivery
Supply/availability/ shortages	On-time delivery	Cost control
JIT/inventory control	FMVs/trade agreement	Memories
Reducing vendor base	Cost control	Quality/reliability
Product obsolescence	JIT/inventory control	Reducing vendor base
Second-sourcing	Surface mount	New products/obsolescence
Forecasting	New products/obsolescence	JIT/inventory control
	ASICs	Fluctuating yen/currency exchange
	Offshore manufacturing and procurement	

Source: Dataquest
March 1988

DATAQUEST CONCLUSIONS

We believe that high technology companies that want to become substantial competitors must be equally expert in design, manufacturing, and marketing. Carefully listening to the customer and keeping attention focused on the customer's customer is the key to remaining innovative. Companies must be able to seek and identify major trends and then react quickly, precisely, and with ease. Constant change is imminent.

To that end, we believe that companies that can effectively integrate marketing, design, purchasing, and manufacturing will be one step ahead of shorter product life cycles and product and market development. Integrated user and supplier relationships are paramount to competitiveness because in this manner, excellence is exchanged and enhanced. The word "partnership" may be overused and trite, but semiconductor buyers and sellers who can effectively tackle and solve the issues discussed in this year's survey will be on the leading edge. The users that are getting their parts today are those that established relationships when the call for "partnerships" was first sounded in 1986.

Overall, we believe that users are somewhat conservative in their estimates of future in purchases. Availability, lead times, and shortages will remain critical issues, but for those with close buyer/vendor ties, supply may be somewhat more secure. These connections may also temper the historical exaggeration seen in industry cycles. The shift to offshore manufacturing appears to be slowing, while cost control and manufacturing strategies continue to play a critical role in determining buyer action.

Anthea C. Stratigos

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1988-11

1988 SEMICONDUCTOR USER AND APPLICATIONS CONFERENCE: SUCCESS BREEDS SHORTAGES

SUMMARY

Dataquest's most successful and widely attended Semiconductor User and Applications Conference ever was held February 22 and 23 in San Francisco. For the 213 people attending, the conference agenda provided an excellent backdrop for users and manufacturers of semiconductors to formally and informally discuss industry issues and how they are coping with the changing marketplace. The theme of the conference, "Buying and Selling Semiconductors in 1988," addressed four main areas: the outlook for 1988, buying strategies, the Dataquest product and technology update, and a panel discussion on government intervention and international trade. This newsletter will summarize the information presented at the conference and discuss how current situations are being addressed. The attendees of this year's conference are listed in Table 1.

Table 1

1988 Semiconductor User and Applications Conference Attendees

Electronic Equipment Manufacturers

3M Company	Ericcson Telecom	Megatest
AMP Inc.	Ford Motor Co.	NCR
AT&T	Fujitsu Espana	Nissei Sanyo
Acuson	GTE Government Systems	Northern Telecom
Apple Computer	General Electric	Poqet Computer Corp.
Bendix Electronics Corp.	Hayes Microcomputer	Research Machines
Boeing Corp.	Hewlett-Packard	Seimens AG
CMI	Honeywell	Storage Technology
Cerberus Ltd.	Hoya Electronics Co.	Tandem Computers
Datapoint	IBM	Tektronix Inc.
Dataproducts	Ing. C. Olivetti	Teradyne
Delco Electronics	Italtel	Timex Corp.
Digital Equipment Corp.	Itausa Export Co.	Unisys
Eastman Kodak	Lex Electronics	Wang Laboratories
Emerson Electronics Corp.	Mars Electronics	Xerox Corp.

(Continued)

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Table 1 (Continued)

1988 Semiconductor User and Applications Conference Attendees

Semiconductor Manufacturers

AMD/MMI	Microchip Technology	Seattle Silicon Corp.
Cirrus Logic	Micron Technology	Seimens Components
Commodore Semiconductor	Mitsubishi Electronics	Shinki Electronics America
Compulab	Mitsubishi Semiconductor	Signetics
Fujitsu Microelectronics	Motorola	Singapore Technology Corp.
General Instrument	NEC	Standard Microsystems Inc.
Gould Semiconductor	National Semiconductor	Texas Instruments
Harris Corp.	Oki Semiconductors	Toshiba America
Hitachi America	Plessey Semiconductor	VLSI Technology
Hyundai	Precision Monolithics	Vitelic
Integrated CMOS Systems	Raytheon	Wyle Labs
Intel Corp.	SGS/Thomson Microelectronics	
LSI Logic	Samsung	
Lattice Semiconductor		

Other Conference Attendees

ABN Bank	Electric Buyers News	Plantek
American Electronics Assn.	Electronic Purchasing	Regis McKenna
Babson College	Financial Times	San Jose Mercury News
Bacher GmbH	Government of Canada	Security Pacific Bank
Bank of America	INSEC	Semiconductor Industry Assn.
CP Ventures	J.H. Whitney	U.K. Dept. of Trade & Industry
CRD	Manufacturers Hannover Trust	U.S. Venture Partners
CS LIU	Montana Science/Tech. Alliance	
Citicorp		
Coopers & Lybrand		

Source: Dataquest
March 1988

1988 OUTLOOK

The two presentations given by Vladi Catto, vice president, corporate staff, and chief economist of Texas Instruments and by Gene Norrett, vice president and director of the Dataquest Components Division, covered how the overall economy will affect the semiconductor and electronic industries in 1988. Both TI and Dataquest forecast gradual growth in the electronics industry, although the semiconductor sector will continue to grow at an 18 to 21 percent clip. Two underlying economic trends that are impacting the economy are the 2.4 percent compound growth rate in the M1 money supply over the past two years and the devalued dollar in the international markets. Mr. Catto explained that the Korean and Taiwanese currencies have not yet realized their full value against the dollar. Although the rest of the world's currencies have come close to balance with the dollar, the Korean won and New Taiwanese dollar are still overvalued by 50 percent. Steady demand for electronic equipment in the computer and telecommunications industries are expected to sustain growth in these areas, as well as the semiconductor industry, in 1988.

In one of the many speeches that formally focused on customer/vendor partnering, Michael Graff, vice president of marketing—Semiconductor Sector at Harris Corp., reinforced the benefits as well as challenges facing companies considering alliance overtures. According to Mr. Graff, the following key factors must be understood and ingrained by these companies:

- Quality must be a given.
- Some form of statistical process control (SPC) must be agreed to by both parties.
- Process control must be used to optimize a customer's total product requirements.
- Ongoing quality communication results in locating where improvements are needed.

The vice president and group executive of Bendix Electronics Corp., Jerome Rivard, spoke on how semiconductor vendors can improve long-term relationships with their customers, using the automotive industry as an example. By combining high quality, SPC, and product uniformity, a buyer/vendor partnership can develop that benefits both parties. As technology continues to hasten the life cycle of products and capital expenditures continue to increase, the global marketplace will keep this tempo going, thus enabling better business relationships for those with foresight.

The third annual procurement survey results, which were presented by Anthea Stratigos, associate director of the Semiconductor User and Applications Group at Dataquest, noted many differences over last year's review. The key areas of change were in offshore production trends, inventory levels, and the ranking of major issues. Offshore production is expected to be de-emphasized after two years of continued increases, as currency exchange rates and prior moves offshore appear to have caused a reevaluation of the need to move offshore. Inventory levels are expected to increase by close to 10 percent over last year's levels, as availability of key semiconductor products has begun to impact inventory plans. In line with inventory trends is a new ranking of key issues that has raised availability/lead times/shortages above pricing for the first time since the survey was conducted. Quality has fallen from the number three issue last year to number six this year because quality levels have significantly risen worldwide.

Thomas Temin, editor of Electronics Purchasing magazine, presented the key pressures facing both semiconductor buyers and suppliers today. Of the many issues discussed, those pertaining to both users and sellers are government intervention, capital spending trends, user familiarity with ASICs, and the trend of purchasing involvement in the design stage of new products.

Jim Bilodeau, director of worldwide materials at Apple Computer, discussed how procurement strategies have enabled Apple to grow to a $2.7 billion company in 11 years. A proactive corporate structure combined with short- and long-term procurement strategies allowed a company that is "highly dependent on the Pacific Rim for product" to increase 1987 revenue 40 percent over 1986 levels. Mr. Bilodeau described the need to provide open communication to vendors, in "up" demand periods as well as "down" periods in order to maintain forecast credibility—one of the areas often overlooked in long-term arrangements.

AT&T's director of market management, Daniel Lankford, spoke from the semiconductor vendor perspective about the ingredients needed to cement a successful buyer/vendor partnership. He stated that the following elements combine to form the basis of a long-term working relationship:

- Coincident technologies
- Top management commitment
- Complementary strategic objectives
- Consistent revenue targets
- Explicitly defined areas of cooperation
- Realistic expectations

Mr. Lankford's presentation focused on the often-overlooked captive semiconductor manufacturer/outside buyer relationship and what one can expect in this type of long-term partnership.

Dan Hamel, semiconductor business operations group manager at Digital Equipment Corporation, described what users require of semiconductor manufacturers to remain competitive. Mr. Hamel discussed needed improvements that will be required by the majority of semiconductor users by the end of this decade, particularly in the following areas:

- Customer service
- Time to market
- Vendor predictability
- Quality improvement programs
- Lead-time reduction
- Just-in-time and ship-to-stock programs
- Electronic data interchange systems

Another perspective on the changing electronics marketplace was presented by Tim Propeck, vice president of marketing at AMD/MMI. Mr. Propeck discussed the areas that need to be addressed when a company's supplier merges with another supplier or company. Complementary product lines and technologies, economies of scale, and service levels are among the most important topics that must be scrutinized whenever a merger of suppliers occurs, in order to minimize any disruption to quality and shipment levels.

Tom Wang, associate director of the Asian Semiconductor and Electronic Technology Service at Dataquest, described the major electronic companies in the Far East and the areas on which each of them is and will be focusing in the semiconductor market. Mr. Wang then discussed the advantages and disadvantages of doing business in this geographic area and what one should be aware of when doing business with or considering Pacific Rim vendors.

DATAQUEST PRODUCT AND TECHNOLOGY UPDATE

The following Dataquest industry analysts presented updates on the major semiconductor product families and provided outlooks for the upcoming year. The topics covered were memories, microdevices, ASIC devices, chip-set trends, and overall prices and lead times.

Victor de Dios, a Semiconductor Industry Service (SIS) senior industry analyst, discussed memory market trends, stating at the outset that he had no good news regarding near-term increases in DRAM supplies. He showed the effect that the strengthening yen has had on the import and export price of Japanese memory products at various exchange rates and how current exchange levels favor internal Japanese sales. Mr. de Dios also discussed the impact that emerging memory technologies and applications will have on the future market.

The microcontroller and processor trends that were discussed by Alice Leeper, an SIS industry analyst, pointed out that the microcontroller market, although not as well publicized, enjoys almost a two-to-one dollar consumption edge over microprocessors ($2.1 billion compared with $1.3 billion). Forecasting that 8-bit microcontroller and 16-bit microprocessor products will show the strongest growth through 1993, Ms. Leeper also reviewed the 32-bit and RISC microprocessor marketplace. Noting that both markets are very young with many competitors and that standards are still being formulated as vendors vie for market share, the watchword given for this area is "caution."

Andy Prophet, an SIS senior industry analyst, showed that the ASIC market is now beyond the start-up stage but that it is not yet fully established compared with more mature standard product semiconductor markets. Mr. Prophet covered gate arrays, cell-based ICs, and programmable logic devices (PLDs), and discussed where these products are going. He showed that the life cycle of gate arrays averages 8 years and that cell-based designs average 10 years, whereas PLDs average 6 years. These life cycles reflect the design time of the devices and the corresponding applications into which these products go. In his speech, Mr. Prophet also highlighted a by-product of the ASIC revolution: the emergence of added-value design centers that create system solutions using ASIC design technology.

An example of this added-value design center approach was shown by Semiconductor User and Applications Group industry analyst Nanci Magoun, who discussed how chip sets are affecting the electronics marketplace. Ms. Magoun listed the advantages and disadvantages of chip sets for both users and manufacturers, and also identified many applications for which chip sets can and have been used with great effectiveness. By identifying the major vendors of chip sets and offering user and supplier strategies, this presentation clarified many of the issues surrounding this emerging market.

Mark Giudici, a Semiconductor User and Applications Group industry analyst, presented the prices and lead times for the major semiconductor families and described the forces that will impact this industry in the future. The product families covered in his presentation were standard logic, microprocessors, memories, and ASIC devices. In general, the mature product lines for each family (i.e., 74-S, LS, HC, C, 4-bit MCUs, slow SRAMs, low-density EPROMs, and 3-micron gate arrays) will slowly rise in price as demand shifts over to newer technologies, thereby reducing the supply of these mature parts. The effect of the economy and the U.S.-Japan Semiconductor Trade Arrangement will keep prices modulated once memory supplies come into line with demand by the end of the third quarter of 1988. It was noted that the advantages of long-term buyer/vendor arrangements described earlier in the conference have offset some of the perturbations of the current market.

GOVERNMENT INTERVENTION AND INTERNATIONAL TRADE

The second afternoon of the conference gathered together all of the parties affected by the U.S.-Japan Semiconductor Trade Arrangement. The following viewpoints were heard: AEA's senior vice president of public affairs, Ralph Thompson; SIA president, Andrew Procassini; Stack GmbH (Europe) managing director, Bernard Hadley; Dataquest senior industry analyst of the Japanese Semiconductor Service (Japan), Sheridan Tatsuno; U.S. DOC senior industry specialist for microdevices, Joan Rolf; Unisys director of procurement and contracts-Component Engineering and Procurement Organization (U.S. user), W.N. Sanabria; and National Semiconductor Corporation vice president and general manager, Microcomponents Systems Division (U.S. vendor), Randy Parker.

After the speakers gave their opening remarks describing the impact that the arrangement has had on them, a lively question-and-answer period ensued that raised many issues regarding freedom of trade and the role of government in a market dominated by one country. The issues raised at the session will continue to affect procurement practices at least through 1991, when the arrangement expires. One item was made very clear: For better or worse, government intervention has become a standardized influence in the memory procurement decision-making process for the near future.

OVERALL CONFERENCE REVIEW

This year's Semiconductor User and Applications Conference provided what most conferences strive for—a forum to discuss topical and strategic issues, both in formal and informal settings. The attendees' exchange of experiences since the last conference, as well as the information presented from the podium, was very enlightening. The theme of buying and selling semiconductors will always have a current undertone; this year, it was the availability of scarce DRAM chips. Possibly next year, the underlying theme will be that supply has come into balance with demand.

Mark Giudici

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Research *Newsletter*

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A COMPARATIVE LOOK INSIDE AMERICA'S LEADING 32–BIT PCs

SUMMARY

As 32–bit personal computers appear on (and under) the desktops of America, new opportunities are emerging for the suppliers of ICs for these systems.

Dataquest expects 32–bit PC shipments, including those based on Intel's 80386 and Motorola's 68020 microprocessors, to exceed 1.5 million units in 1988. Shipments in 1990 will top 4 million, and perhaps reflect a much higher tally, should today's leading workstation vendors introduce PC–based systems.

While no less than 25 companies introduced 32–bit PCs last year, three manufacturers (Compaq, IBM and Apple—the "CIA" of the PC world??) captured the spotlight as the market drivers. Because these OEMs set the standard on which most clones are built, the following IC analysis of their respective products can lend some insight into the semiconductor demands for these systems. Figure 1 summarizes the IC content for system logic of 32–bit PCs offered by Apple, Compaq, and IBM. (All systems include 1MB of RAM, and only the IBM PC has graphics built into the motherboard.)

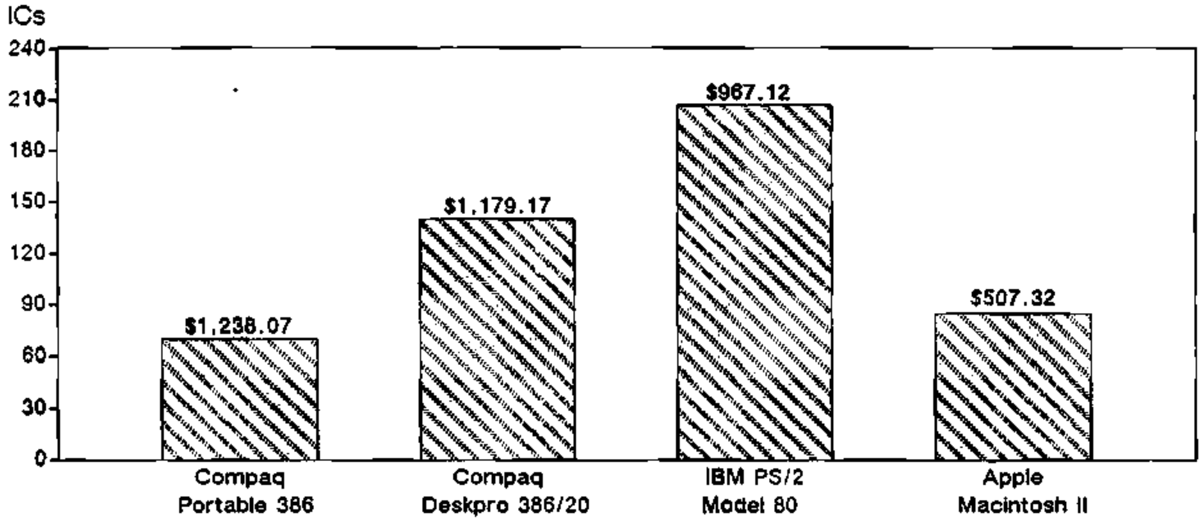
Each of these systems—Apple's Macintosh II, Compaq's Portable 386 and Desktop 386/20 with cache memory, and IBM's PS/2 Model 80—boasts proprietary features and benefits. Each has carved out its own segment: Compaq shipped an estimated 90,000 386–based PCs last year, IBM shipped more than 100,000 units, and Apple reportedly sold more than 100,000 Mac IIs too. Despite their differences, however, the following common elements with respect to IC usage and functionality have become evident:

- CMOS continues to replace TTL standard logic.
- System logic and other proprietary functions are being integrated into application–specific ICs.
- Functions such as graphics and disk drive control, once offered through add–on boards, are now being incorporated more often into the motherboard, or, at least, graphics boards are shipped with the system.

- The standard for graphics resolution is increasing.
- Smart, higher-performance disk drive interface chips are being used.
- Large standard RAM offerings (1MB) and easy memory expandability through OEM-supplied SIP modules are the norm.
- The reduced quantity of chips and use of surface-mount packaging continue to shrink the system footprint.

Figure 1

PC System Logic IC Comparison



Source: Dataquest
March 1988

MACINSIGHT INTO THE FUTURE OF PCs AND SEMICONDUCTORS

The Mac II brings a new and somewhat more serious character to Apple. Unlike the old Mac, this one has color, a large monitor, expansion slots, more on-board and addressable memory (256 times more, in fact), and is much, much faster. In other words, Apple is finally ready to compete head to head for the business and technical environments currently dominated by Big Blue (the Mac's new IBM-look-alike cabinet seems symbolic of this goal).

Most importantly, the Mac II has an open architecture. So critical was the open architecture to Apple, in fact, that Jean-Louis Gassee, vice president of product development, ordered a license plate reading "OPEN MAC," according to an article in the New York Times. The Mac's architecture combines NuBus, a well-documented multiprocessor environment developed at Massachusetts Institute of Technology, with the popular interface standard Small Computer Systems Interface (SCSI). These two elements have brought Apple a plethora of support products and peripherals from third-party vendors. This combination, in turn, affords customers a wide choice of applications and options early in the new Mac's life and is critical to its acceptance in business and technical environments.

Mac II Semiconductor and Packaging Analysis

The Mac II, built around Motorola's 68020 32-bit microprocessor and 68881 floating-point coprocessor running at 15.7 MHz, is designed to be a computational workhorse. It is shipped with 1MB of RAM—expandable to 8MB on-board and up to 2GB with NuBus expansion boards.

A look at the Mac II motherboard (Figure 2) provides evidence that Apple intends to keep pushing board and IC technologies in its quest for price/performance leadership. The Mac II motherboard contains a mere 50 ICs, excluding system RAM. It is interesting to note that the quantity of ASICs (custom and programmable chips) is approaching that of SSI/MSI standard logic devices (with counts of 16 and 21, respectively).

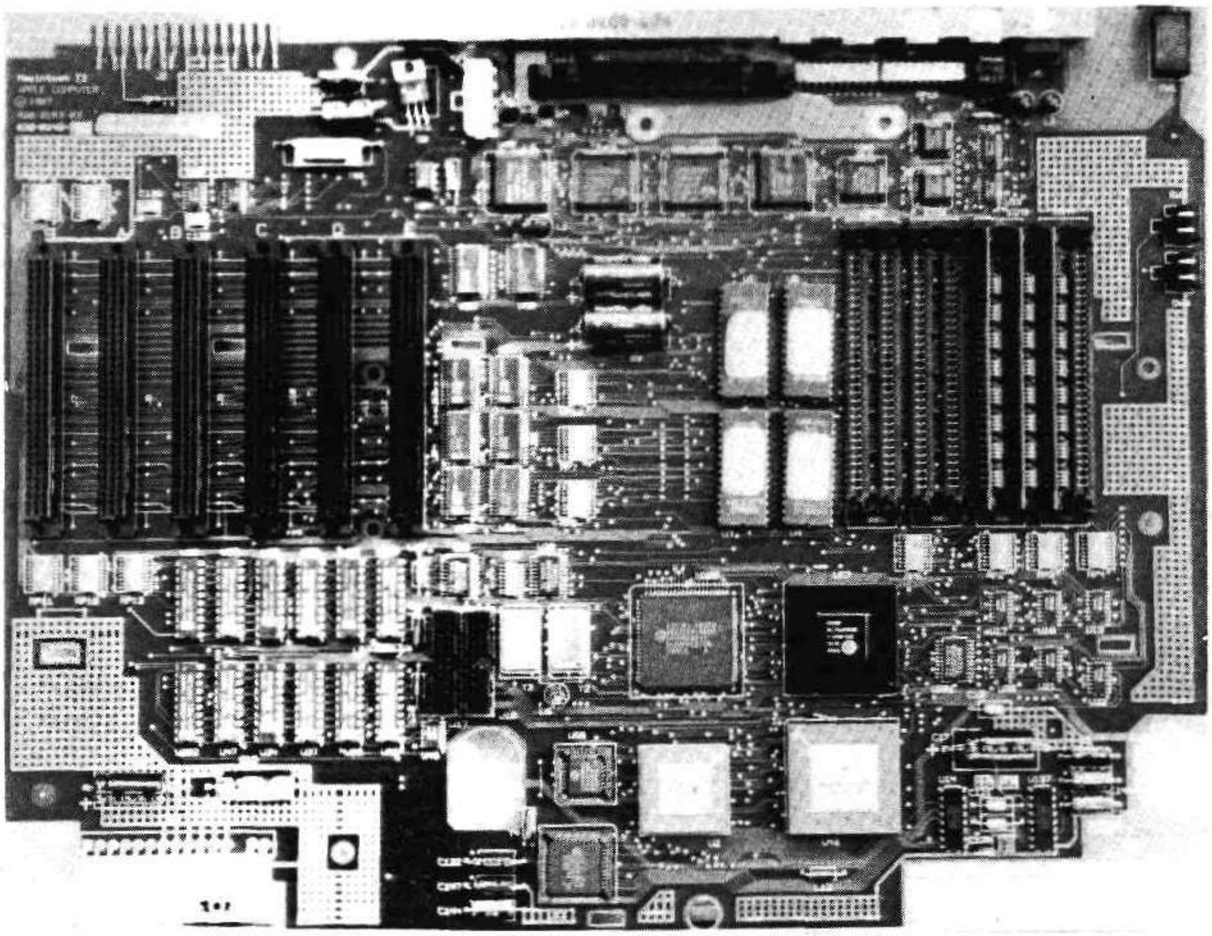
All of the four custom parts used on the Mac II motherboard reportedly were supplied by VLSI Technology, Inc., and include the 44-pin Apple Sound Chip (ASC), which contains two 1K sound buffers, as well as the system's 168-pin socketed Memory Management Unit (MMU). With the upcoming release of the Mac UNIX operating system (A/UX), however, VLSI's MMU will be replaced with Motorola's 68451 PMMU. The remaining eight motherboard ASICs, 15ns HAL devices in plastic dual-in-line packages (DIPs), were supplied by MMI and reportedly provide control logic functions.

Apple made use of numerous special-purpose peripheral controllers and included two Sony power amplifier/sound chips, an Integrated Woz Machine (IWM) floppy disk controller, two Apple Desktop Bus (ADB) chips, a serial port controller, as well as NCR's 53C80 CMOS SCSI controller.

Table 1 provides a breakout and estimated cost of the components used on the Mac II motherboard.

Figure 2

Mac II Motherboard



Source: Dataquest
March 1988

Table 1

Mac II Motherboard IC Analysis

Component	ICs per Component	Supplier	Estimated Cost
Standard Logic			
FAST	2	Motorola	
LS	12	Motorola, MMI	
ALS	1	Texas Instruments	
AS	2	Texas Instruments	
HCL	2	Motorola	
Other	2	VLSI Technology, Motorola	
Subtotal	21		$ 7.84
ASICs			
Custom/Gate Arrays	4	VLSI Technology	
Programmable Logic	12	MMI	
Subtotal	16		118.58
Micros/Peripherals			
68020, 17.7-MHz MPU	1	Motorola	
68881, FPU Coprocessor	1	Motorola	
Peripherals/Controllers	7	Motorola, AMD, NCR, GI, Rockwell, Sony	
Subtotal	9		257.30
Memory			
DRAM (256K, 120ns)	32	NEC	
EPROM	4	GI	
Subtotal	36		123.60
Total	82		$507.32

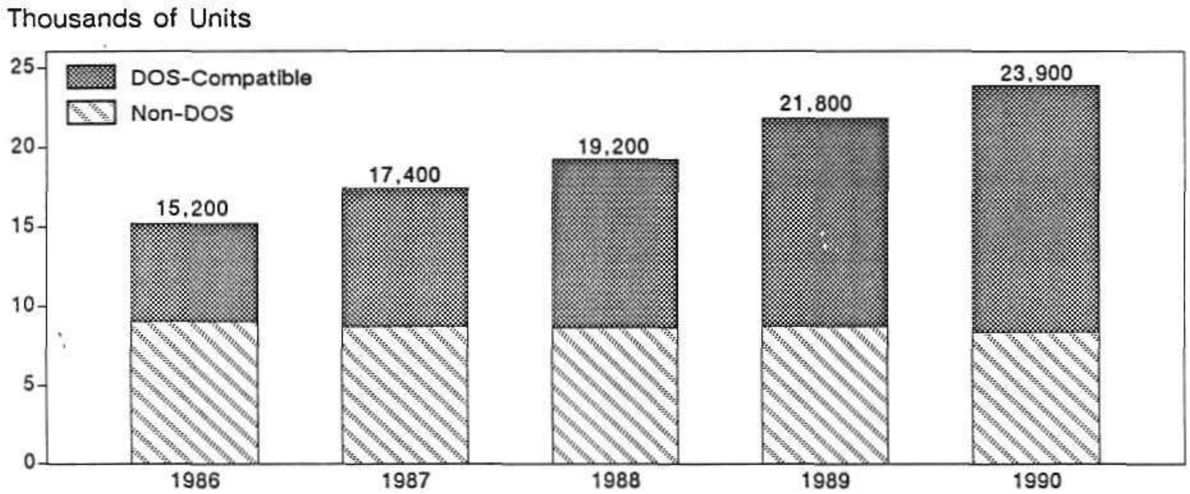
Source: Dataquest
March 1988

Macinferences

Whether or not the Mac II will be a success in the marketplace is another issue. After all, for most single-user PC applications, DOS machines already lead the market and, as shown in Figure 3, are expected to gain even more momentum throughout 1990. And even though the Mac II can be fitted with a $1,500 DOS board (with its own Intel 80286 processor), those wanting DOS are likely to buy a true DOS machine. (The minimum price of a DOS-fitted Mac II is $5,500 versus about $2,000 for one of many available IBM PC AT clones.)

Figure 3

PC Operating System Trends



Source: Dataquest
March 1988

As a UNIX-based technical workstation, the Mac II shows more promise by offering users its friendly Apple environment for other tasks such as word processing, graphics, and desktop publishing. But in the UNIX world too, the Mac is seeing competition from more mature 32-bit workstations from makers such as Sun Microsystems. These workstations are now offered for less than $5,000.

Because it offers its own operating system, Apple has built a loyal following of patrons, and, for them, the Mac II provides their long-awaited faster and expandable machine. Its new capabilities for high-resolution color graphics, on-board memory expandability (to 8MB today, and up to 2GB later), as well as connectivity to a wide variety of input and output devices will appeal to Apple's audience of scientists, engineers, graphics artists, educators, and business users.

Undoubtedly, Apple continues to be a technical innovator, and, regardless of its long-term marketability, the Mac II can provide some good insight into the future of the PC and the related semiconductor market.

OVERVIEW

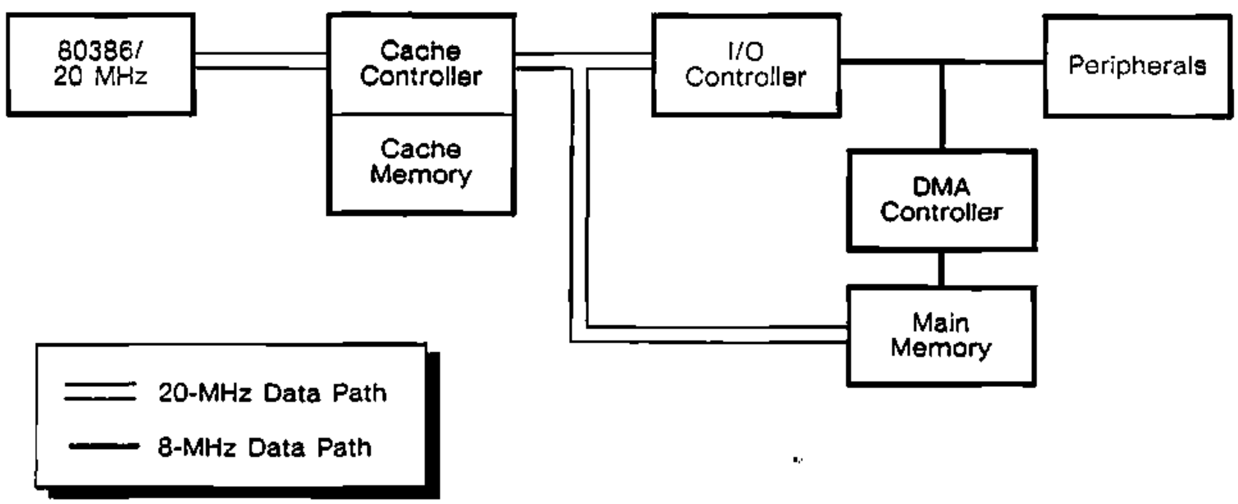
Compaq's Deskpro 386/20: Caching In

As the first manufacturer of an 80386-based PC (see SAM newsletter number 1987-08, "Impact of the Compaq 386: How the 32-bit PC Market is Shaping Up"), Compaq continued in its pioneering spirit by introducing, several months ago, one of the industry's earliest PCs with a cache memory system.

In order to implement its cache system, Compaq designed its own new architecture (Flex Architecture), which provides separate buses for concurrent memory and I/O operations. Compaq claims that such a scheme (see Figure 4) allows the system's 20-MHz 80386 processor to run at its peak performance level, while the peripheral I/O bus runs at the industry-standard 8-MHz speed.

Figure 4

Compaq Flex Architecture



Source: Compaq

The Deskpro 386/20 also incorporates a 121-pin coprocessor slot that accommodates either the Intel 80387 or pin-compatible, floating-point coprocessor board built by Weitek. The latter option reportedly provides improvement over the 80387 option in that the processing speed is more than doubled.

Compaq is the leading PC IBM clone manufacturer, capturing nearly 5 percent of the total worldwide PC market in 1986. Key to Compaq's success is its uncompromised, total compatibility with IBM's PCs. (Compaq has claimed, in fact, that its line of PCs is more compatible across the complete line of IBM PCs than are members of IBM's own line among themselves.)

As with other Compaq models, the Model 386/20 adheres to IBM's AT architecture, with Compaq not yet committing itself to Big Blue's new Micro Channel Architecture. From operating system and software points of view, at this point, there are no significant differences. From a hardware point of view, however, none of the new Micro Channel adapter boards will fit in Compaq's PCs, due to a different connector scheme. But since the PS/2 and Micro Channel are still in their infancy, Compaq has adopted the theory (shared by Dataquest) that much life is left in the AT-type architecture. When it becomes clear that the world is moving to Micro Channel, Compaq will likely move too.

Compaq Model 386/20 IC Analysis

Compaq's use of a cache memory scheme introduced some new ICs and capabilities into the personal computer arena. With Intel's new 82385 cache controller chip and 32KB of high-speed static RAM (35ns), for instance, system performance has been improved greatly over that of Compaq's earlier 80386-based models.

From an integration standpoint, Compaq has never been on the leading edge—perhaps in keeping with its compatibility with IBM. Not only did Compaq use a number of standard logic and peripheral devices that could have been integrated easily into ASICs (and, in fact were integrated into the new portable version), but also relied almost totally on space-consuming, through-hole packages. Likewise, with the standard 1MB of system RAM, Compaq uses a full add-on board (housed in a dedicated slot) with 36 256K DRAMs (80ns), 20 standard logic devices, and 2 programmable logic devices—all in through-hole packages. Tables 2 and 3 provide the IC content of the Deskpro 386/20 motherboard and memory card.

Table 2

Compaq Deskpro 386/20 Motherboard ICs

Component	ICs per Component	Supplier	Estimated Cost
Standard Logic			
FAST	22		
LS	14		
ALS	12		
AS	3		
AC	1		
Other	2		
Subtotal	54		$ 19.83
ASICs			
Custom/Gate Arrays	2	Compaq	
Programmable Logic	2	MMI, Signetics	
Subtotal	4		82.80
Micros/Peripherals			
80386, 16-MHz MPU	1	Intel	
80387, FPU Coprocessor	1	Intel	
82385-20	1	Intel	
Peripherals/Controllers	8	Intel, Signetics	
Subtotal	11		872.95
Memory			
16K SRAM, 35ns	16	Sony	
Subtotal	16		52.00
Total	85		$1,027.58

Source: Dataquest
March 1988

Table 3

Compaq Deskpro 386/20 Memory Card ICs

Component	ICs per Component	Supplier	Estimated Cost
Standard Logic			
FAST	11		
LS	4		
ALS	5		
Other	1		
Subtotal	21		$ 7.09
ASICs			
Programmable Logic	2	MMI, Signetics	
Subtotal	2		9.50
Memory			
256K S-Column DRAM	32	Fujitsu	
Subtotal	32		$ 135.00
Total Memory Board ICs and Cost	55		$ 151.59
Total Systems ICs and Cost	140		$1,179.17

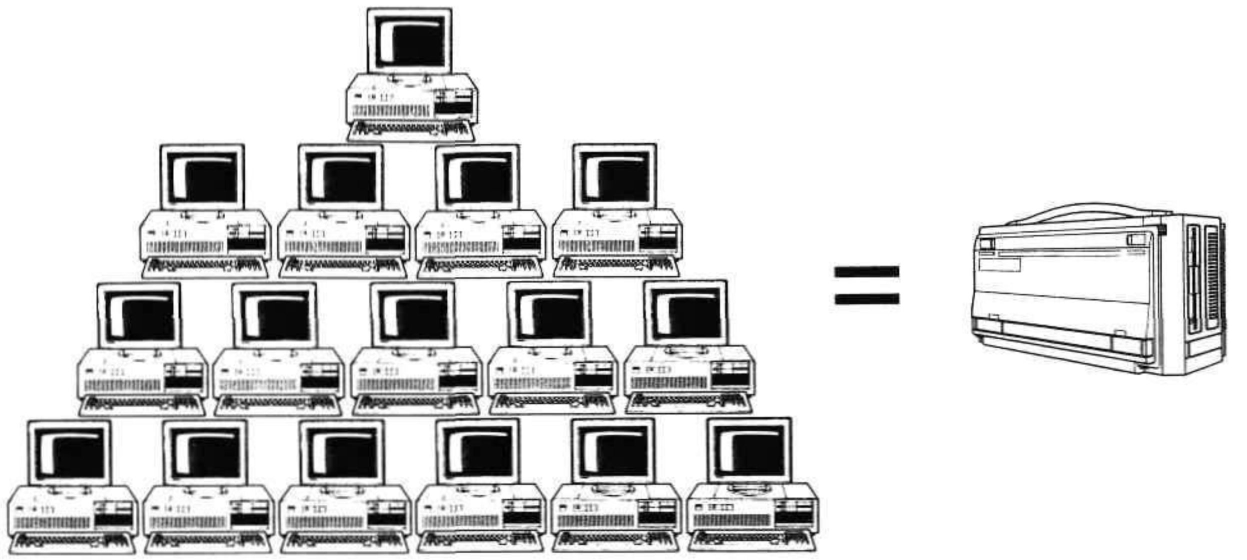
Source: Dataquest
March 1988

Compaq's 386 to Go

Squeezed into its 20–pound, 16 x 8 x 10–inch housing, Compaq's Portable 386 has the highest performance level (and the highest price, at $7,999) of all the currently available carry–along PCs. As illustrated by Compaq in Figure 5, much power has been squeezed into a small space over the years.

Figure 5

Evolution and Miniaturization of PCs



16 Original IBM PC's
Circa: 1981
Cost: $48,000 @ $3,000 ea.
Weight: 800 lbs @ 50 lbs ea.
Performance: Total of 4.8 MIPS* @ .3 MIPS ea.

1 COMPAQ PORTABLE 386™
Circa: September 29, 1987
Cost: $7,999
Weight: 20 lbs
Performance: 5 MIPS

***Million Instructions Per Second**
COMPAQ PORTABLE 386™ is a trademark of Compaq Computer Corporation

Source: Compaq

In order to support the large installed base of old DOS-compatible software, the Compaq Portable has speed-selectable options allowing operation ranging from a full 20 MHz down to an XT-compatible 6 MHz. Because the Portable 386 is being marketed into compute-intensive technical, scientific, and business environments, the system comes equipped with 1MB of RAM, a 40MB fixed disk drive with 30ms of access time, and built-in software to support the Lotus/Intel/Microsoft (LIM) extended memory specification. (This lets software address RAM above 640KB.) For even greater performance, expansion options include an 80387 coprocessor, a 100MB fixed disk drive (25ms access time), RGB interface for hook-up of an external color monitor, as well as 32-bit memory expansion up to 10MB.

Compaq Portable 386 IC Analysis

Needless to say, squeezing so much power into such a small box necessitated the use of ASICs and surface-mount technology (SMT) packaging. Compaq used seven ASICs, all SMT, integrating a wide range of functions. Table 4 provides a summary of the functionality and number of pins for each of these parts.

Besides the ASICs and a Zilog floppy disk controller, none of the remaining 56 nonmemory ICs used SMT packaging. It is likely that future versions of this PC may require a change in packaging.

In terms of memory, as with the other PC models compared here, a standard 1MB of system RAM was included on the motherboard. The 1MB of RAM was supplied on two memory modules with six ICs each (four 256Kx4 and two 256Kx1 DRAMs), resulting in a final 512KB (with parity) in a 256Kx18 organization. Table 5 summarizes the ICs included on the Compaq Portable 386 motherboard.

Table 4

Compaq Portable 386 ASICs

Part Name (Supplier)	Package	Functions
SMAP ASIC (Fujitsu)	100-pin LCC	DMA memory page register CPU status port Memory-refresh timer
System ASIC 1	100-pin LCC	Timer/interrupt Word DMA
System ASIC 2	100-pin LCC	Timer/interrupt Byte DMA
Paged Memory Controller ASIC	80-pin LCC	CPU memory execution Cycle requests Address decoding
Expansion Bus Interface ASIC	80-pin LCC	Latch/buffer logic Data bus conversion logic Bus logic and control
Peripheral ASIC	80-pin LCC	Disk drive functions Data transfer rate control Serial/parallel interface Fixed disk drive interface Other disk drive control
FSPDS ASIC (IMP)	28-pin LCC	Floppy disk data separation Floppy disk interface circuitry

Source: Dataquest
March 1988

Table 5

Compaq Portable 386 Motherboard ICs

Component	ICs per Component	Supplier	Estimated Cost
Standard Logic			
FAST	7		
LS	17		
ALS	11		
AC	1		
Other	9		
Subtotal	45		$ 16.42
ASICs			
Custom/Gate Array	7	Fujitsu, IMP, Compaq	
Subtotal	7		227.40
Micros/Peripherals			
80386-20, 20-MHz MPU	1	Intel	
80387-20, 20-MHz FPU	1	Intel	
Peripherals	3	Zilog, Signetics, Fujitsu/Intel	
Subtotal	5		748.75
Memory			
256K EPROM	2	TI	
1Mb DRAM (80ns)	8	Toshiba	
1Mb DRAM (85ns)	4	NMBS	
Subtotal	14		245.50
Total	71		$1,238.07

Source: Dataquest
March 1988

IBM'S "MICRO CHANNEL" TO SUCCESS IN THE 32-BIT ARENA

In April of 1987, just one month after Apple's introduction of the Mac II, IBM introduced its next generation of personal computers, the PS/2. In many respects, however, IBM's announcement represented a flip-flop with Apple in corporate philosophies: As the Mac II NuBus opened up Apple's architecture, the PS/2 Micro Channel bus closed IBM's.

Consistently losing market share to a host of clone makers since its first PC introduction in 1981, IBM has an opportunity to start anew with the Micro Channel. Like NuBus, Micro Channel is an intelligent bus. When it is combined with the upcoming new operating system (OS/2), the combination enables the PS/2 to offer quantum leaps in performance and features over the previous line of IBM PCs.

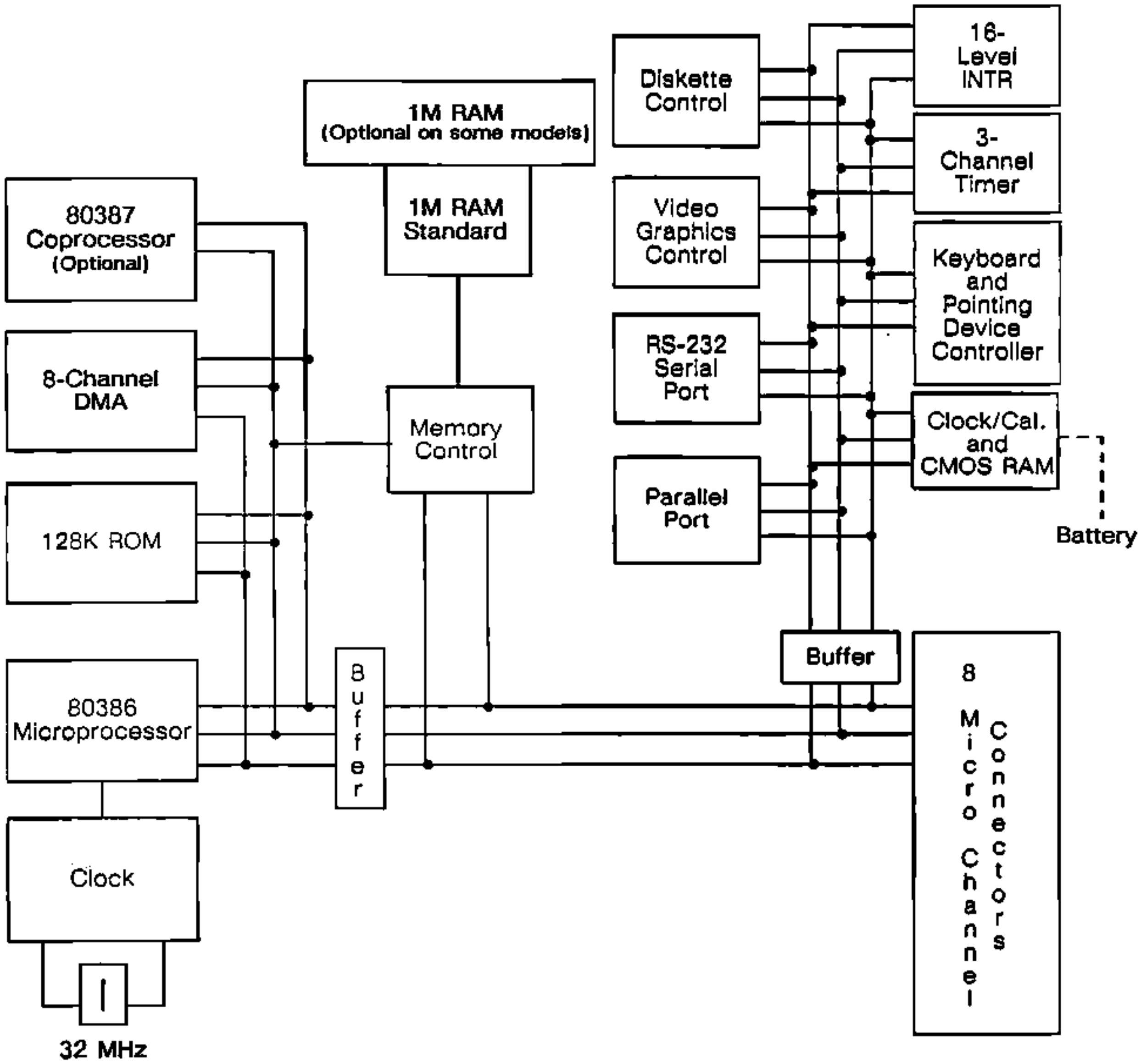
Model 80 Semiconductor Analysis

IBM continues to base its PCs (migratory products in the DOS world) on the Intel 80xxx line of microprocessors. In the case of the Model 80, then, the costly ($250) 16 MHz 80386 is the heart of the system. Unlike its 80286-based counterparts, Models 50/60, the Model 80 uses an inordinate amount of standard logic components (144 versus 56). But because IBM currently offers only a bulky, free-standing 386 system, board space was not necessarily a big concern. (Perhaps the tower model was introduced prematurely as an answer to Compaq's 386, which was introduced nearly seven months earlier, before IBM had a chance to integrate much of the design into custom chips.) If, and when, the desktop version arrives, a new board design that uses more ASICs will be needed.

IBM did use several proprietary CMOS ASICs for the Model 80, including a 121-pin direct memory access (DMA) controller, a 212-pin video graphics array (VGA) chip, and an 84-pin floppy disk controller that supports two 3.5-inch drives (one 720KB drive and one 1.44MB drive). The drives can read and write into both low- and high-density disks. Interestingly, despite IBM's agreement with Intel for the latter's peripherals library, the interrupt controllers were not integrated into ASICs. Clone chip makers suggest that perhaps the function was not available as an ASIC cell. It is just as likely, however, that IBM is waiting to include additional functionality into future proprietary chips and was in no rush to integrate everything. Integration is surely in the plans, however, as evidenced by IBM's near-total use of surface-mount components. Figure 6 is an illustration of the Model 80 motherboard with its key integrated functions. This is followed by a summary of the ICs used in the Model 80 (Table 6).

Figure 6

IBM PS/2 Model 80
System Logic Block Design



Source: IBM

Table 6

Model 80 Motherboard IC Analysis

Component	ICs per Component	Supplier	Estimated Cost
Standard Logic			
FAST	80		
LS	12		
ALS	34		
AS	2		
HCT	1		
S	9		
Other	6		
Subtotal	144		$ 49.12
ASICs			
Custom/Gate Arrays	4	IBM	
Programmable Logic	15	AMD, MMI	
Subtotal	19		$138.55
Micros/Peripherals			
80386, 16-MHz MPU	1	Intel	
80387, FPU Coprocessor	1	Motorola	
Peripherals/Controllers	6	Intel, National, NEC	
Subtotal	8		$593.00
Memory			
64K DRAM	8	NEC	
27256-12 256K EPROM	4	Intel	
IMSG171S VLUT	1	Inmos	
1MB DRAM, 80ns	10	IBM	
Subtotal	36		$186.45
Total	207		$967.12

Source: Dataquest
March 1988

DATAQUEST COMPARISONS AND CONCLUSIONS

In addition to the trends cited within the "Summary" section, our look inside these PCs reveals that the IC content of a PC—particularly in the higher-performance spectrum—represents an increasing portion of the total system cost.

Dataquest estimates that, on the average, the semiconductor I/O ratio (the cost of components compared with the final system price) for PCs priced above $1,000 was about 6.4 percent in 1987. Growth to 7.2 percent (equaling a 9 percent jump) is expected in 1988, caused largely by the migration of functionality and by the increased performance and memory requirements on the PC motherboards. As summarized in Table 7, in the cases of the four high-end PCs analyzed here, the I/O ratios were higher, averaging 12.8 percent with a coprocessor and 8.3 percent without a coprocessor.

Table 7

Integrated Circuit I/O Ratio Summary

System	PC Price	IC Cost	I/O Ratio (with Coprocessor)	I/O Ratio (no Coprocessor)
Compaq 386/20	$9,499	$1,179	12.6%	7.6%
Compaq Portable 386	$7,999	$1,238	15.5%	9.9%
IBM Model 80 (16 MHz)	$6,995	$ 967	13.8%	8.4%
Apple Mac II	$5,499	$ 507	9.2%	7.4%
Average Ratios			12.8%	8.3%

Source: Dataquest
March 1988

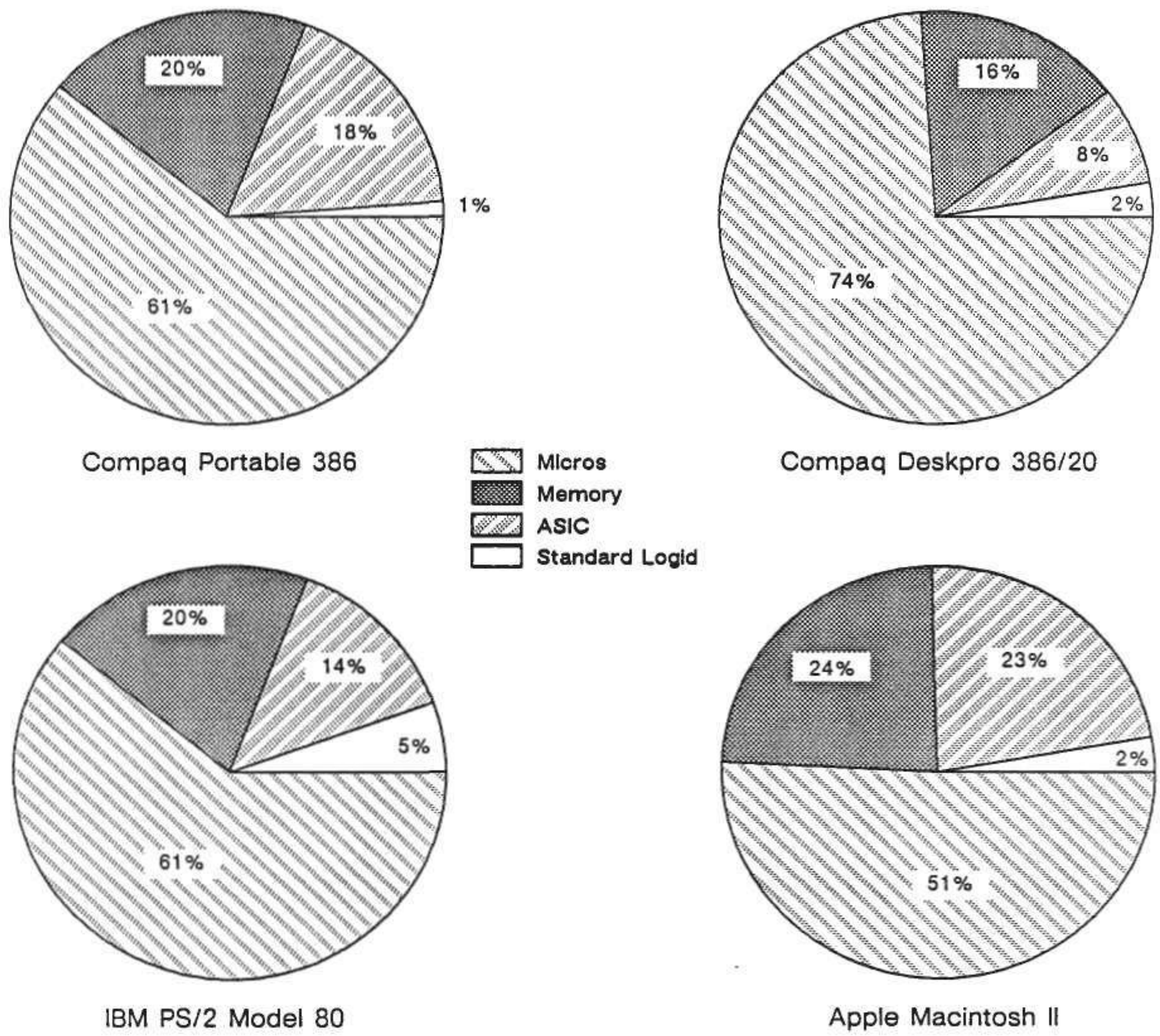
From Table 7, it appears that Apple optimized its IC usage. But this comparison is not so simple. The Mac II, after all, with its own proprietary operating system, is based on the much lower-priced Motorola microprocessor, in contrast to the other DOS-based PCs requiring Intel-designed parts. In fact, if one factored in the incremental cost ($510) of Intel parts—a 20-MHz 80386 and 80387—over the IC cost of Motorola parts in a Mac II, Apple's semiconductor I/O ratio would jump to 18.5 percent.

With respect to these microdevices, it is also interesting to note the much greater drop in the I/O ratios for the DOS-based machines when the coprocessor cost is omitted. This relates to Intel's practice of charging a heavy premium for a coprocessor ($450 in volume for a 20-MHz 80387, which is 65 percent more expensive than the 80386 microprocessor to which it attaches) versus Motorola's strategy to attract the incremental business ($100 for the 20-MHz 68881 coprocessor and $130 for the 68020 in volume).

A look at the overall consumption of the various types of ICs used in each of the PCs is presented in the pie charts in Figure 7. As illustrated, next to the microdevices, memory chips account for the largest IC expense in building PCs. Given today's volatile memory market and skyrocketing prices due to the worldwide memory chip shortage, memory chips now represent a higher portion of the total system cost. (The IC costs for each PC in this report are based upon estimated prices in the quarter of product introduction.)

Figure 7

Comparison of ICs in the 32-Bit PCs
(Percentage of Total System IC Cost)



Source: Dataquest
March 1988

Finally, though not surprisingly, the two PCs with the smallest system logic footprints made the heaviest use of ASICs, in terms of both percentage of the total IC cost as well as functionality per IC. In all cases, it is evident that the use of ASICs has displaced most of the small- and medium-scale integration (SSI/MSI) standard logic components in these PCs. (SSI/MSI parts average just 2.5 percent of the total IC dollars spent per system.) This does not imply that standard logic has met its end in the PC world: New opportunities are arising for more highly integrated (LSI) parts as well as for the hybrid (application-specific standard logic) devices known as chip sets.

With the demand for high-end PCs to handle desktop publishing, office automation and networking, and technical applications, system architectures and operating systems will continue to evolve rapidly in the years to come. As predicted for some time, OEMs will utilize more and more ASIC technology (and surface-mount packaging) in order to push performance and integration. (Apple Computer has recently established an ASIC task force to research its own market demands and industry trends for the next 5 to 10 years.)

As IBM and Microsoft begin to deliver their next-generation PC operating system, OS/2, memory chip suppliers will see their greatest challenges, and rewards, in recent times. For instance, users of IBM's enhanced version of OS/2, known as the extended edition (OS/2EE), will require a minimum of 4MB of system RAM. In addition, the need for ever faster, higher-density, and safer permanent data storage will drive continued development of removable storage devices requiring fast, dense, and nonvolatile memory ICs.

Another area of growing interest and applicability to IC suppliers and OEMs alike is that of software emulation products that can allow DOS applications to run on previously non-DOS compatible platforms. A company named Insignia Solutions, for instance, introduced a software package that allows a Sun workstation (and reportedly soon, a Mac II) to operate totally as a fully functional DOS-compatible PC. Disk drives can be attached and DOS floppy disks can be used—all running as one window or multiple windows under the host operating system, UNIX. Several other companies are working on similar products. The implications of such products, if they are fully developed as promised, are great. PC buyers will be able to select any platform that best suits their primary needs and, at the same time, satisfy their company's requirements for fully DOS-compatible systems. This, of course, could open the doors to an even greater array of system and IC suppliers.

In any case, PCs continue to be major consumers of ICs, and a mutual dependency is growing stronger between OEMs and silicon suppliers. Those who are able to establish strong relationships in the near term will be best suited to face the design, supply, and pricing challenges for PCs in the next decade.

Nanci J. Magoun

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THE GROWTH CONTINUES: FOURTH QUARTER ELECTRONIC EQUIPMENT UPDATE

SUMMARY

Dataquest forecasts that the 1987 turnaround in electronics will continue into 1988, with 7 percent growth in 1988 over 1987. Excluding the military electronics industry, the overall electronics picture looks healthier at 9 percent growth over 1988. We expect data processing, the largest semiconductor market, to grow at 10 percent, a faster pace than the industry as a whole.

This newsletter outlines the major events in each of the six application markets, and discusses the trends that we believe to be the most important to semiconductor manufacturers and users in the near future. The following observations summarize the most important points of this newsletter:

- Personal computers are still eating up the lion's share of semiconductors, tightening up supplies of DRAMs and 80386 microprocessors.

- The telecommunications industry will continue to face the following issues in 1988:

  - Judge Greene's decision to limit the RBOCs
  - Consolidation in the industry
  - The battle to connect the desk

- New technologies in factory automation offer niche opportunities for semiconductor vendors.

- The depreciation of the dollar, trade pressure, and a desire to be close to their markets is making manufacturing in the United States desirable to many consumer electronics manufacturers.

- The military electronics market will remain sluggish through the 1990s. However, pervasiveness of semiconductors into electronic systems will push military semiconductor consumption to a 5.8 percent compound annual growth rate (CAGR) through 1992.

- The slowdown in automobile production has tempered automotive semiconductor growth; however, automotive electronics will continue to grow.

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OUTLOOK FOR APPLICATION MARKETS

Table 1 displays Dataquest's most recent electronic equipment forecast. We expect the industry as a whole to grow 7 percent in 1988. Figure 1 displays the North American electronic equipment forecast by application market in 1988 and 1991.

Table 1

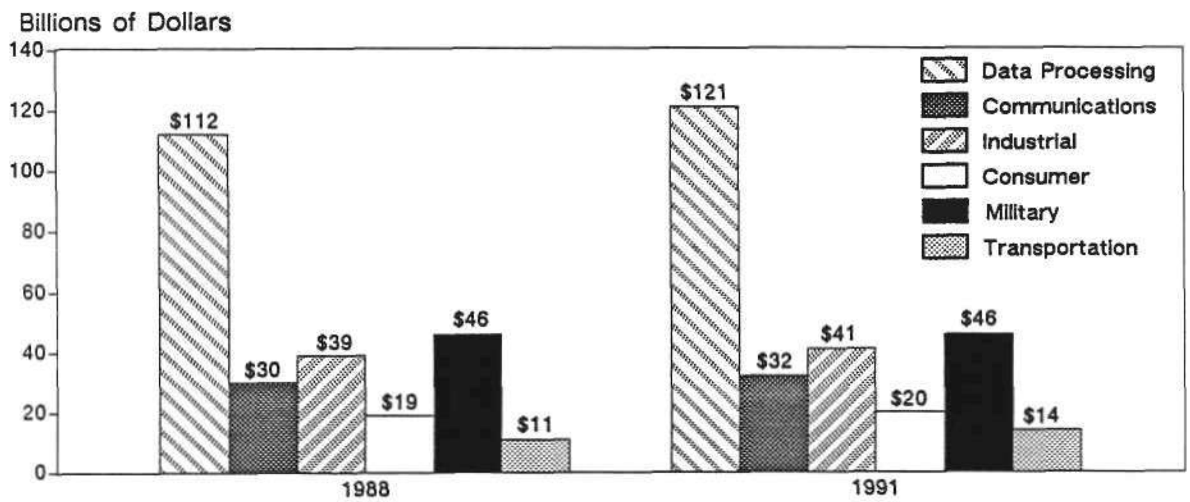
North American Electronic Equipment Forecast
(Millions of Dollars)

Application	1987	1988	1989	1990	1991	CAGR 1987-1991
Data Processing	$101,872	$111,834	$120,940	$127,903	$135,784	7.4%
Communications	26,962	29,548	32,376	35,226	37,917	8.9%
Industrial	35,162	39,084	41,276	44,321	48,204	8.2%
Consumer	18,355	19,067	20,114	21,611	22,816	5.6%
Military	48,200	45,500	45,000	44,500	44,600	(1.9%)
Transportation	10,199	10,964	11,692	13,152	14,809	9.8%
	$240,750	$255,997	$271,398	$286,713	$304,130	6.0%

Source: Dataquest
March 1988

Figure 1

North American Electronic Equipment Forecast

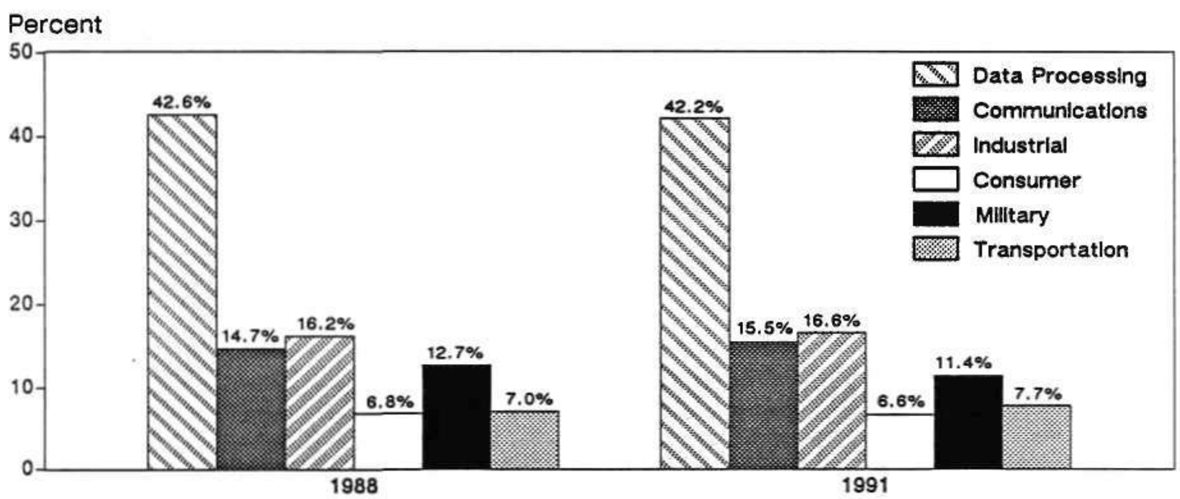


Source: Dataquest
March 1988

We believe that the data processing application market will continue to be the largest consumer of semiconductors throughout the forecast period with more than 40 percent share. The communications application market will gain the largest share of the total with a 0.8 percentage point jump in market share from 1988 to 1991. The military application market will lose share of the total North American semiconductor consumption through 1991. The consumer and transportation markets will continue to keep relatively constant market share through 1991. Figure 2 illustrates North American semiconductor consumption by application market for 1988 and 1991.

Figure 2

North American Semiconductor Consumptiom by Application Market



Source: Dataquest
March 1988

Data Processing

Personal computers continue to drive semiconductor consumption. Apple Computer's turnaround in 1987, Compaq's high growth, and the IBM PS/2 family's fast-paced sales have led to high growth in semiconductor sales to the PC market. The demand will increase even more dramatically during 1988 as OS/2, the new operating system for IBM and IBM-compatible machines, begins to take off. The recommended internal memory to run OS/2 properly is 4 Mbytes. This surge in memory demand will come at a time when the DRAM supply is already tight as manufacturers are moving capacity from 256K to 1-Mbit memories. However, increased DRAM shipment volumes by the end of 1988 should alleviate the temptation to double-book orders for these crucial parts. Dataquest forecasts that the personal computer market will grow 17 percent in 1988.

Growth in the personal computer market has driven the peripheral markets as well. This growth is epitomized by Conner Peripherals, which manufactures 3.5-inch rigid disk drives. Conner's sales exceeded $100 million in its first year of production. Dataquest expects overall storage production growth to slow to 4 percent in 1988, with the exception of optical and 3-inch rigid disk drives with 143 percent and 53 percent growth, respectively.

Another peripheral product that has benefited from the growth of the PC industry is the low-end laser printer. Desktop publishing and a desire for letter-quality printing have helped make page printers successful. As prices drop with introductions of low-cost laser printers from Apple Computer and Hewlett-Packard, sales volume should increase.

Communications

Judge Greene's decision to limit the RBOCs, more acquisitions and alliances, continued testing of ISDN, the continuing battle to connect the desk, and a slowdown in growth were the highlights of the 1987 telecommunications market.

Judge Greene's Decision

The major impact to semiconductor manufacturers from Judge Greene's decision to limit the RBOCs is the decision that RBOCs cannot manufacture telecommunications equipment, thus closing off potential clients from semiconductor vendors. Judge Greene's September 10, 1987, decision covered the following areas:

- It prohibits the RBOCs from manufacturing telecommunications products.
- It prohibits the RBOCs from providing interexchange telecommunications services.
- It allows the RBOCs to provide information transmission services, but not to generate information itself.
- It removes the requirement for waivers to enter nontelecommunications businesses.

Acquisition and Alliances

The following list of recent mergers displays the trend toward consolidation in the telecommunications industry:

- Unisys/Timeplex
- 3COM/Bridge Communications
- Vodavi/ISOTEC/Executone
- Tandon/Ungermann-Bass
- DCA/Fox Research
- Datatel/Dowdy

Battle to Connect the Desk

In the battle to connect the desk, Dataquest forecasts that an incremental 22.7 million desktops will gain information devices in the next five years. Of the 29.7 million devices in the installed base today, more than half are connected. By 1991, nearly two-thirds of the 58.4 million devices will be connected. Taking into account some replacements as well as new additions to the installed base, this translates to 22.4 million new desktop devices being connected in the next five years. At an average sales revenue of $400 per connected unit, there is a $9 billion market opportunity at stake.

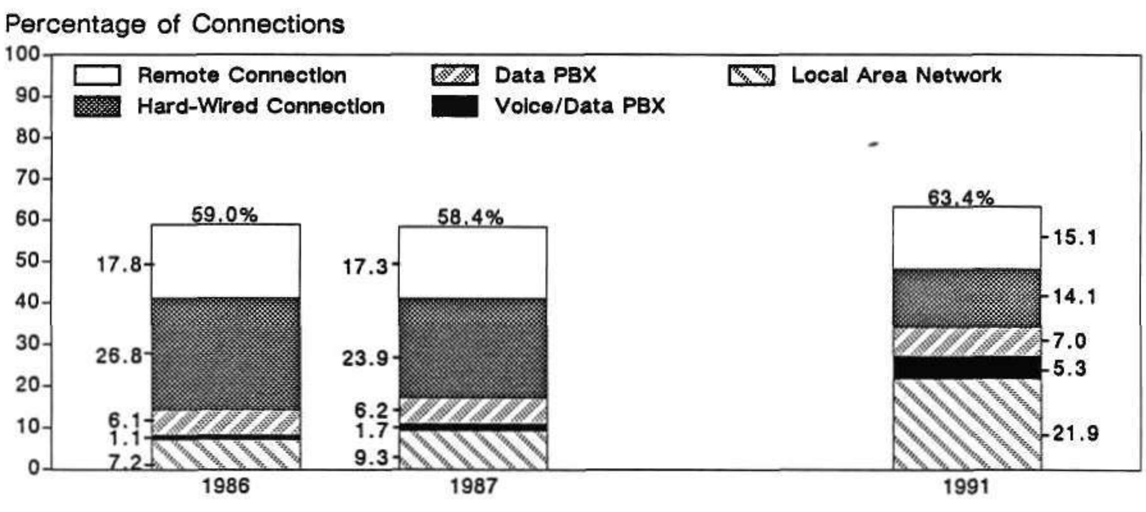
Figure 3 shows the connection technology trends for all desktop devices combined. Approximately 41 percent of these desktop devices were not communicating in 1986, but we expect this percentage to shrink to 37 percent by 1991. In 1991, desktop device suppliers will be facing a replacement market, while connectivity suppliers will be looking at the estimated 21.4 million still unconnected desktop information devices.

Hard-wired connection traditionally has been the most popular connection technology, but its share is expected to decline from 26.8 percent to 14.1 percent by 1991, due to the increasing popularity of other technologies that offer more flexibility and are more semiconductor intensive.

We expect local area networks to demonstrate the most significant growth as a connection technology rising from 7.2 percent of the installed base of devices in 1986 to 21.9 percent in 1991. Growth is expected to be fueled by declines in wiring cost and in price per connection, demand for higher transport speeds, increased deployment of PCs, and the focus on work groups that increase group and corporate productivity by sharing computer and information resources.

Figure 3

Estimated U.S. Connection Technology Trends for all Desktop Devices (Percentage of Connections)



Source: Dataquest March 1988

Slowdown in Growth

We expect the telecommunications market to grow 8 percent in 1988. However, there will still be higher growth opportunities in the following areas: facsimiles, T-1 multiplexers, voice messaging, LANs, and data network control systems.

Industrial

In a recent analysis of the factory automation market, Dataquest's Manufacturing Automation Service (MAS) found that factory automation vendors are targeting new markets.

In the United States, the automotive industry has been a prime target for many vendors of manufacturing equipment and services. Automotive companies traditionally have allocated relatively large amounts of capital expenditures for automation and have acted as pioneers in the development and adoption of advanced automation techniques. With the downturn in automotive spending that started in 1986, automation companies are devising new strategies to target markets that either are emerging or represent new expansion opportunities.

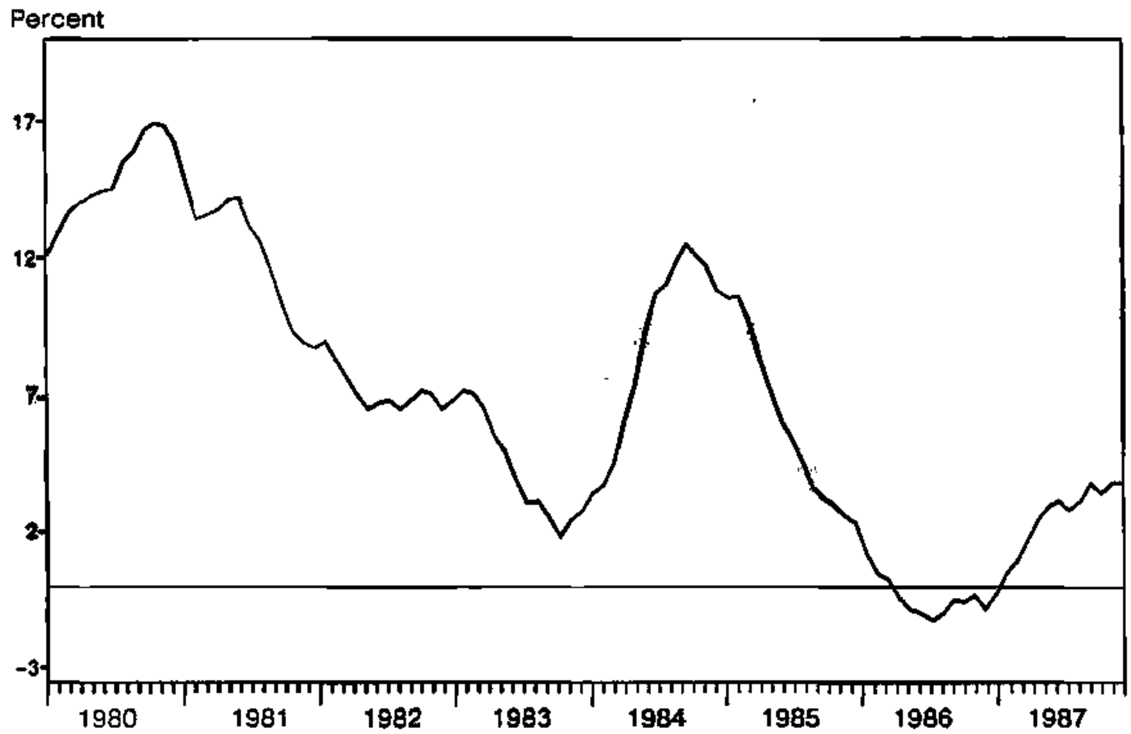
Dataquest found that the potential opportunities for automation vendors and systems integrators are limited only by their creativity, willingness to take risks, and perseverance in researching and cultivating the new marketplace.

For semiconductor vendors, this means that they can increase their business with factory automation manufacturers as the factory automation vendors penetrate new markets. For example, digital single-station controllers offer greatly increased control capability for continuous manufacturing processes, while occupying the same panel board space as older analog controllers. The versatility of single-station controllers means that they can be used to solve difficult control problems in continuous, sequential, and mixed applications. By connecting several single-station controllers through a local area network to a central operator station, a low-cost alternative to distributed control systems can be installed. What this boils down to for semiconductor manufacturers is that, by adding functionality using digital semiconductor technology, older products (e.g., single-station controllers) are being rejuvenated.

The most recent U.S. Department of Commerce data (December 1987) show electronic instrument shipments closing the year 3.8 percent above 1986. Figure 4 displays a 12/12 rate of change curve for electronic instrument shipments.

Figure 4

U.S. Scientific and Engineering Instrument Shipments
(12/12 Rate of Charge)



Source: U.S. Department of Commerce
Dataquest
March 1988

Consumer

The consumer electronics industry continued its unsuccessful search for the VCR of 1987. Manufacturers had to rely on the old standbys—television sets, VCRs, and audio equipment—to keep production from dropping below 1987 levels.

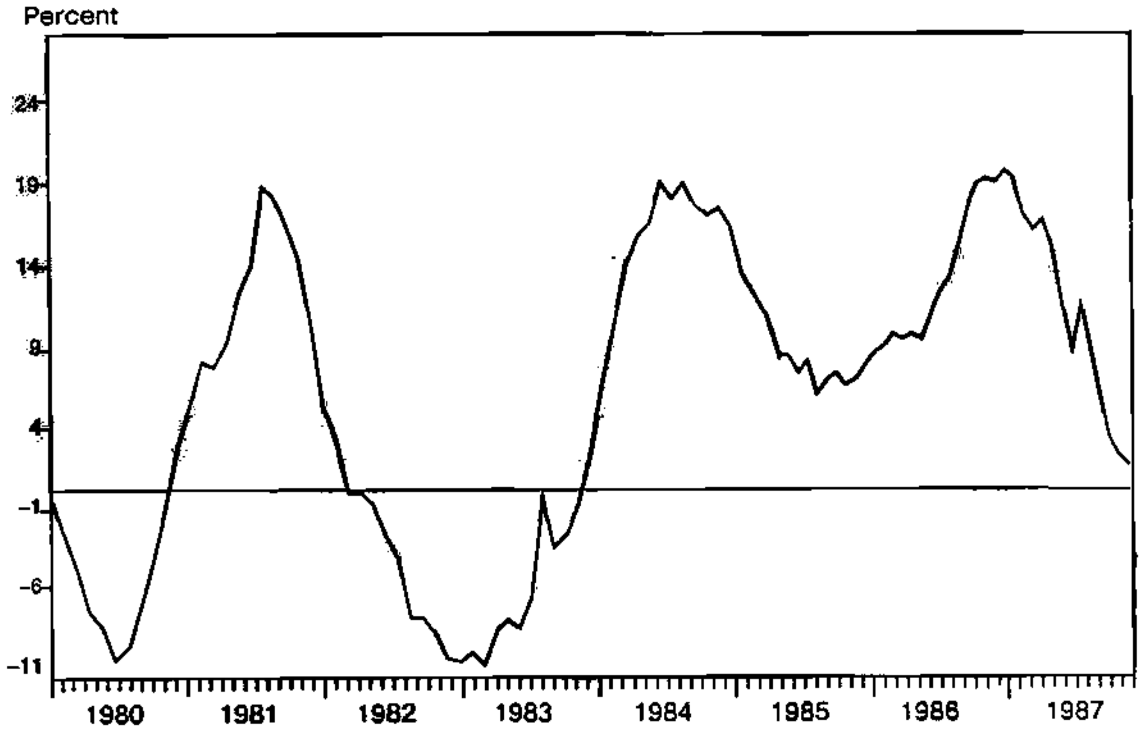
The major 1987 milestone for this application was the purchase of GE/RCA's consumer electronics business by Thomson of France. This event left Zenith as the last major U.S.-owned consumer electronics manufacturer. However, this does not mean that there is no North American consumer electronics manufacturing. Many Japanese and even Korean companies manufacture in the United States. For example, Goldstar makes television sets and microwave ovens in Alabama, and Sony makes television sets in San Diego. As U.S. government pressure on its trade partners continues, more consumer electronics companies will move manufacturing to the United States. With the Japanese yen appreciating and the Asian newly industrialized countries (NICs) fearing U.S. government protectionism, moving production to the United States is a very appealing idea.

In the personal electronics area, the biggest news of 1987 was the fall of Worlds of Wonder (WOW), the darling of the toy industry. WOW is now reorganizing under Chapter 11 of the U.S. bankruptcy code. What makes WOW unique and important to the semiconductor industry is its innovative use of semiconductors for high-volume applications; for example, the use of Texas Instruments' DSP chips in WOW's Julie doll.

The U.S. Department of Commerce rate of change curves for radio and TV SICs shows that production slowed to 1.6 percent at the end of 1987 (see Figure 5). This is due to inventory buildup in the middle of 1987 and slow fourth quarter sales.

Figure 5

Radio and Television Shipments (12/12 Rate of Change)



Source: U.S. Department of Commerce
Dataquest
March 1988

Military

The outlook for military electronics remains much the same as when we began the year, indicating a gradual downward trend over the next three years followed by very slow growth out to 1997. The latest Electronics Industry Association (EIA) forecast indicates that electronic content of defense spending will decline 5 percent to $51.9 billion in 1988 and will remain essentially flat through 1993. This estimate was predicated on continued deficit-cutting measures by Congress, with defense spending receiving the lion's share of the reduction.

Recent news from Washington centers on the negotiations between the new U.S. Department of Defense (DOD) chief, Frank Carlucci, and Congress. The latest proposal indicates that the fiscal 1989 budget might be reduced by as much as 10 percent (about $30 billion) in an effort to keep DOD autonomy on how the money will be spent. In spite of increasing content of semiconductors, if this situation transpires it could have a further negative impact on military electronics spending.

International sales for North American military electronics firms remained mixed because the new era of sharing projects with NATO countries is limiting opportunities for North American manufacturers.

Semiconductor sales into military applications grew sluggishly in 1987, at only 0.5 percent. Although more sophisticated ICs like gate arrays and 16- and 32-bit microprocessors are penetrating this market rapidly, poor demand compounded by excess inventory and declining prices hurt overall growth. Based on the assumption of increasing penetration of semiconductors into electronic systems, military semiconductor use is forecast to grow at a 5.8 percent CAGR through 1992.

Transportation

In spite of vehicle unit production cutbacks in 1987 (see Table 2), the North American auto and truck electronics market still registered moderate growth. Auto and light truck production finished 1987 4.9 percent below unit production in 1986. However, automotive electronics revenue managed to grow 6.5 percent in 1987. This was primarily due to the rapid year-to-year increase of electronics devices per average vehicle. Dataquest estimates that the electronic content of the average North American automobile was $805 in 1987 but was only $549 in 1984, a 13.6 percent CAGR. Growth in electronic engine control and factory-installed audio equipment is slowing as the 10 percent penetration mark approaches. However, excellent growth is occurring in the body control, driver information, and safety and convenience areas. Electronic steering, antilock braking, advanced driver displays, and collision avoidance are samples of the new systems beginning to show up in new high-end automobiles.

Because it is relatively immune to the consumer cycle, automobile and light truck sales, and thus the transportation electronics market, is expected to grow at a 9.8 percent CAGR through 1991. This will subsequently drive semiconductor consumption in transportation to 10.8 percent over the same period.

Table 2

North American Automobile Production (Units)

	January 1 to December 19, 1988	January 1 to December 20, 1987	% Change 1986-1987
American Motor Corp.	43,336	15,994	(66.9%)
Chrysler Motors	1,275,880	1,068,772	(16.2%)
Ford Motors Co.	1,729,089	1,793,315	3.7%
General Motors	4,047,314	3,386,480	(16.3%)
Honda	231,510	318,587	37.3%
Mazda	0	3,997	N/A
Nissan	61,859	112,518	81.9%
Nummi	191,854	186,040	(3.0%)
Volkswagon	81,524	64,977	(20,3%)
Total U.S. Automobile	7,667,366	6,950,630	(9.3%)
Total Canadian Automobile	1,047,051	788,972	(24.6%)
Total North American Automobile	8,714,417	7,739,602	(11.2%)
Total North American Truck	4,224,330	4,563,794	8.0%
Total North American Automobile and Truck	12,938,747	12,303,396	(4.9%)

N/A: Not Applicable

Source: Automotive News
Dataquest
March 1988

DATAQUEST CONCLUSIONS

The high growth in the personal computer industry, coupled with the resurgence in growth in most other markets, has caused availability problems for DRAMs and 80386 microprocessors. These problems will continue through the first half of 1988, when new capacity comes on-line and demand begins to slow. Suppliers and users should work very closely to let one another know their supply/demand forecasts. In the short term, this cooperation will help both parties survive product shortages.

David G. Norman

Dataquest
a company of The Dun & Bradstreet Corporation

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A MODEM'S EYE VIEW OF THE WORLD

SUMMARY

Because the analog modem as we know it today is experiencing a downturn in sales revenue, Dataquest believes that it is important to understand alternative technologies that will overlap the modem's traditional domain throughout our forecast period.

The modem market will show some increase in unit shipments from 1987 through 1989. After 1989, purchasing decisions will be affected by ISDN transition products. From 1987 through 1989, Dataquest expects T-1 transmission circuits and digital services to gather an increasing share of users' communication budgets.

Also, the importance of the telephone companies cannot be ignored. AT&T, the seven regional holding companies (RHCs), and the 1,404 local telephone companies have a tremendous influence not only on the movement of computer data but also on trends in technology development through their network design agreements, tariffs, and rates for various services and their control of rates for access lines.

Judge Greene and Mr. Patrick from the FCC may be headed for a confrontation regarding jurisdiction and compliance issues that will have impacts on networking developments and will only be resolved over time. Dataquest will closely observe these proceedings and report on important developments.

The issues are critical as companies define strategies to meet future market requirements. Since the market crash of October 19, many other economic factors must now be considered, as the outlook for the near term seems bleak. Information has never been more critical as a basis for decisions in this time of uncertainty.

THE MODEM MARKET

The projection of any market's development or decline for a period of up to five years will never be exact, especially in high-technology areas. When we present our data for our analyses of unique markets, it is not always apparent how we arrive at our conclusions. This newsletter will explain some of the assumptions behind the data represented in Dataquest's modem service section and identify major emerging technologies that affect this market.

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Currently, the modem market's revenue is flat—the rapid growth which occurred from the late 1970s through 1984 has not reappeared. The last few years has seen several modem companies in serious trouble. Novation used to be a major force in the modem market and is now in Chapter 11. Prentice Corporation has had several layoffs, the last of which reduced the entire staff to less than 20 people. Racal/Vadic dropped dramatically in sales revenue in the last two years and is now starting to recover. Anchor Automation's sales have also plummeted. Most of the other modem companies saw limited growth in 1986.

In the data terminal modem market, Codex has maintained its leadership position, staying ahead of AT&T, GDC, Paradyne, and Racal/Milgo, all of which have had little or no sales increases in the last two years.

A brief look at some of the major changes in the modem marketplace in the last year and how these trends represent major challenges for modem manufacturers will help illustrate previously discussed developments.

PC MODEM TRENDS

300-bps Modem: All But Gone

The 300-bps modem is quickly disappearing as the 300/1,200-bps 212A modem is so affordable. In fact, Dataquest no longer covers the 300-bps speed segment.

300/1,200-bps Modem: Price Decline

The 300/1,200-bps modem is seeing tremendous price erosion; products priced as low as $59 were seen this year. Throughout the forecast period, Dataquest estimates that this unit will migrate to a single chip and will be included in every PC and terminal.

2,400-bps Modem: Unit Growth

The 2,400-bps modem is currently experiencing increasing sales in units and will see some dollar growth from 1988 through 1989. During this time, price reductions will negatively impact total revenue; this trend is expected to continue through the forecast period.

9,600-bps Modem: Highest Growth Overall

The 9,600-bps modem will see the highest market growth, with units and revenue continuing to grow through 1991. Dataquest estimates a 41.6 percent CAGR for shipments from 1987 through 1991.

A factor affecting the growth of these products is the issue of integration with other technologies, specifically ISDN. Dataquest believes that ISDN will be implemented by the mid-1990s. However, integration products, such as terminal adaptors, will soon appear as customers decide to purchase customer premise products that are compatible with ISDN.

ISDN will become a reality because the telephone companies want to implement this service. It is a solution that represents great labor cost reductions as all of their services, both voice and data, are integrated into an automated network. Currently, these companies are investing millions of dollars in ISDN development. ISDN will impact both PC modems and data terminal modems; however, data terminal modem manufacturers face other factors, which are discussed in the following paragraphs.

DATA TERMINAL MODEMS

300-bps Modem: Too Slow

Again, the 300-bps modem, except in a few niche markets where very low speed data is acceptable (such as process monitoring systems or utility control networks), is quickly disappearing.

1,200-bps Modem: Limited

The 1,200-bps modem has some applications but is still considered too slow for most of today's requirements.

2,400/4,800-bps Modem: Good Support

The 2,400-bps modem shows more strength because synchronous dial-up, as it is used in the IBM bisynchronous world, is still popular. The same is true for the 4,800-bps modem, which has many applications for both dial-up and leased-lines. Continued support of these products and their well-accepted standards will uphold sales for the next few years.

9,600-bps Modem: The Leader

The 9,600-bps leased-line modem currently is the market leader, with estimated sales of $381 million in 1986. We believe that pricing will be lower during the forecast period, and that this decrease will lower the total revenue through 1991.

The 9,600-bps data terminal modem shows continued strength in unit sales because applications, especially those in the IBM environment, support this product. System users with large data communications networks using front-end processors find that these units operate efficiently at speeds not exceeding 9,600 bps. Another consideration is the user's resistance to change: Higher speeds may require new software, which may affect total system performance. Many times, expenses are associated with these changes, either for new software or hardware, or both, and many users feel that the benefit does not warrant these additional costs. Current applications and an extensive installed base for the 9,600-bps modem are the two major factors negatively influencing customer acceptance of higher-speed data transmission.

High Speed: 14,400–bps, 16,800–bps, and 19,200–bps Modems

The transition to the higher speeds has been slower than most predictions by industry observers. The benefit of higher speeds, with its associated higher costs, both for modems and for communications facilities, has not yet overcome user resistance. The same reasoning may be applied to the relation between 9,600–bps digital services and 56,000–bps services. In terms of sales volume, 9,600 bps leads 56,000 bps by a ratio of three or four to one.

Dataquest estimates that interim speeds (that is, speeds between 9,600 bps and 56,000 bps) will not develop with a strong market from 1987 through 1991 because users will go directly to 56,000 bps and T–1 circuits.

TECHNOLOGY ALTERNATIVES

T–1 Technology

The major technology growth in 1987 has been in the T–1 industry overall. The T–1 technology offers unique advantages, with its higher bandwidth and its ability to handle voice and data, as well as other functions such as fax and video. By 1987, several major companies formed alliances with T–1 companies: Unisys acquired Timeplex, Micom acquired Spectrum Digital, Dowty acquired Datatel, Codex has an agreement with StrataComm, and IBM has an agreement with Network Equipment Technologies (NET). Clearly, major corporations are convinced that they must have a T–1 solution in their networking strategies. Dataquest estimates that T–1 will continue to grow during the forecast period, at a CAGR of 17.9 percent in terms of revenue, and that this growth will negatively impact modem sales.

ISDN

ISDN is much written about and discussed in articles and conferences worldwide. The recent Telecom '87 show in Geneva was heavily ISDN–oriented. We believe that ISDN really will be implemented and be a major technology alternative by the mid–1990s, from 1993 to 1995. However, we also recognize that decisions based on technology trends will be influenced as early as 1990 and that 1991 and 1992 will be heavily affected by ISDN interum products.

These interum products will be defined as products that bridge the gap between the traditional modem and ISDN. It is becoming consistently easier to incorporate more functionality with products, as components that support unique applications become smaller and easier to support. Therefore, products that function as modems, DSU/CSUs, PADs, and ISDN interfaces will be integrated into single units that will not require additional space. Dataquest will consider these products as terminal adaptors.

ISDN's Champions

The telephone companies are looking to ISDN as their solution for integrating all their diverse service offerings into one efficient, manageable, and profitable package. Currently, the RHCs are spending millions of dollars through their R&D arm, Bellcore, to develop an ISDN support strategy and clearly define its implementation in the United States. It is these companies' commitment that leads Dataquest to believe that ISDN implementation will become a reality.

DATAQUEST CONCLUSIONS

In view of the current economic outlook, which has many companies reevaluating their potential market growth and ability to raise capital, coupled with increased programs of stock buy-backs and acquisitions of competitors or simply driving them out of business, Dataquest realizes the importance of its role as an information service. We will closely monitor these developments and frequently generate reports to keep our clients informed as they direct their companies' transition strategies.

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David Norman
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Dataquest
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Research *Newsletter*

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IBM: SEMICONDUCTOR SUPPLIER AND BUYER

OVERVIEW

IBM is facing a future where its position in computer markets is being challenged. Between plug-compatible mainframe makers and PC clone houses, IBM's is under attack in almost every market that it serves. The road to survival will test, among other skills, IBM's ability to utilize new technology effectively. Its case could prove to be a model for OEMs and a useful guidepost for merchant semiconductor suppliers.

Crucial elements of IBM's forward strategies are the management of semiconductor technology and its application to system solutions. Having the right technology at the right time is vitally important to this quest. Although IBM secures a large part of its semiconductor needs on the outside, it also has recognized the need to develop its own technology and production facilities. Toward this end, IBM has embarked on a plan to invest heavily in semiconductor technology development and manufacturing capability.

Dataquest estimates that in 1986, IBM had $36.0 billion in worldwide hardware revenue and consumed an estimated $2.9 billion in semiconductors. We believe that IBM purchased $1.1 billion of its total semiconductor consumption. This made IBM, for that year, the largest buyer of semiconductors in the world, accounting for 4 percent of the total open semiconductor market. The remainder of IBM's consumption, $1.8 billion, was satisfied internally, making the company also one of the top three producers in the world.

The balance between making and buying semiconductors is affected directly by IBM's competitive strategies. The strategic sensitivity of the target system will determine, to a great degree, the source of the technology. If the system is commodity-like, then, typically, it will utilize a high percentage of merchant components. IBM's first personal computers typified commodity-like systems, as they consisted of 95 percent merchant semiconductors. If a system is deemed strategic, then IBM typically will use captive semiconductor technology. With captive capability, it can create computer systems that not only hit new price/performance goals but also create defensible competitive boundaries with proprietary silicon architectures. The PS/2 and the implementation of the Micro Channel Architecture are good cases in point.

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MAKE OR BUY DECISIONS

Although the strategic nature of a system most heavily affects the source of technology, several secondary factors also affect the process. An ever-present factor in any of these decisions is the very real event of not-invented-here (NIH), especially in a situation in which there is some overlap with internal programs. In this situation, objectivity is paramount. Often, the best technology-sourcing decisions are made by placing a project in a semiautonomous environment, as IBM did with its highly successful PC program. The following are many of the factors that IBM or any OEM considers when assessing the semiconductor make-or-buy crossroad:

- These factors favor captive sourcing:
  - Proprietary or advanced technology required for system differentiation
  - Custom needs (e.g., military, consumer, packaging)
  - Controllable supply, delivery, costs, and quality
- These factors favor merchant sourcing or alliances:
  - Up-front investment not possible
  - Proprietary hardware technology not needed
  - Technology incubation in an entrepreneurial environment
  - Surge demand coverage
  - Supplementary or complementary extension of internal resources

ELECTRONIC EQUIPMENT MANUFACTURING

Dataquest compiled the following list of various electronic equipment manufacturing and technology locations for IBM's worldwide operations. With the exception of the personal computer (Entry Systems Division) and military/aerospace (Federal Systems Division) groups, these locations are involved in very little volume procurement. However, the engineering and manufacturing input to the procurement decision can come from any of these locations.

- Personal computers and workstations:
  - Boca Raton, Florida
  - Raleigh, North Carolina
  - Austin, Texas
- Mainframes
  - Poughkeepsie, New York

- Midrange and special computers
  - Endicott, New York
  - Rochester, Minnesota
  - Boeblingen, West Germany
  - Kingston, New York
  - Yasu, Japan
- Storage systems
  - San Jose, California
  - Rochester, Minnesota
  - Tucson, Arizona
  - Fujisawa, Japan
  - Hursley, United Kingdom
- Printers
  - Charlotte, North Carolina
  - Endicott, New York
  - Boeblingen, West Germany
  - Lexington, Kentucky (phasing out)
- Display terminals
  - Raleigh, North Carolina
  - Hursley, United Kingdom
  - Kingston, New York (graphics also)
  - Fujisawa, Japan
- Typewriters/keyboards
  - Lexington, Kentucky
- Copiers
  - Charlotte, North Carolina

- Military/aerospace
  - Manassas, Virginia
  - Owego, New York
  - Houston, Texas
  - Gaithersburg, Maryland
  - Huntsville, Alabama
- Communication
  - Raleigh, North Carolina
  - Gaithersburg, Maryland
  - Santa Clara, California
  - La Gaude, France
- Research
  - Yorktown Heights, New York
  - Zurich, Switzerland
  - San Jose, California

Table 1 presents a detailed breakdown of the PS/2 manufacturing organization.

Table 1

PS/2 Manufacturing Organization

Location	Internal Role
Austin, Texas	Main board production
Boca Raton, Florida	Final assembly and test
Fujisawa, Japan	Production of 3.5-inch disk drives
Lexington, Kentucky	Keyboard and 5.25-inch Winchester drive controller production
Raleigh, North Carolina	Display production and Model 30 assembly
Rochester, Minnesota	Production of 5.25-inch Winchester disk drives
Toronto, Canada	Austin subsidiary and power supply assembly
Greenock, Scotland	Board and final assembly
Guadalajara, Mexico	Board and final assembly
Wangaratta, Australia	Board and final assembly

Company	External Role
Alps Electronics, Ltd.	Source of 3.5-inch disk drive
Avco Electronics	Assembler of memory and graphics boards
SCI Systems, Inc.	Prime off-load of main processor board production
Solectron Corporations	Secondary off-load of main processor board
Tatung, Co.	Display source
Texas Instruments, Inc.	Secondary off-load of main processor board

Source: Electronics Busines
March 1988

SEMICONDUCTOR TECHNOLOGY AND MANUFACTURING

IBM has extensive capabilities in fundamental semiconductor research and applied research and development, as well as manufacturing technology. Although often associated with avant-garde developments in solid-state physics, such as the recent breakthroughs in superconducting, IBM also has a proven track record in bringing semiconductor technology into volume application. IBM is, in fact, one the world's leading 1 Mbit DRAM suppliers—its market being itself.

IBM is in a position to cover a full spectrum of system architectures and performance requirements by possessing both submicron MOS as well as high-performance bipolar processes. It is also strong in the area of packaging, in which it has developed a high-density, high-heat-dissipation technology called Thermal Conduction Module (TCM). This packaging technique has helped IBM flagship 3090 computer family achieve vast performance improvements over prior offerings. They also have extensive presence in ASIC technology. Given the level of gate array usage, especially in its mainframes and personal computers, IBM is believed to be the world's largest producer of gate arrays.

The company has also taken a leading position in the Sematech program. Along with AT&T, IBM has offered some of its leading-edge products (1 and 4 Mbit DRAMs) to the project as test vehicles to perfect new manufacturing techniques.

IBM is estimated to have invested $2 billion in semiconductor manufacturing capability over the past three years. Research and development expenditure, as related to semiconductor technology, is also estimated to be $2 billion for the same time period. Manufacturing investments have been global. Both the Vermont and New York facilities were expanded, as were international facilities in France, West Germany, and Japan. It is believed that the bulk of the resources is going toward development of CMOS processes and products and toward the continued refinement of bipolar capability. CMOS technology is needed for IBM's program of supplying the needs of both the Entry Systems Division as well as the small and midrange computer groups. IBM is also believed to be the only United States-based company to have invested in 8-inch wafer processing capability. Moreover, IBM also participated in the VHSIC program and is using that technology through the Federal Systems Division.

Table 2 is a listing of IBM's principal semiconductor-related facilities located worldwide.

As an integral part of its technological strategy, IBM acquires technology from outside entities, as necessary. Through a series of strategic alliances ranging from direct investments to joint developments and exchanges, IBM has complemented its internal resources. Table 3 lists a sampling of some of those relationships.

Table 2

IBM Semiconductor Facilities

Location	Activity
Essex Junction/Burlington, Vermont	R&D, MOS and bipolar production
Hopewell Junction/East Fishkill, New York	R&D, MOS and bipolar production
Manassas, Virginia	R&D, VHSIC production
Corbeil-Essones, France	R&D, MOS and bipolar production
Sindelfingen, West Germany	MOS memory production
Hannover, West Germany	MOS memory production
Yasu, Japan	MOS production
Boeblingen, West Germany	R&D
Zurich, Switzerland	R&D
San Jose, California	R&D

Source: Dataquest
March 1988

Table 3

Technological Alliances

Company	Purpose
GE	ASIC and BICMOS smart power, joint development and production
Intel	Access to microprocessor designs, ASIC joint development
Oxford Instruments	Development of synchnrotron for X-ray lithography (0.1 micron)
Rockwell	Digital GaAs joint development
Texas Instruments	Local area network ICs

Source: Dataquest
March 1988

PROCUREMENT PRACTICES

It has been said that the effort of getting a product qualified for sale to IBM is not unlike the approval process for military markets. The scrutiny under which IBM places the product design, the manufacturing methods, the management, and general service issues is unsurpassed. But more often than not, when the qualification process is completed, the vendor has a better product and better overall system to serve the needs of its customer base.

Corporate Component Procurement (CCP) in Poughkeepsie, New York, and Component Procurement European Center (COMPEC) in Canejan, France, coordinate the majority of IBM's semiconductor procurement worldwide. In the past, varying degrees of procurement control have been delegated to the Entry Systems and Federal Systems Divisions to serve their unique needs.

The following is a list of vendor qualification criteria applied by IBM's procurement personnel to potential suppliers:

- Latest technology available
- Business/technical interfaces
- Local manufacturing
- Internal data to support qualification
- Competitive pricing
- Just-in-time (JIT) delivery
- Serviceability
- Flexibility of supply
- Zero-defect quality

Qualification can take from from 6 to 18 months. Both product performance and reliability are assessed through electrical testing and defect analysis (life test and physical analysis). Initially, quality is assessed by IBM, but, in time, as vendor relationships mature, responsibility for quality assurance can be delegated to the vendor. As a preventative measure, IBM may ask that key process control data be submitted on a regular basis. Upon qualification of a product, IBM will place the vendor on an annual program of quality improvement, complete with monthly monitoring, quarterly reviews, and regular meetings.

Semiconductor Procurement

IBM worldwide hardware revenue was approximately $36 billion in 1986. Table 4 is a breakdown of IBM's revenue, based, in part, on its annual report and on market share estimates from other technology services within Dataquest. The largest revenue segment was in mainframe or corporate resource computing systems, accounting for an estimated 36.5 percent of the total. Personal computers reflected the second largest segment, accounting for 19.1 percent, and storage systems for 18.7 percent.

By using a combination of input/output (I/O) modeling and industry surveys, Dataquest estimates IBM's total 1986 semiconductor consumption is in Table 5. The total of $2.86 billion represents an I/O factor of 7.9 percent.

Figure 1 presents the estimated 1986 semiconductor purchases for IBM. These numbers are based on both primary and secondary research sources. We estimate that semiconductor purchases represented 39 percent of IBM's total needs. Its also estimated that the Entry Systems Division, in sourcing for the personal computer line, accounted for 60 percent of those purchases. The Federal Systems Division is also a heavy user of merchant components. Prior content analyses done at Dataquest indicate that the low-end printers and display terminals also use a high percentage of outsourced devices.

Table 4

Estimated IBM 1986 Worldwide Revenue
by Major Product Line
(Millions of Dollars)

Product	Revenue
Mainframe Systems	$13,133
Personal Computers	6,880
Storage	6,736
Midrange Systems	3,666
Military/Aerospace	2,121
Display Terminals	1,040
Communication	900
Printers	800
Typewriters	393
Copiers	326
Total	$35,995

Source: Dataquest
March 1988

Table 5

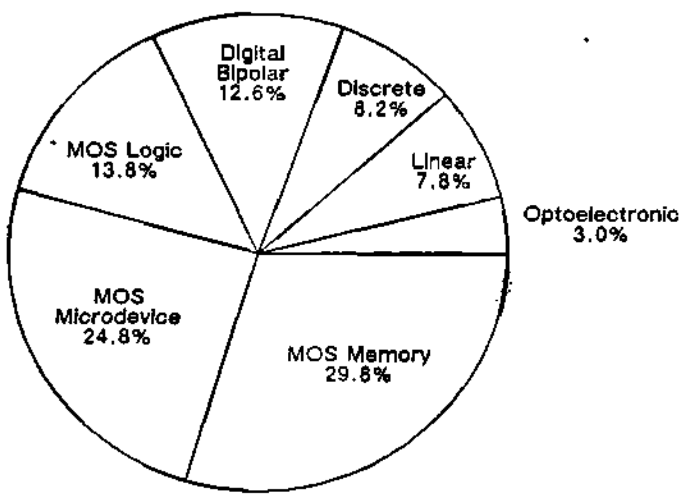
Estimated IBM 1986 Semiconductor Consumption by Major Product Line (Millions of Dollars)

Product	Semiconductor Consumption
Mainframe Systems	$1,160
Personal Computers	790
Midrange Systems	384
Storage	235
Military/Aerospace	105
Communication	65
Display Terminals	60
Printers	42
Typewriters	12
Copiers	7
Total	$2,860

Source: Dataquest
March 1988

Figure 1

Estimated IBM 1986 Semiconductor Purchases



Total = $1,125 Million

Source: Dataquest
March 1988

DATAQUEST CONCLUSIONS

In the battle for the global computer system markets, IBM has chosen to rely heavily on internal semiconductor technology as part of its overall strategy. Although IBM's complete 1987 financial results were not released before publication of this newsletter, we estimate that outside semiconductor purchases were down 5 to 10 percent from 1986. The prime component driving the declining purchases is the ramp-up of the PS/2 line, which uses predominantly captively produced components.

Given the desire to incorporate proprietary technology to differentiate its strategic systems as well as the intensity of semiconductor capital investment and R & D, we believe that IBM will continue to reduce its dependency on merchant supply. However, the "leftovers" could well continue to be a billion dollar opportunity for fortunate suppliers.

Gregory L. Sheppard

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Research Newsletter

SAM Code: 1987–1988 Newsletters: January–March
1988–06

TECHNICAL WORKSTATION MARKET—A FUTURE VISION; STRONG MARKET GROWTH AND NEW SEGMENTATION EXPECTED Part I

OVERVIEW

This is Part I of a two-part newsletter on the technical workstation market—one of the hottest markets in the computer business today. Part I will do the following:

- Characterize the technical workstation market
- Discuss market size and forecast
- Analyze vendor market shares
- Analyze and forecast by applications

Part II will analyze the expected new market segmentation, as follows:

- Future trends
- PC/workstations
- Traditional technical workstations
- Superworkstations
- Graphic supercomputers
- Server processors

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

This newsletter summarizes the results of an in-depth Dataquest research project entitled Technical Workstations, which contains analysis for:

- Four new market segments
- Eleven technical applications
- Segment and application forecasts
- Product and company profiles
- Future market and technology trends

The Technical Workstations report, containing more than 400 pages of analysis, is available now. To receive more information, contact your Dataquest marketing representative.

THE TECHNICAL WORKSTATION MARKET

Workstations Are Becoming the "In Thing"

Many computer companies are entering the technical workstation market because they recognize that the technical workstation of today is the personal computer of three years from now. The technical workstation offers technology that is destined to decline in price to the PC range in about three years; hence, several personal computer companies have or will introduce workstation products. Because personal computers play such an important role in their businesses, these companies are entering the workstation market now. Technical workstations have evolved from a specialized niche to the mainstay of computing.

The workstation business is evolving rapidly, with new technology and intense competition. Since 1980, 8 companies have left the market; 14 companies were still involved at the end of 1986.

- So far in 1987, 15 new vendors have entered the technical workstation market, 10 of which are based in the Far East. These 15 companies and their locations are as follows:
  - Convergent Technologies (United States)
  - Counterpoint (Japan)
  - Hitachi (Japan)
  - Meidensha (Japan)
  - Mitsubishi (Japan)
  - NEC (Japan)

- Nihon Univac (Japan)
- Prime Computers (United States)
- Sharp (Japan)
- Sony (Japan)
- Tektronix (United States)
- Toshiba (Japan)
- Xerox (United States)
- UStation (Japan)
- TeleVideo (United States)

- Dataquest expects eight more companies to announce technical workstation products in late 1987 and early 1988. They are:
  - Ardent Computer (United States)
  - Stellar Computer (United States)
  - Three unspecified Japanese companies
  - Three unspecified European companies

Size of the Market

The technical workstation market began in 1980 and grew to $1.54 billion by 1986. In 1986, the leading vendors ranked by revenue were Apollo, Sun Microsystems, Hewlett-Packard, and Digital Equipment Corporation. By 1991, Dataquest expects the technical workstation market to be more than $6.00 billion, growing at a 30.0 percent compound annual growth rate (CAGR) from 1987 to 1991. In 1986, the technical workstation segment represented 9.9 percent by revenue and 8.3 percent by units of the total technical systems industry.

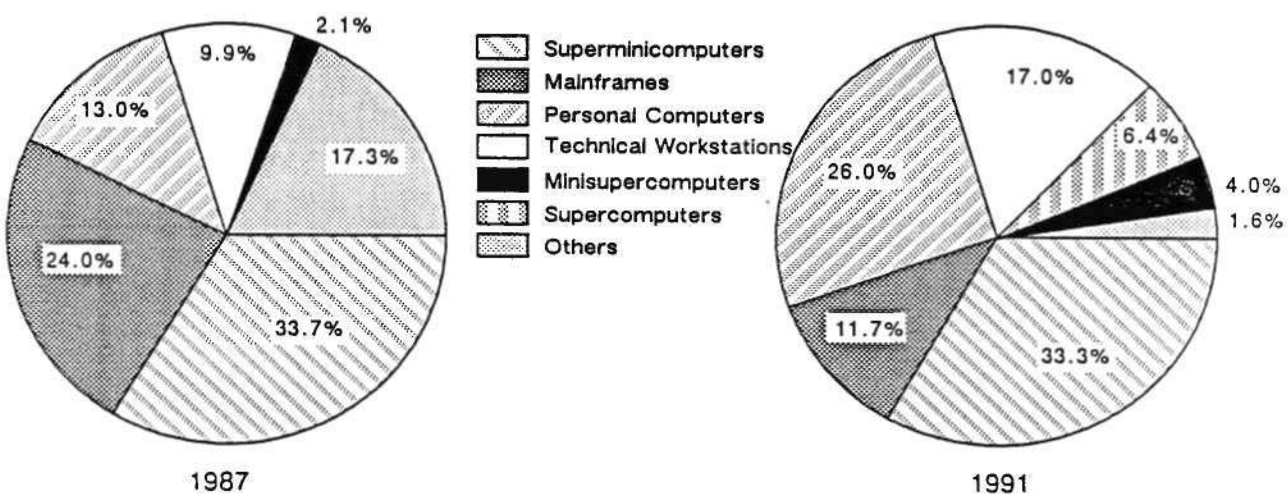
Figure 1 illustrates the size of the technical workstation segment relative to other technical computer product segments. We expect the technical workstation market share to grow from 9.9 percent share of the total market revenue in 1987 to 17.0 percent by 1991.

From 1980 to 1986, Apollo shipped more than $1 billion worth of workstations, and Sun has shipped more than $590 million since its first shipments. In 1987, these companies may add more than $1 billion of technical workstations to the installed base. Several start-up companies have come and gone. The big companies—Digital, Hewlett-Packard, and IBM—entered the market after it reached a size to support their businesses. Now, in 1987, we are starting to see many Japanese vendors begin their assault. The total installed base of systems from 1980 to 1986 is valued at $3,184 billion, with shipments totaling 113.6 thousand units. By the end of 1987, value may reach more than $5 billion, with more than 200,000 units installed.

It is estimated that workstations are being sold into a potential base of more than 8 million engineers, scientists, and programmers worldwide, and market saturation is nowhere near in sight.

Figure 1

Product Segment Analysis 1987 and 1991



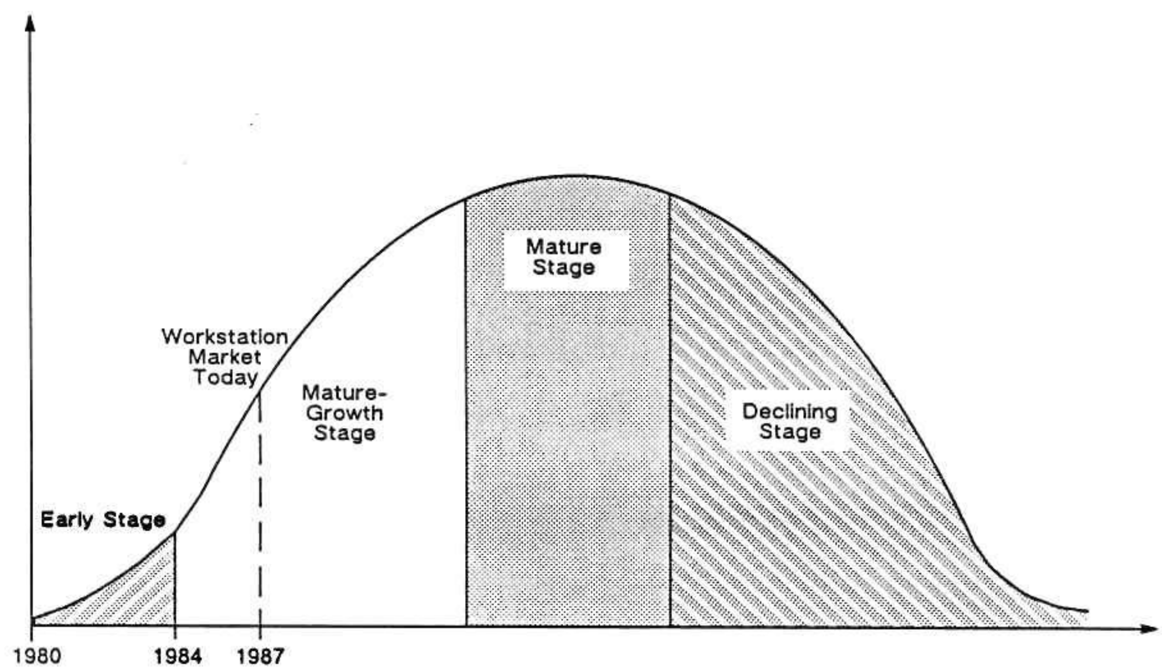
Source: Dataquest February 1988

State of the Market

The technical workstation market could best be described as being in its mature-growth phase, as illustrated in Figure 2. Several vendors continually introduce new products and price changes at a very fast pace designed to keep the competition off balance. As a result, the workstation business is one of the fastest paced, most intensely competitive businesses in the computer industry.

Figure 2

Technical Workstation Market Development Cycle



Source: Dataquest February 1988

Market Shares

Fourteen workstation vendors currently offer more than 45 product models. Year-to-year growth rates are slowing, which is expected as the market matures and increases in size. Tables 1 and 2 and Figures 3 and 4 present the technical workstation factory revenue and unit shipment historical data and forecasts for 1982 through 1991.

Vendor market shares by revenue for 1986 are listed in Table 3 and Figure 5. The top three companies—Apollo, Hewlett-Packard, and Sun Microsystems—hold 66.5 percent of the revenue and 75.0 percent of the unit shipments for the entire workstation segment. Sun, Digital Equipment, and IBM showed market share gains at the expense of Apollo, Symbolics, and companies in the Others category. We note the following:

- Sun is the biggest market share gainer, gaining 5.9 percentage points; it is followed by Digital with a gain of 3.2 percent, and IBM with a gain of 2.4 percent. (IBM was not in the market prior to 1986.)

- Hewlett-Packard, not traditionally thought of as a design automation leader, has made tremendous strides in industrial automation (ATE) and laboratory and medical applications, where the company has a strong position with its instrument product lines (meters, oscilloscopes, automatic test equipment).

- The biggest market share loser was Apollo, losing 5.8 percentage points; this loss was probably due to the bad third quarter of 1986 reported by the company and a slowing of capital equipment purchases from design-automation OEMs (such as Calma and Mentor), which heavily weights Apollo's sales.

- The Others category also lost market share, containing a number of companies that exited the workstation market.

We expect that Sun may move into first place in 1987 and that Digital Equipment, which has become very aggressive in 1987, may challenge Hewlett-Packard for third place. IBM has increased performance and added features to its RT product line but still has not leaped ahead in the market as many expected.

Table 1

Technical Workstation History
Factory Revenue and Unit Shipments
(1982–1986)

	1982	1983	1984	1985	1986	CAGR 1982-1986
Revenue ($M)*	35	164	471	938	1,563	157.9%
Percent Change	N/M	362.7%	188.1%	99.1%	66.7%	
Shipments (K Units)*	1	6	13	33	61.3	170.9%
Percent Change	N/M	402.4%	125.9%	151.6%	88.6%	
Average Selling Price ($K)	35	27.3	36.2	28.4	25.5	(19.0%)
Total Cumulative Shipments (K Units)	1.5	7.2	20.1	52.6	113.6	195.0%

*All numbers adjusted to calendar year
N/M = Not Meaningful

Table 2

Technical Workstation Forecast
Estimated Factory Revenue and Unit Shipments
(1987–1991)

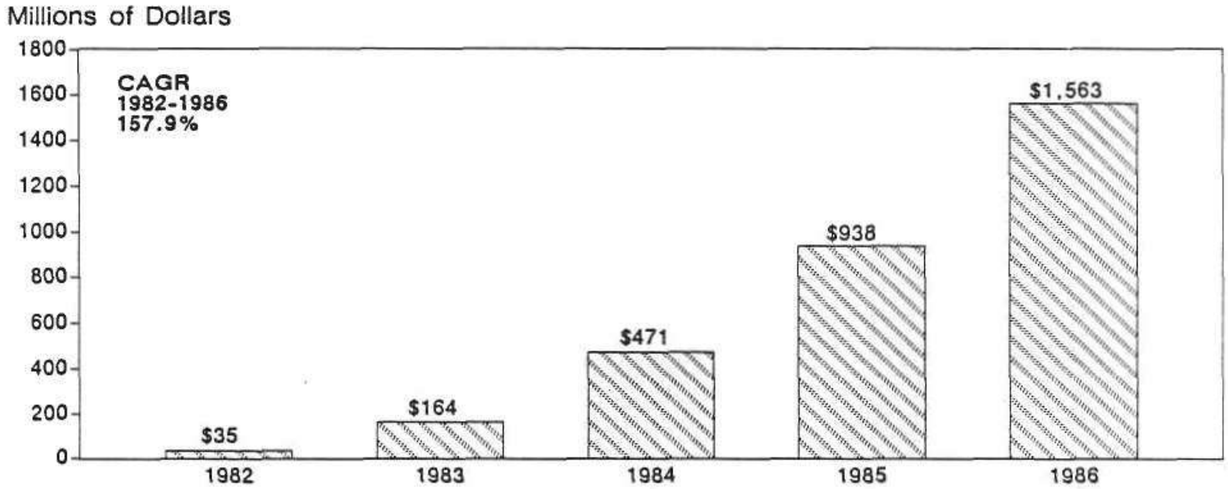
	1987	1988	1989	1990	1991	CAGR 1987-1991
Revenue ($M)*	$2,092	$2,835	$3,781	$ 5,172	$ 6,336	30.0%
Percent Change	38%	35%	30%	27%	28%	
Shipments (K Units)*	95	168	291	455	627	60.4%
Percent Change	55%	78%	72%	56%	38%	
Total Cumulative Shipments (K Units)	208.5	378.0	667.0	1,145.0	1,817.0	71.9%
Average Selling Price ($K)	22.7	17.2	13.0	10.5	9.8	(19.0%)

*All numbers adjusted to calendar year

Source: Dataquest
February 1988

Figure 3

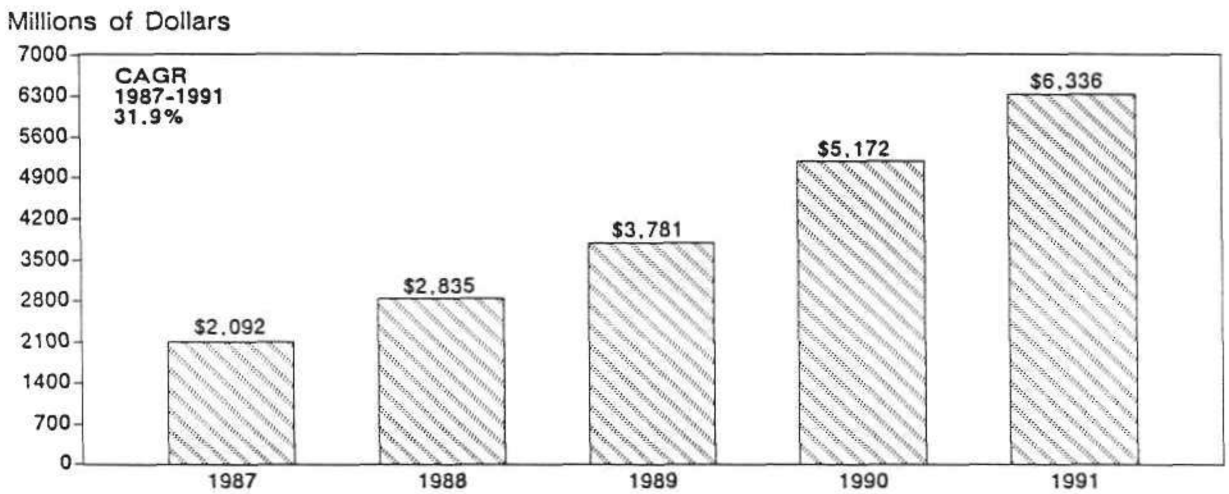
Technical Workstation History
Estimated Vendor Revenue
(1982–1986)



Source: Dataquest
February 1988

Figure 4

Technical Workstation Forecast
Estimated Vendor Revenue
(1987–1991)



Source: Dataquest
February 1988

Table 3

Technical Workstation Vendors
Factory Revenue and 1986 Market Share
(1982–1986)*
(Millions of Dollars)

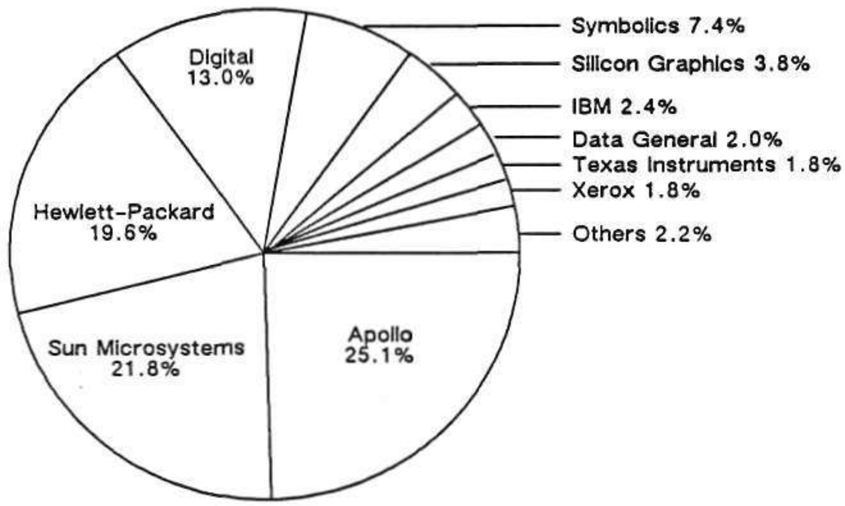
Company	Revenue ($M)**					Market Share		
	1982	1983	1984	1985	1986	1985	1986	Change
Apollo	$18	$ 81	$211	$290	$ 392	30.9%	25.1%	(5.8%)
Sun Microsystems	3	24	70	149	341	15.9	21.8	5.9%
Hewlett-Packard	2	21	52	186	307	19.8	19.6	(0.2%)
Digital Equipment	0	0	0	92	203	9.8	13.0	3.2%
Symbolics	4	18	47	80	115	8.5	7.4	(1.1%)
Silicon Graphics	0	0	5	27	59	2.9	3.8	0.9%
IBM	0	0	0	0	38	0.0	2.4	2.4%
Data General	0	0	14	26	32	2.8	2.0	(0.8%)
Texas Instruments	0	0	5	22	29	2.3	1.8	(0.5%)
Xerox	0	0	12	20	28	2.1	1.8	(0.3%)
MASSCOMP	0	0	4	5	13	0.5	0.9	0.4%
Others	0	1	2	41	6	4.5	0.4	(4.1%)
Total#	$35	$164	$471	$938	$1,563	100.0%	100.0%	

*All figures adjusted to reflect calendar year revenue
**Reflects shipments and revenue for workstations; and does not include graphics terminals
#Columns may not add to totals shown because of rounding.

Source: Dataquest
February 1988

Figure 5

Top 10 Technical Workstation Vendor Market Shares
1986 Factory Revenue



Source: Dataquest
February 1988

WORKSTATION APPLICATIONS

Background

Technical workstations are used in almost all technical applications with the possible exception of communications. This section will analyze technical workstations used in each Technical Computer Systems Industry Service (TCSIS) segment application listed below:

- Industrial Automation
- Design Automation
- Earth Resources
- Scientific
- Real-Time Laboratory
- Graphics & Image Processing
- Software Development
- Computer-Aided Publishing
- Laboratory
- Medical
- Other

In the early stages of the workstation market growth, sales were greatest to computer-aided design (CAD) and software development applications. CAD applications are primarily involved with physical design. In the last two years, however, a new market application has developed that is primarily involved with functional design, or computer-aided-engineering (CAE). Sales have also been concentrated in the areas of software development—computer-aided software engineering (CASE) and artificial intelligence (AI)—and computer-aided publishing. In the future, we expect new applications to be run on technical workstations; furthermore, we expect workstation technology to expand to all types of interactive computing environments.

The high-growth and large-revenue applications for technical workstations will continue to be the applications where there is a need to share graphic information between several people and/or several computers. We expect the applications of design automation and software development (including CASE and AI) to remain the two largest markets over the 1987 to 1991 forecast period. These two applications are often characterized by large projects with a high content of graphic information distributed across many individual workers.

We expect computer-aided publishing to follow in third place because workstations are used to manipulate engineering documentation and therefore follow design automation market growth. These three applications represented 72.1 percent of the workstation market revenue in 1986; we believe that they will continue to hold a dominant position of 67.5 percent of revenue in 1991. Computer-aided publishing and software development applications will utilize more of the low-cost PC/workstation and traditional technical workstation products, whereas design automation will use all of the product types.

Many of the other TCSIS segment applications often have a large need for real-time computing that is machine driven, such as real-time control, laboratory analysis, medical patient monitoring, and industrial automation control. Frequently, these applications do not require huge amounts of computing resources, and workstations are more often used for their communication and graphic display capabilities. The PC/workstations and traditional technical workstations are expected to serve the bulk of these applications.

Earth resources mapping, real-time cockpit simulators, graphics, and medical scanner applications will use the high-end workstations such as superworkstations and graphic supercomputers for their graphic processing and computational speed.

New applications that are expected to be run on technical workstations include computer-aided styling for product design and marketing departments, law enforcement, stock trading, and military applications.

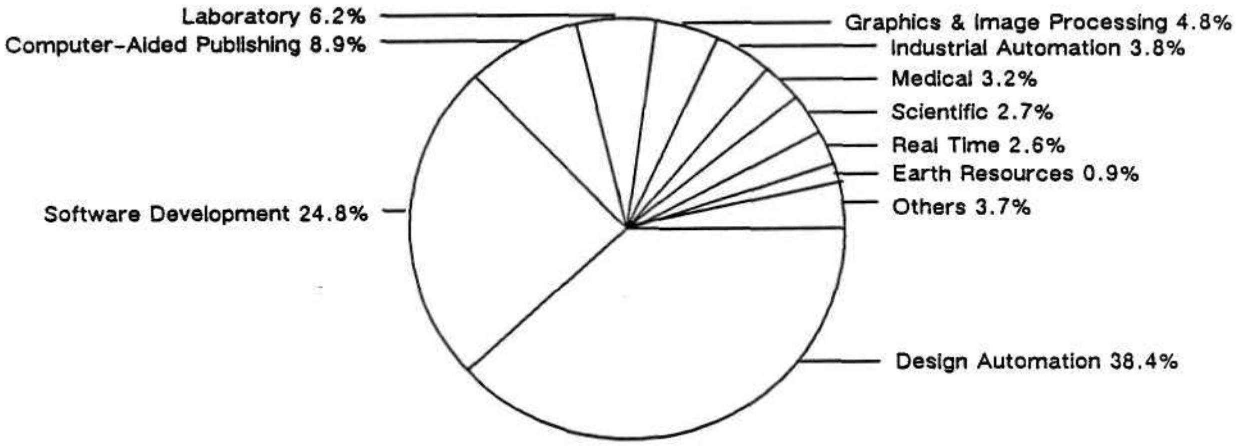
Application History, Forecast, and Analysis

Figure 6 presents Dataquest's estimates of the workstation market by percent of total revenue for 11 technical applications in 1986 and 1991. Application analysis includes the following:

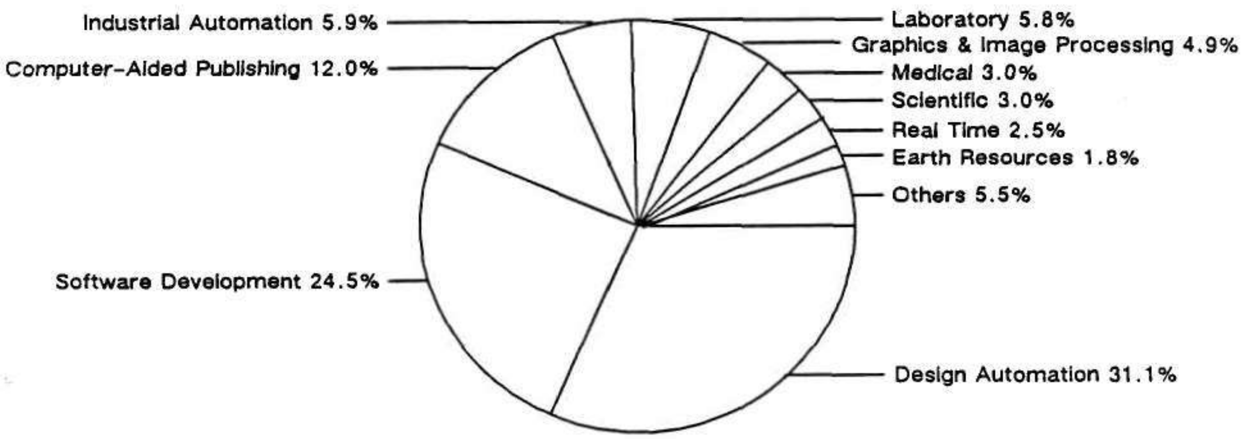
- The workstation market will expand into almost all technical applications.
- The top three applications in 1991 are expected to be design automation, software development, and computer-aided publishing—together commanding 67.5 percent of revenue and 65.0 percent of unit shipments.
- All other TCSIS application segments will adopt technical workstations to smaller degrees; the needs of these applications don't match as well as the benefits that workstations provide.
- Midrange technical workstation technology of 1987 is expected to be the personal computer technology of 1991.
- Technical workstations will always maintain a price and performance separation from personal computers because most PC applications do not require fast floating point, the computation of large tasks, or high-performance graphics.

Figure 6

Technical Workstation Revenue Summary and Forecast
All Applications
1986 and 1991
(Percent of Total Dollars)



1986



1991

Source: Dataquest
February 1988

NEW SEGMENTATION EXPECTED

Interactive distributed processing is a new way of computing, and we expect it to penetrate more than just the engineering applications. We believe that the needs of users vary with different applications and at different price levels. In the past, workstation-style computing was offered only with systems priced between $15,000 and $60,000. Now, however, we expect the price points to move both downward and upward. Additionally, we expect a surge of new vendors to enter the market in the new price bands. Personal computer vendors will have products priced below $15,000, and the new companies will sell products for prices above $75,000.

We believe that the workstation market is about to split into four distinct segments, as described in Table 4 and illustrated in Figure 7. Figures 8 and 9 illustrate the impact that these new segments will have on the existing market between 1988 and 1991 in terms of revenue and unit shipments, respectively.

This market split will be driven by low-priced personal computer technology moving upward and by the emergence of high-performance workstations based on advanced computer, graphics, and VLSI technologies. These two forces will cause many changes in the marketplace over the next few years, creating a major product restructuring. The market strategies and dynamics of selling into each of these product segments will be very different and distinct.

Table 4

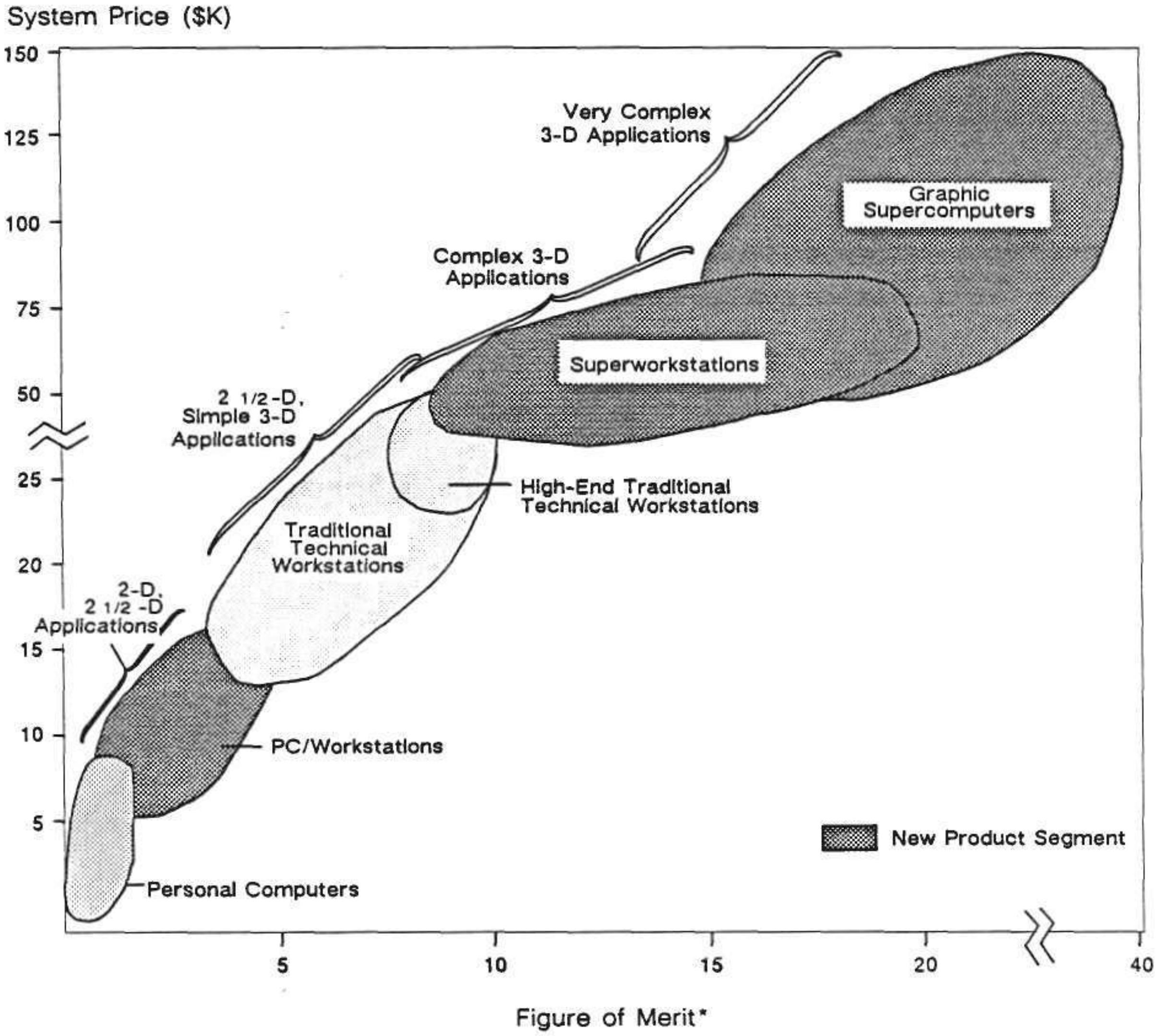
New Workstation Market Segmentation

Segment	Description	Approximate Price Range
Low End	PC/workstations	$5,000 to $15,000
Midrange	Traditional workstations	$15,000 to $50,000
High End	Superworkstations	$40,000 to $80,000
Very High End	Graphic supercomputers	$75,000 to $150,000

Source: Dataquest
February 1988

Figure 7

Technical Workstations—New Segments
Estimated Price/Performance Positioning
1987–1991

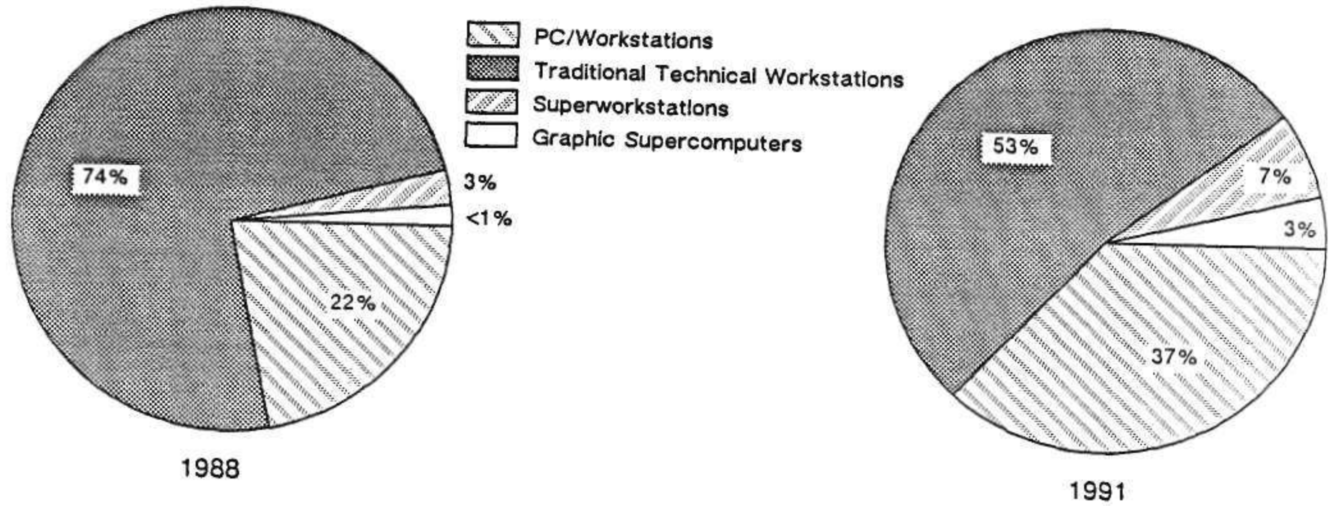


*Based on mips, mflops, Mbytes, vectors, and polygons-per-second

Source: Dataquest
February 1988

Figure 8

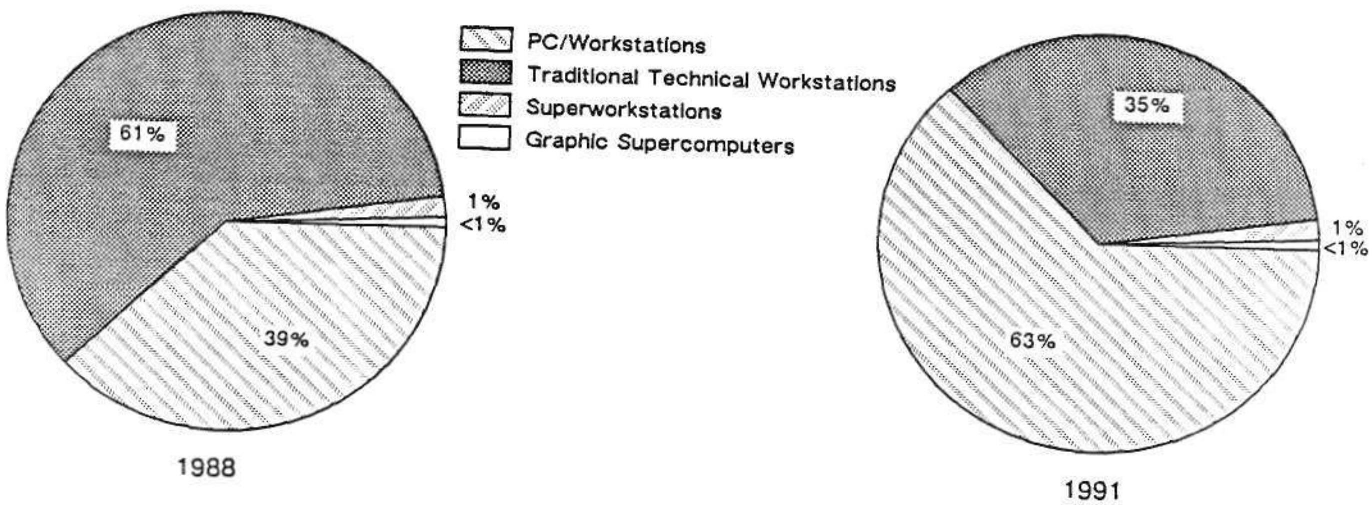
Technical Workstations—All Segments
Estimated Revenue by Segment
1988 and 1991



Source: Dataquest
February 1988

Figure 9

Technical Workstations—All Segments
Estimated Unit Shipments by Segment
1988 and 1991



Source: Dataquest
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DATAQUEST SUMMARY

The technical workstation market is maturing and can no longer be considered a single entity in system price and performance range. The future will bring systems spanning a 20:1 performance range and a 25:1 price ratio.

We predict that the single-user workstations of various performance ranges (PC/workstations, traditional workstations, superworkstations, and graphic supercomputers) will assume their roles parallel to multiuser systems such as superminicomputers, minisupercomputers, mainframes, and supercomputers. Interactive distributed processing (workstation-style) computing will become an accepted method of computing for processing graphic information that needs to be shared by members of an organization.

Dataquest expects continued strong growth for existing vendors, with expansion into new applications and price bands. Additionally, we continue to see opportunities for both existing vendors and new vendors entering the market.

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David Norman
Brad Smith

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Research Bulletin

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1988–05

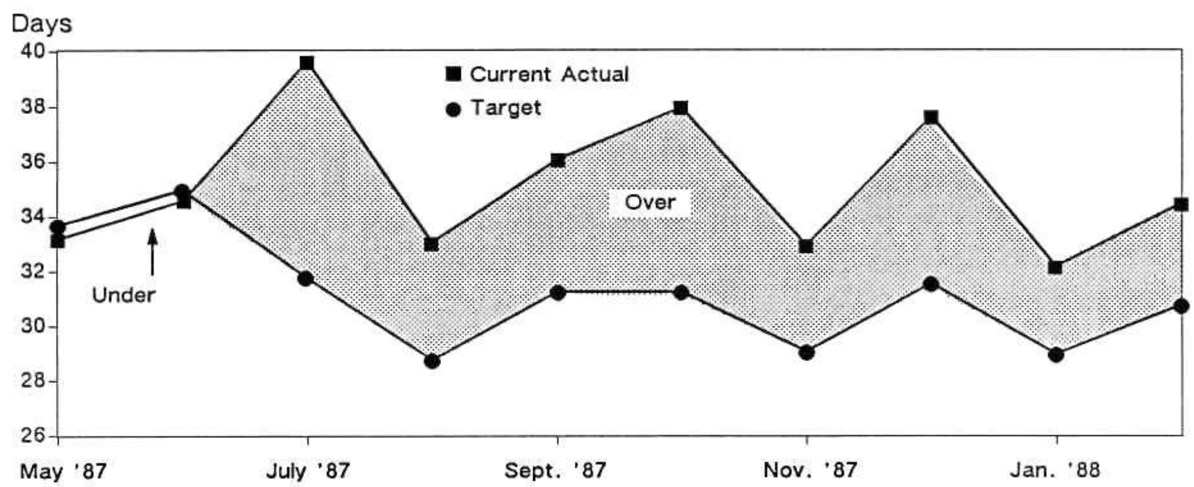
FEBRUARY PROCUREMENT SURVEY: THE WATCHWORD IS AVAILABILITY

INTRODUCTION

The supply–demand balance in the semiconductor marketplace noted in last month's survey still exists for the majority of commodity semiconductors, but was short-lived for key DRAM and 32-bit microprocessor parts. Allocation notices for the high-density and high-speed versions of these two device families are beginning to appear in the latest survey responses. Although lead times remain a relatively stable 12 weeks and overall pricing is steady, 1Mb DRAMs and 32-bit MPUs have registered price increases of 10 percent over our last review. The overall survey inventory levels shown in Figure 1 have risen slightly to approximately 12 percent above targeted levels, while the computer segment of the survey depicted in Figure 2 is actually 2 percent below its targeted inventory range.

Figure 1

Current Actual versus Target Inventory Levels (All OEMs)



Source: Dataquest
February 1988

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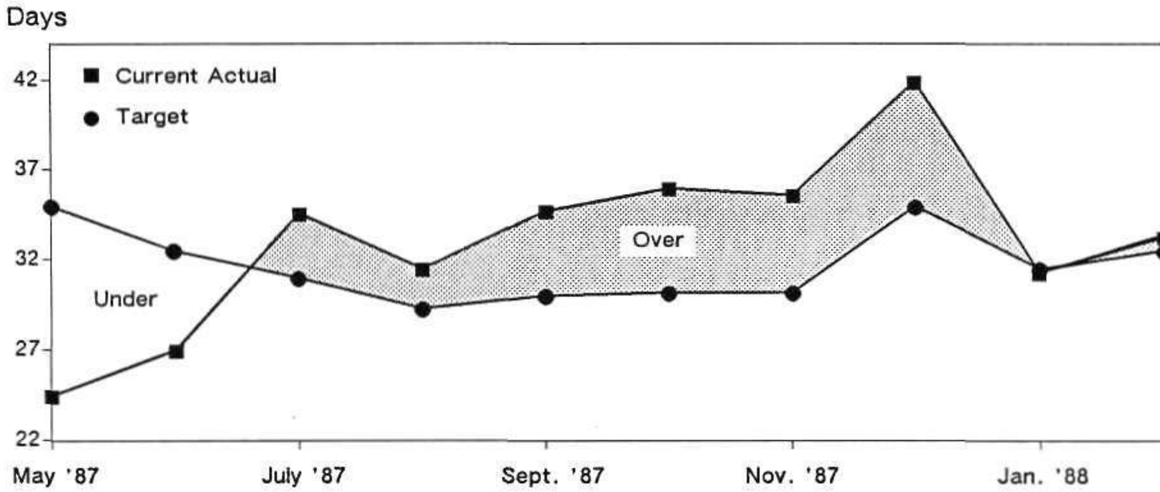
Figure 2

Current Actual versus Target Inventory Levels
(Computer OEMs)



Source: Dataquest
February 1988

The majority of the survey respondents cited the 1986 U.S.–Japan semiconductor agreement as being the root cause of the current DRAM supply shortfall. Orders to distributors have increased slightly, partially in response to the availability issues noted above. Sales of the surveyed companies remained steady but flat after adjusting for the beginning of the year slow period.

DATAQUEST OBSERVATIONS

It appears that the demand for key semiconductors, although never truly in balance with supply, continues to exaggerate delivery schedules and pricing. The transition in fabrication capacity from the 256K to the 1Mb DRAM is also constraining supply of both parts at a time when buyers are beginning to ramp up production for the new part. Dataquest expects this situation to be remedied by mid-1988 because a multitude of vendors will then have 1Mb DRAM product available. We will continue to watch the availability issue closely in upcoming surveys.

Greg Sheppard
Mark Giudici

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Research Newsletter

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PS/2 IS CLONED!!!

A host of hardware and software products that will enable OEMs to produce 100 percent–compatible versions of IBM's new personal computer family, the PS/2, was jointly announced today by Chips & Technologies (CHIPS), Phoenix Technologies, and Adaptec. Highlighting this announcement are:

- Micro Channel–compatible system logic chips provided by CHIPS
- Micro Channel–compatible ROM BIOS (read–only memory, Basic Input/Output System) provided by Phoenix Technologies
- Micro Channel–compatible disk drive controller chips from Adaptec

This unprecedented move from three oft–competitive PC product suppliers has resulted in a well–orchestrated, total solution to the PS/2. (See summary in Table 1.) In fact, as clones must do to steal market share away from the inventor, this PACT (Phoenix, Adaptec, Chips & Technologies) promises to offer price, performance, and functionality leaps over the original PS/2s.

CHIPS' chip sets for clones of the Models 50, 60, and 80 (IBM's 80286– and 80386–based PS/2s) integrate all of the system logic in about half the number of chips that IBM's models use. Figure 1 shows CHIPS' solution for a Model 80 clone.

CHIPS also claims that designed–in coupling between its CPU controller and its memory, peripheral, and VGA–compatible graphics controller chips provides significant speed improvements over real PS/2s.

Next, as the undisputed leading supplier of the last generation of PC ROM BIOS products, Phoenix Technologies' announcement provides the missing link to PS/2 clonability. The Phoenix BIOS, supplied on a ROM chip, provides system initialization software as well as the handshaking between the PC hardware and the operating system—either DOS or OS/2. Without a working BIOS, there would be no PS/2 clones. Phoenix's BIOS support for the CHIPS products reportedly offers features beyond those of the real PS/2, including BIOS–selectable use of faster graphics cycles and selectable direct memory access (DMA) cycle periods.

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Table 1

The PS/2 Clone Chip Product Family

Product Name	Description	Number of Chips	1K Unit Price	Samples Available
Models 50/60 Products				
CHIPS/250 Set		7	$157 to $169	Q1
CS8225	System logic	5		
82C451/2	Graphics/VGA	1		
82C607	Comm/floppy I/O	1		
Other				
82C611	For MCA memory or I/O cards	1	$8.60	Now
82C612	For MCA adapter cards with slave DMA	1	$11.10	Now
Adaptec Controllers				
ACB-2610	MCA to ST412 MFM	Board	$160	Q1
ACB2670	MCA to ST412 RLL	Board	$180	Q2
Model 80 Products				
CHIPS/280 Set		7	$202 to $239	Q2
CS8238	System logic	5		
82C451	Graphics	1		
82C607	Comm/floppy I/O	1		
Adaptec Controllers				
ACB-26M20	MCA to ESDI	Board	$205	Q3
AHA-1640	MCA to SCSI	Board	$249	Q3
Software Products				
Phoenix Technologies				
Phoenix ROM BIOS		N/A		
Santa Cruz Operations				
SCO Xenix 286			$695	Now
SCO Xenix 386			$795	Now

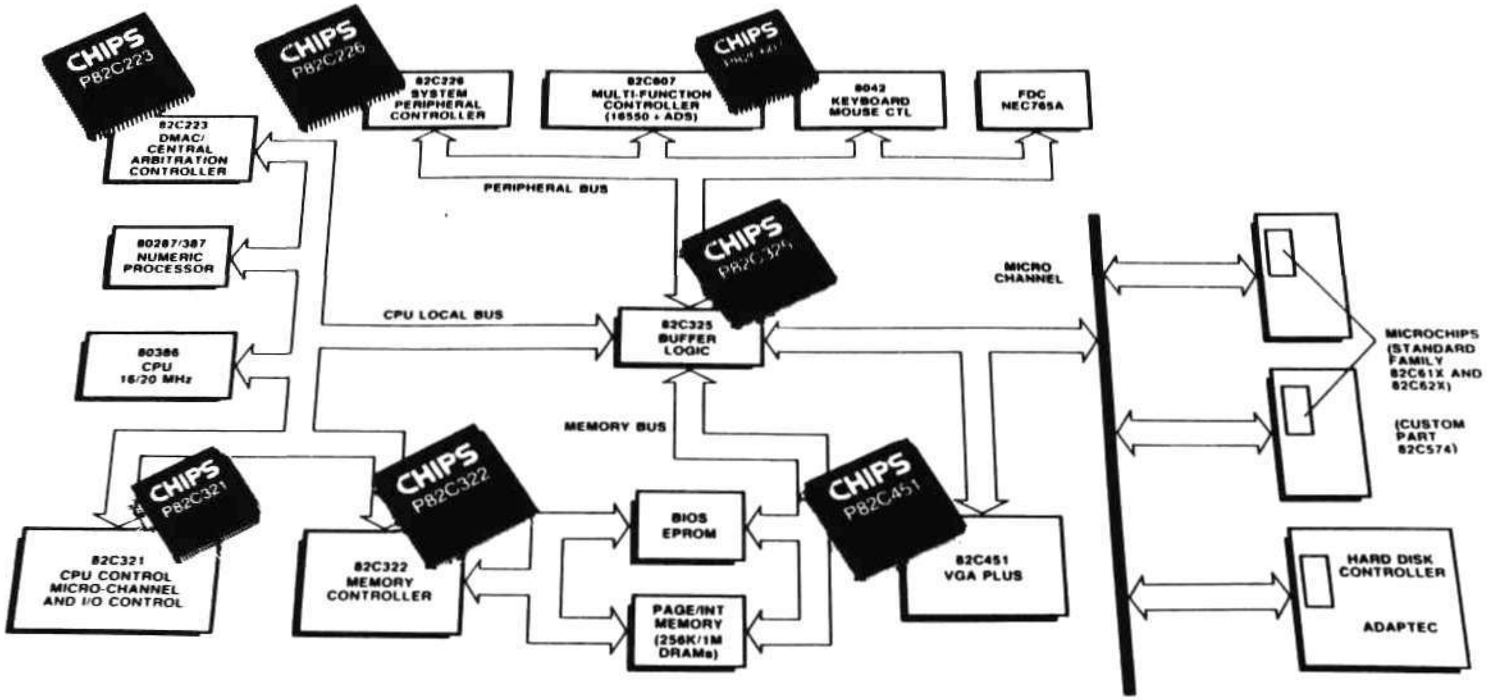
N/A = Not Available

Notes: The CHIPS/280 set uses the same graphics and communications chips as the 250 set. The 82C611/12 MCA adapter parts are compatible with the Model 80 as well. Adaptec products listed under the Models 50/60 are also compatible with the Model 80.

Source: Dataquest
January 1988

Figure 1

The Compatible Model 80 with CHIPS/280



Source: Chips & Technologies

If CHIPS' offering is the cake, then Phoenix's is the "glue" holding the layers together—and finally, Adaptec puts the icing on top of the cake. As the inventor of the Small Computer Systems Interface (SCSI) protocol, Adaptec gives OEMs the ability to offer a popular, high-performance interface to floppy and rigid disk drives, printers, scanners, and other peripherals.

SCSI, known as an intelligent protocol, allows "daisy-chaining" of up to eight devices off a single port and runs at significantly higher rates than the traditional ST506 protocol used in most PCs today. Also inherent in SCSI are multitasking capabilities. In addition to the Micro Channel-to-SCSI controllers, Adaptec is offering an ST412/506 and even higher-performing Enhanced Small Device Interface (ESDI)-to-Micro Channel controllers.

Finally, though no means integral to PS/2 compatibility, a fourth company, Santa Cruz Operations (SCO), joined into the big announcement—perhaps as the candles on the cake. SCO, developer and supplier of popular versions of the UNIX/Xenix operating systems, announced availability of a PS/2 version of its Xenix System V.

SUMMARY

Had each of these products been announced separately by their respective developers, we may have responded with a lot of doubt and uncertainty. But together these leading developers show promise of delivering a cloned PS/2 family that brings:

- True and total PS/2 and Micro Channel compatibility
- Enhanced performance at lower cost than IBM
- Higher system integration, allowing production of a conspicuously absent Model 70 (a desktop 386 PS/2)
- Easy migration to a super high-performance workstation based on support of other popular standards including UNIX and SCSI. (CHIPS has also alluded to a cache-based PS/2 chip set that would provide the added performance needed for such a system.) It is possible that such a system would be available for about $5,000, compared with Compaq's new 386 offering at more than twice the cost
- Very fast design turnaround using CHIPS' PS/2 development kit, which includes masks for the complete board design

On the other hand, what this seemingly indestructible PACT does not bring is LEGAL PROTECTION FROM IBM.

Not surprisingly, no one in the PACT has received the blessing of IBM, which is reportedly in the process of applying for numerous patents and copyrights. What legal actions will be forthcoming from IBM are unknown. CHIPS, Adaptec, and Phoenix all believe that they are well within legal bounds. They do strongly advise all of their OEMs (PS/2-compatible manufacturers), however, to apply for licensing through IBM. Assuming delivery of parts as scheduled and prompt licensing from IBM, we believe that PS/2 Models 50 and 60-compatible systems could come to market as soon as the third quarter of 1988. Permission or not, it appears that the PS/2 has been cloned, and we can all look forward to some exciting times ahead.

Nanci J. Magoun

Dataquest
a company of The Dun & Bradstreet Corporation

Research Newsletter

SAM Code: 1987–1988 Newsletters: January–March
1988–03

SOME G2 ABOUT THE PC CHIP SET MARKET

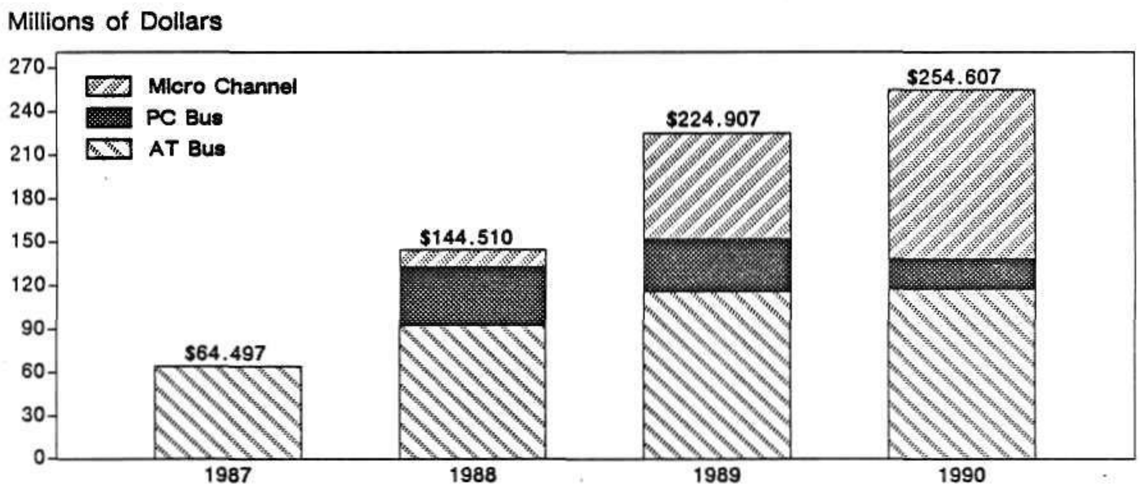
SUMMARY

As another company jumps into the PC chip set business, it leads one to wonder: How many companies can this market support? Will competitors drive chip sets into the treacherous price-driven commodity battle (i.e., CMOS gate arrays)? Can new suppliers offer anything unique? Has IBM, with its new PS/2 PC line, developed a closed system that will wipe out the clone market and, with it, the chip set makers too?

To say that the variables that come into play in answering these questions are complex would be an understatement. There are many, many unknowns. But somehow, in their own wisdom, companies such as Chips & Technologies, Zymos, Western Digital (owner of chip set maker Faraday), VLSI Technology, Inc., and LSI Logic's G2 (see "Author's Notes" at the end of this newsletter) have determined that underneath all these uncertainties lies an appealing and lucrative market. Therefore, in the interest of providing an objective sizing of the market (to the delight of some and the chagrin of others), Figure 1 is Dataquest's first official estimate of the PC chip set market.

Figure 1

Estimated Worldwide DOS-Compatible Chip Set Market



Source: Dataquest
January 1988

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THE PC CHIP SET FORECAST PROCESS

Arriving at a total PC chip set forecast required, of course, that Dataquest make a number of assumptions and other supporting forecasts. The following summarizes the most significant assumptions supporting our forecast:

- The PC market will continue to grow through 1990.
- DOS and compatible operating systems will continue to gain share.
- The market is shifting quickly to 16-bit machines, followed by 32-bit, with a rapid fall-off of 8-bit PCs.
- IBM's PS/2 family will become a mainstream product in business and office environments, and, as a result, IBM will maintain market share through 1990.
- IBM's proprietary new bus architecture, Micro Channel, is legally cloneable, and the new ROM BIOS (system chips) will be available.

Supporting Forecasts

The Overall PC Market

Dataquest regularly forecasts worldwide shipments for personal computers, with current projections seeing growth from slightly more than 17 million units in 1987 to nearly 24 million in 1990. In 1987, DOS-compatible PCs accounted for approximately half of all shipments, and this volume is expected to rise about 5 percent each year throughout our forecast period. By 1990, DOS-compatible PCs will hold a 65 percent market share, with about 15 million units shipped.

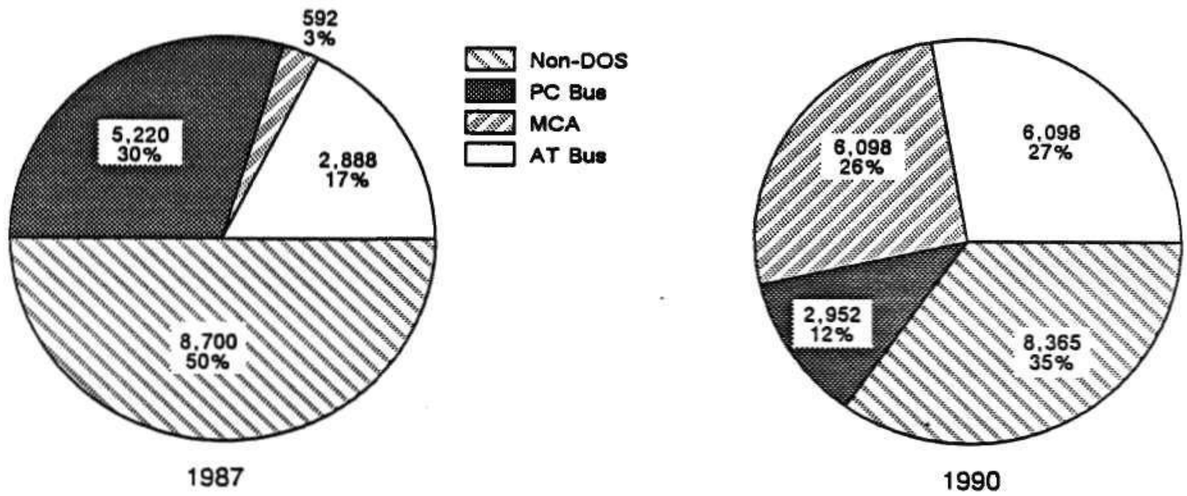
Within the DOS-compatible arena, Dataquest segments PCs into three major architectures or bus structures—PC, AT, and Micro Channel Architecture (MCA). Each is characterized by the microprocessor used, the system bus bit width, and certain unique performance capabilities. Figure 2 shows Dataquest's forecast for worldwide PC unit shipments for 1987 and 1990 by architecture.

DOS PC Architectures

The oldest architecture, known as the PC bus, was the basis of IBM's original PCs, which used Intel's 8-/16-bit 8088 microprocessor. Later, IBM introduced the XT, which was based on the same bus structure but used the higher performance 16-bit 8086 microprocessor. From 1981 through 1987, these 8088/8086 (and compatible processor) PC XT boxes accounted for the majority of DOS PC shipments. Given new and better systems, however, we expect PC-bus boxes to decline nearly 10 points this year, from the 1987 60 percent market share. While IBM's announcement of two PS/2 products based on the PC bus (Models 25 and 30) brings a temporary reprieve to this market segment, the demise of the PC bus is likely to continue through 1990.

Figure 2

PC Shipment Trends by Architecture
(Units in Thousands)



Source: Dataquest
January 1988

With the average selling price (ASP) for a typical 80286-based AT clone—including a 20MB hard disk drive and graphics monitor—now at or less than $2,000 (thanks, in large part, to PC chip sets), the 286 market segment has virtually exploded. Dataquest expects this 16-bit portion of the DOS market (including 80286-based PS/2s) to gain nine points over last year, growing to a 45 percent share of market (SOM) in 1988. By 1990, 80286-based boxes will dominate the market, with a 56 percent SOM. We estimate that more than three-fifths of those will utilize the AT bus.

Also part of the AT bus architecture is the host of 80386-based PCs that have emerged, beginning with the Compaq Deskpro 386 in September 1986. While, undoubtedly, these new 32-bit machines offer great leaps in performance—in terms of both raw processing speed and memory addressability—in design terms, they are quite similar to the 286-based boxes. The first 80386 PC was introduced, in fact, by Intel in April 1986 at a public display, and Voila!, at the flip of a switch on a PC AT, processing responsibility was transferred from an 80286 to an 80386. Also characteristic of the AT arena is the slew of players and accompanying price wars. Almost weekly, a new 386 PC is announced, with a resulting price drop from $6,499 as of one year ago to less than $3,000 today. By 1990, 32-bit PCs are likely to capture 25 percent of the DOS world, with an expected two-thirds using the AT bus.

IBM's new MCA, introduced last April, is used in its 80286- and 80386-based PS/2 line. In an attempt to recapture much of the PC market it has lost over the years, IBM reportedly incorporates a host of proprietary new features and capabilities into its MCA.

Because the PS/2 line is currently running standard DOS (Version 3.3), it still looks and behaves essentially the same as the older PCs using the AT architecture, with several notable exceptions. The following summarizes some of the new features of the MCA:

- New adapter card connector scheme. Old IBM and compatible-PC adapter cards do not work with the new configuration.

- Programmable Option Select (POS), which reads and arbitrates configuration information from adapter cards (contained in on-board ROM) into dedicated system memory. The POS feature is analogous to automated dip-switch settings.

- Support of a central arbitration control point. This feature allows up to 15 devices to arbitrate for control of the Micro Channel.

- An I/O bus width of 16 bits and memory address widths of 24 and 32 bits. IBM's AT I/O and memory bus widths were both 16 bits. The new configuration offers greatly enhanced speed and memory addressability.

Table 1 lists the various DOS PCs currently available and their respective characteristics. Figure 3 presents an overview of worldwide shipments of these PCs by base processor. Finally, Table 2 shows our detailed assumptions and forecasts for architectures, base processors, and model types for the worldwide PC market.

Table 1

DOS-Compatible PC Models and Architectures

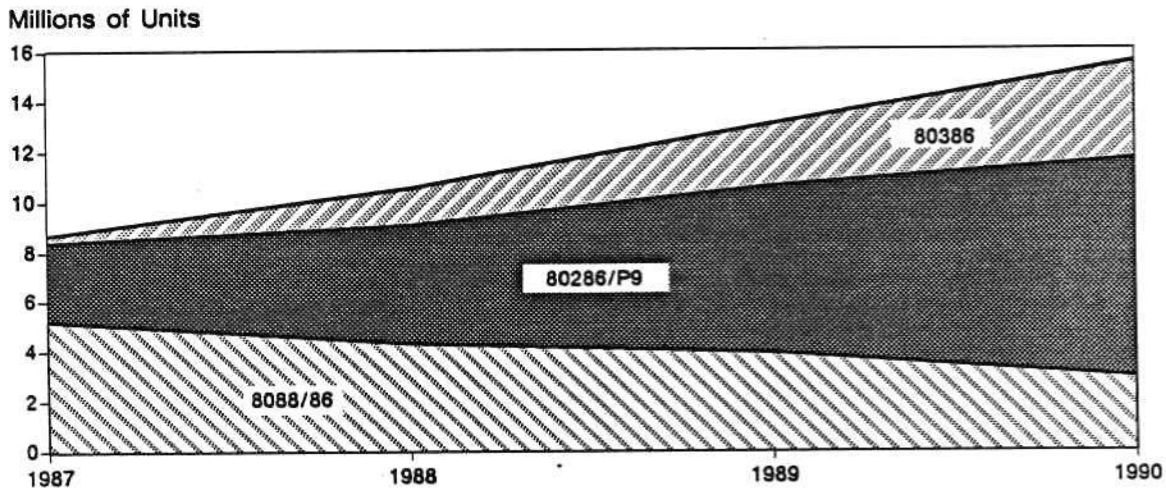
	Base Processor	Architecture	Operating System
PS/2 Products			
Models 25/30	8086	PC Bus	DOS
Models 50/60	80286	Micro Channel	DOS, OS/2*, OS/2 EE**
Model 80	80386	Micro Channel	DOS, OS/2, OS/2 EE
Other PCs			
XT	8088/8086	PC Bus	DOS
AT	80286/80386	AT Bus	DOS, OS/2

*OS/2 = Operating System/2
**OS/2 EE = Extended Edition

Source: Dataquest
January 1988

Figure 3

Trends in DOS Shipments by CPU



Source: Dataquest
January 1988

Table 2

Overview of the Estimated Worldwide
Personal Computer Market
(Millions of Units)

	1987	1988	1989	1990
Worldwide PCs	17.400	19.200	21.800	23.900
DOS PCs as Percentage of Worldwide PCs	50.00	55.00	60.00	65.00
Worldwide DOS PCs	8.700	10.560	13.080	15.535
8088/86	5.220	4.330	3.924	2.952
80286/P9	3.176	4.752	6.671	8.700
80386/486/586	0.305	1.478	2.485	3.884
CPU as Percentage of DOS PCs				
8088/86	60.00	41.00	30.00	19.00
80286/P9	36.50	45.00	51.00	56.00
80386/486/586	3.50	14.00	19.00	25.00
Total	100.00	100.00	100.00	100.00

(Continued)

Table 2 (Continued)

Overview of the Estimated Worldwide Personal Computer Market (Millions of Units)

	1987	1988	1989	1990
Units by Model Type				
All PCs	17.400	19.200	21.800	23.900
Non-DOS PCs	8.700	8.640	8.720	8.365
DOS PCs	8.700	10.560	13.080	15.535
PS/2	1.479	2.534	3.139	3.728
IBM				
Models 25/30 (PC Bus)	0.887	1.039	0.942	0.708
Models 50/60 (MCA)	0.444	1.140	1.601	2.088
Models 70/80 (MCA)	0.148	0.355	0.596	0.932
Clones	0	0.300	2.000	3.800
Models 25/30 (PC Bus)	0	0.123	0.600	0.722
Models 50/60 (MCA)	0	0.135	1.020	2.128
Models 70/80 (MCA)	0	0.042	0.380	0.950
Other DOS PCs	7.221	7.726	7.941	8.007
8088- /8086-Based (PC Bus)	4.333	3.167	2.382	1.521
286- /P9-Based (AT Bus)	2.732	3.477	4.050	4.484
386-Based (AT Bus)	0.157	1.082	1.509	2.002

*Columns may not add to totals shown because of rounding.

Source: Dataquest
January 1988

The Saleable DOS Market

Dataquest believes that maturation and standardization within the PC market, combined with incredible competition and lower profit margins, will result in a consolidation of vendors. Last year, the top 10 DOS PC vendors, excluding IBM, accounted for nearly 35 percent of all unit shipments. In most cases (excepting Taiwanese vendors Mitec and Multitech), these large manufacturers used either discrete or proprietary ICs within their systems and, thus, were not part of the chip set saleable market.

By 1990, we believe that the nonsaleable market will increase to more than 50 percent for the older PC-/AT-bus systems and to about 60 percent for Micro Channel PCs. Table 3 lists our assumptions for the saleable market (SAM) for PC chip sets through 1990. These data, when multiplied against total PC shipments, enabled us to derive the saleable unit forecast presented in Table 4.

Table 3

Estimated PC Chip Market
(Percentage of Total Units)

Saleable Market	1987	1988	1989	1990
PS/2 and Clones				
Models 20/30	N/A	75	70	65
Models 50/60	N/A	90	75	60
Models 70/80	N/A	90	75	60
Other				
8088/86 PC Bus	65	60	55	50
286/P9 AT Bus	65	60	55	50
386 AT Bus	20	30	50	50

N/A = Not Applicable

Source: Dataquest
January 1988

Table 4

Estimated PC Chip Market
(Millions of Units)

Total Saleable Market	1987	1988	1989	1990
PS/2 and Clones	0	0.252	1.470	2.316
Models 20/30	0	0.092	0.420	0.469
Models 50/60	0	0.122	0.765	1.277
Models 70/80	0	0.038	0.285	0.570
Other	4.623	4.311	4.292	4.003
8088/86 PC Bus	2.816	1.900	1.310	0.761
286/P9 AT Bus	1.776	2.086	2.227	2.242
386 AT Bus	0.031	0.324	0.754	1.001

*Columns may not add to totals shown because of rounding.

Source: Dataquest
January 1988

In 1987, there was a rapid erosion of PC chip set prices, as several new suppliers entered the market. As more vendors appear on the scene, we expect price competition to increase further. Table 5 is Dataquest's forecast for chip set ASPs through 1990. These prices applied to the number of saleable units seen in Table 4 supply our total saleable market forecast, as shown in Table 6.

With respect to Micro Channel, we expect "transitional" clones to appear, offering both AT-bus and MCA features and compatibilities. For the purpose of our forecast, we have included these and any other clones that claim to be MCA-compatible within the Micro Channel category. It is our belief that as the new operating system, OS/2, gains popularity through third-party support (i.e., available application software), and as clones are able to demonstrate full compatibility, the MCA clone market will become very strong indeed.

Undoubtedly, such forecasting leaves much room for debate and uncertainty. Modifications to any of the assumptions could cause radical shifts in the final market opportunities presented here. With this foundation, however, it is possible to expose a number of myths about this market and to decide if it is worth the heavy investment to participate.

Table 5

Estimated Chip Set ASPs
(Actual Dollar Amounts)

	1987	1988	1989	1990
PS/2 and Clones				
Models 20/30	N/A	$25	$25	$20
Models 50/60	N/A	$70	$65	$60
Models 70/80	N/A	$85	$80	$70
Other DOS PCs				
8088/86 PC Bus	N/A	$20	$20	$15
286/P9 AT Bus	$35	$35	$35	$30
386 AT Bus	$75	$60	$50	$50

N/A = Not Applicable
Note: Prices are based on volume orders of more than 10,000 units

Source: Dataquest
January 1988

Table 6

Worldwide Chip Set Saleable Market
(Millions of Dollars)

	1987	1988	1989	1990
Total	$64.497	$144.510	$224.907	$254.607
PS/2 and Clones	0	$ 14.024	$ 83.025	$125.898
Models 20/30	0	2.306	10.500	9.386
Models 50/60	0	8.505	49.725	76.612
Models 70/80	0	3.213	22.800	39.900
Other DOS PCs	$64.497	$130.485	$141.882	$128.709
8088/86 PC Bus	0	38.010	26.205	11.409
286/P9 AT Bus	62.148	73.007	77.959	67.259
386 AT Bus	2.349	19.469	37.719	50.041

*Columns may not add to totals shown because of rounding.

Source: Dataquest
January 1988

MYTHS AND REALITIES OF THE PC CHIP SET MARKET

Myth 1: I'll jump in and target 10 percent of the market.

Reality: So will everyone else. Throughout 1987, one company (Chips & Technologies) has virtually owned this market. Several notable competitors have attempted, largely unsuccessfully, to steal away market share. This year, many more will try, including a host of Japanese silicon vendors and Taiwanese system manufacturers, which, at this moment, are in the process of bringing up IC manufacturing capabilities. Table 7 lists the most notable chip set vendors to date.

Myth 2: If I can pick up Chips & Technologies' "left overs," I'll be happy.

Reality: See Myth 1.

Myth 3: We have great design tools and can turn a new product overnight.

Reality: As long as the would-be vendor has a complete set of schematics, as with the PC AT, there is no problem. But with Micro Channel, new graphics and communications standards, faster processors, and a slew of emerging system enhancements, it takes a whole lot more than design tools to be successful. PC product life cycles have been reduced to a number of months, and only those companies with the highest PC system development expertise (among people, not just machines) can compete.

Table 7

PC Chip Set Vendors

Vendors	PC Bus	AT 286	AT 386	PS/2
Chips and Technologies	X	X	X	Y
Faraday		X		Y
G2		X		
Intel				
Logic Star		X		
TI		X		
UMC		X		
VLSI Technology, Inc.		X		
Zymos		X	X	Y

Note: X - Chips are currently available.
Y - Company has publicly stated its intent to produce these chips.

Source: Dataquest
January 1988

Myth 4: The chip set is just another addition to our existing standard product silicon business.

Reality: In addition to the realities of Myth 3, the marketing of chip sets has many of the characteristics associated with the marketing of application-specific integrated circuits (ASICs). Designs must be quickly customizable and the vendor must intimately understand and anticipate each OEM's needs. As with ASIC sales, applying old standard product sales and marketing tactics is bound to fail.

Myth 5: All the "Five Tigers" care about is price—if we can add a few more dollars to their margins, they'll go with us.

Reality: The Asians, to date, have been extremely brand loyal. OEMs in the Pacific Rim are extremely quality conscious and are unwilling to take big risks to save a few dollars. This position was voiced by a consortium of about 30 PC manufacturers from Taiwan that visited Dataquest last fall. Efforts to save money on silicon are likely to take the form of building up their own capabilities in the near future.

Myth 6: Chips & Technologies is in trouble with all of the new competition, and when they fall the market will open up.

Reality: Au contraire, contraire. Chips & Technologies posted revenue of $80 million for its fiscal year 1987 ending last June equaling a 500 percent jump over the previous year. Revenue per employee was a staggering $750,000. Chips & Technologies' success has been due to its continuing ability in the following areas:

- Leading the market with new system logic designs (by the time most competitors have copied the Chips & Technologies lead, the market window is gone)

- Providing unequaled customer support including development kits and documentation

- Diversifying products into a number of other PC support areas, including graphics, communication, and storage devices.

Table 8 Shows Chips & Technologies' current product offerings.

Table 8

Chips' Quick Reference Guide

PART NO.	DESCRIPTION	PROCESS	PACKAGE TYPE	SPEED
SYSTEMS LOGIC				
82C100	**Model 30 Compatible Chip**	CMOS	PFP-100	10MHz
82C101	**Low Cost XT Chip**	CMOS	PLCC-84	10MHz
CS8220	**PC/AT Compatible CHIPSet™**			8MHz, 10MHz, 12MHz
82C201	System Controller	CMOS	PLCC-84	8MHz, 10MHz, 12MHz
82C202/A	Memory Decoder & I/O Controller	CMOS	PDIP-48/PLCC-68	8MHz, 10MHz, 12MHz
82A203	High Address Buffer & Port B	Bipolar	PLCC-68	8MHz, 10MHz, 12MHz
82A204	Low Address Buffer & Refresh Control	Bipolar	PLCC-68	8MHz, 10MHz, 12MHz
82A205	Data Bus Buffer & Parity Generator	Bipolar	PLCC-68	8MHz, 10MHz, 12MHz
CS8221	**New Enhanced PC/AT CHIPSet™ (NEAT)**			12MHz, 16MHz
82C211	Bus Controller	CMOS	PLCC-84	12MHz, 16MHz
82C212	Memory Interleave Controller	CMOS	PLCC-84	12MHz, 16MHz
82C215	Data Bus Buffer & Transceiver	CMOS	PLCC-84	12MHz, 16MHz
82C206	**Integrated Peripheral Controller**	CMOS	PLCC-84	12MHz, 16MHz
CS8226	**CS8220 with an IPC (82C206)**			10MHz, 12MHz
CS8230/1/2	**AT/386 CHIPSet™**			16MHz, 20MHz
82C301	Bus Controller	CMOS	PLCC-84	16MHz, 20MHz
82C302	Memory Controller	CMOS	PLCC-84	16MHz, 20MHz
82A303	High Address Buffer	Bipolar	PLCC-68	16MHz, 20MHz
82C303	High Address Buffer	CMOS	PLCC-68	16MHz
82A304	Low Address Buffer	Bipolar	PLCC-68	16MHz, 20MHz
82C304	Low Address Buffer	CMOS	PLCC-68	16MHz
82A305	Data Buffer (2 incl. in CS8230)	Bipolar	PLCC-68	16MHz
82B305	Data Buffer (2 incl. in CS8230-20)	Bi-CMOS	PLCC-68	16MHz, 20MHz
82C305	Data Buffer (2 incl. in CS8232)	CMOS	PLCC-68	16MHz
82A306	Control Signal Buffer	Bipolar	PLCC-68	16MHz, 20MHz
82C306	Control Signal Buffer	CMOS	PLCC-68	16MHz
82C312	**Cache Controller (Incl. w/CS8231)**	CMOS	PFP-100	16MHz, 20MHz
DK8210	**Model 30 Compatible Development Kit**			
DK8220	**PC/AT Compatible Development Kit**			
DK8221	**NEAT Development Kit**			
DK8230	**AT/386 Development Kit**			
GRAPHICS				
CS8240	**4-Chip (EGA) CHIPSet™ (PLCC)**	CMOS		24MHz
CS8240B	**4-Chip (EGA) CHIPSet™ (Flatpack)**	CMOS		24MHz
82C431	Graphics Controller	CMOS	PLCC-68	24MHz
82C432A/B	Sequencer	CMOS	PDIP-40, PFP-44	24MHz
82C433	Attributes Controller	CMOS	PDIP-40, PFP-44	24MHz
82C434A	CRT Controller	CMOS	PLCC-84	24MHz

(Continued)

Table 8 (Continued)

Chips' Quick Reference Guide

82C435	**Enhanced Graphics Controller**	CMOS	PLCC-84, PFP-100	30MHz, 38MHz
82A436	**Bus Interface**	Bipolar	PLCC-68	38MHz
82C437	**SharpScan™**	CMOS		60MHz
CM82C437	**SharpScan™ Chips Module**			
CS8241	**SEGA CHIPSet™ with BIOS**			30MHz
CS8245	**VGA CHIPSet™**			30MHz, 38MHz
82C441	VGA Controller	CMOS	PLCC-84, PFP-100	30MHz, 38MHz
82C442	VGA Bus Interface	Bipolar	PLCC-68	38MHz
DK82C435	**SEGA/BEGA Development Kit**			
DK8245	**VGA Development Kit**			
COMMUNICATIONS				
82C550A	**Starlan Serial Interface**	CMOS	PDIP-20	
82C551	**Starlan Hub Controller**	CMOS	PDIP-40	
82C605	**CHIPSport™: Multifunction Controller**	CMOS	PLCC-68	
82C606	**CHIPSpak™: Multifunction Controller**	CMOS	PLCC-68	
DK82C605/6	**CHIPSport™/CHIPSpak™ Development Kit**			
MASS STORAGE				
82C764A	**Floppy Disk Data Separator**	CMOS	PDIP-28	
DK82C764A	**Data Separator Development Kit**			
		D/S-Data Sheet D/B-Data Book	SYS DIAG-System Diagram PI-Preliminary Information	APP Note-Application Note

Source: Chips & Technologies

WHAT DOES ALL OF THIS MEAN?

Regardless of one's own assumptions on this point or that, it is just common sense to realize that there is not room for everyone. True, total PC chip revenue (including discrete logic, custom chips, and chip sets) exceeded $1.2 billion in 1987 and will grow to more than $1.7 billion in 1990. (Maybe the market is not so dismal after all.) But the PC chip set portion is rapidly changing, with highly specialized and demanding requirements. Vendors that plan to play follow-the-leader with dedicated chip sets will find the cost of entry high and the probability of success low.

On the other hand, chip sets (for PCs as well as many other electronic systems) are here to stay. Over the past several years, an alphabet soup of chip sets has been brewing. Graphics chip sets (EGA-, CGA-, and VGA-compatible); communications chip sets for ISDN and FDDI; and storage chip sets with ESDI, SCSI, and ST412/506 interfaces—among others—lead to the conclusion that buyers want quick, easy, and complete system solutions in their semiconductors.

Therefore, it behooves IC vendors (and silicon-bound OEMs as well) to focus on their areas of strength, to build up unique system design capabilities (again with people, not machines), and to line up with system manufacturers for cooperative growth, as opposed to competition. With ever-shrinking design and market windows, it is essential that semiconductor manufacturers intimately understand and participate in shaping their target system markets.

Chip set revenue is likely to explode in the upcoming years, and those companies poised to participate will reap the rewards. Those who continue along the path of neutrality and inaction will lose out on the next bastion in the semiconductor arena.

Nanci J. Magoun

Author's Notes:

1. G2 is a military term for intelligence data, usually secretive in nature (also known as "the inside scoop"). G2 is also the name of LSI Logic's new chip set start-up company.

2. A PC chip set comprises one or several ICs available off-the-shelf. A chip set combines most or all of the system logic required for a personal computer. See Dataquest newsletter entitled "The Clones Are Coming" (SAM Code 1987-21) for more detail.

Dataquest
a company of The Dun & Bradstreet Corporation

Research Newsletter

SAM Code: 1987-1988 Newsletters: January-March
1988-02

FOREIGN EXPANSION: DATAQUEST EXAMINES IMPENDING CHANGES IN GLOBAL MANUFACTURING

SUMMARY

Since the late 1970s, the printer industry has experienced ongoing changes in manufacturing. This newsletter addresses some of the important issues related to manufacturing, specifically covering the following topics:

- A brief overview of the history of offshore manufacturing
- Characteristics of offshore operations, including labor costs, the high Japanese yen, and currency and trade issues
- The trend toward onshore manufacturing, discussing foreign companies that are successfully manufacturing on U.S. soil
- Foreign investment in the United States, including major players and lucrative incentives
- An overview of foreign electronics investment
- Dataquest's conclusions about the current situation and outlook for the future

OFFSHORE BACKGROUND

Since the United States has become more involved with global trade, its European and Far Eastern competitors have become more sophisticated and have captured markets previously dominated by U.S. firms. Today, with global competition increasing, the United States must compensate sufficiently to accommodate the changed economic competition.

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The trend toward offshore manufacturing of U.S.-designed products has increased significantly over the past five years. In an increasingly competitive market, U.S. high-technology vendors have sought to lower materials and labor costs, alleviate taxes, and relocate their production facilities offshore to avoid U.S. environmental laws. Among many manufacturing strategies, offshore manufacturing has become an inevitable reality for many U.S. firms.

Historically, the two major reasons for companies to manufacture offshore have been:

- Proximity to markets served
- Low labor costs

Although labor costs may have been the initial force for offshore manufacturing, the labor content in the manufacture of electronic products has been decreasing, signifying that the allure of offshore manufacturing by U.S. companies is becoming less advantageous. Essentially, as manufacturing becomes more automated and less labor intensive, overseas production becomes less cost beneficial.

Recently, U.S. manufacturers have started either to bring overseas operations home or switch from foreign to domestic suppliers in response to the fall of the U.S. dollar against foreign currencies. In addition, U.S. manufacturers are realizing the advantages of shorter supply lines. Although some companies continue to move offshore to take advantage of low component and engineering costs, the trend to move homeward is a positive development that is likely to continue.

OFFSHORE OPERATIONS

Trade and Currency Issues

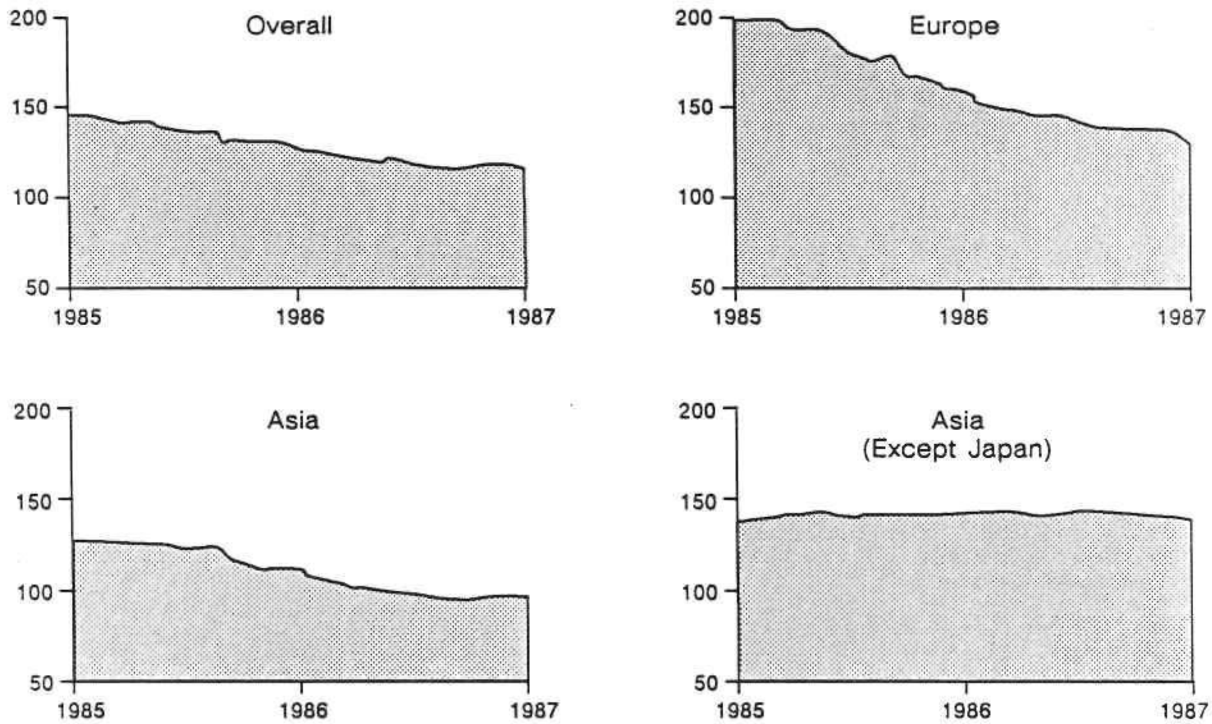
Since 1980, the U.S. trade balance in high-technology goods has been rapidly deteriorating. In 1986, the high-technology trade balance turned red when import growth outstripped export growth to the tune of $2.6 billion.

According to the American Electronics Association (AEA), the electronics trade deficit (including telecommunications, components, computers, and consumer and medical electronics) resembles that of high-technology goods. In 1986, the electronics trade deficit was $13.1 billion. Since 1980, that figure has dropped after reaching its peak of a $7.4 billion surplus, and has been in deficit since 1984.

In theory, a weaker U.S. dollar makes imported goods more expensive in the United States and American goods a better buy abroad. Thus far, however, the decline of the dollar (see Figure 1) has not been sufficient to improve the U.S. trade deficit with Japan. The Japanese are willing to keep prices competitive to preserve market share at the expense of profit margins. In addition, Japanese producers have shifted some of their production plants to the United States or to plants in third-world countries.

Figure 1

The Decline of the Dollar
(Index: 1980 = 100)



Source: Dataquest
January 1988

U.S. electronics companies relying on Japanese components for their products view the dollar's drop as a mixed blessing. On one hand, as the yen price of Japanese components rises, the price of U.S. products relying on them also rises. However, the dollar's decline is lowering the overseas price of U.S.-made products, creating a stagnant U.S. trade balance due to the double-edged nature of exchange rates.

Because of pricing strategies of U.S. and foreign competitors, as well as nonprice competitive factors, including existing offshore production facilities and long-term contracts between U.S. and foreign companies, the full effects of the dollar depreciation will not be felt until some time has elapsed. Dataquest believes that eventually U.S. price and cost improvements will offset nonprice factors and that U.S price and cost competitiveness will strengthen as factory productivity continues to improve.

Offshore Advantages

Since end-user markets in Asia are smaller than those in Europe and the United States, proximity to Asia inadvertently creates a greater distance between the manufacturer and the world's markets for high-technology products. However, several factors are continuing to encourage U.S. vendors to employ offshore manufacturing:

- Low component costs from local offshore firms
- Lower overseas engineering labor costs
- Foreign incentives

Low Component Costs

A motivating factor in locating manufacturing operations abroad is the research and industrial parks set up by countries. These parks offer attractive terms to U.S. manufacturers. In exchange for U.S. investment, the countries provide various incentives such as free rent, five-year tax holidays, duty-free importation of machinery and equipment, equity and debt financing, and access to local component suppliers. Most U.S. companies believe that these incentives constitute the competitive edge they need.

Low Labor Costs

Through contracts with government-sponsored research and development parks, U.S. companies can hire foreign engineers for only about one-fifth the salary of a U.S. engineer. Some companies believe it is imperative to work with Asian firms now to avoid head-on competition in the future since the white-collar salary will eventually be the cost-differentiating issue.

Foreign Incentives

Currency fluctuations can impact a manufacturer's decision to acquire lower-cost materials from offshore firms. The advantages of both the lower cost of labor and components from offshore sites outweigh the disadvantages of offshore production, such as higher communication and transportation costs, and duty taxes to export the products to the United States.

MOVING ONSHORE

In the past, Japanese firms located plants in the United States to ease trade tension. However, many Japanese peripherals manufacturers are now breaking ground in the United States because of the strong yen as well as the desire to develop closer ties with American customers. Dataquest believes that, in particular, Japanese acquisition of production facilities in the West is primarily driven by fear of anticipated quotas and other forms of import restrictions.

Companies such as NEC (which employs more than 5,000 workers in five U.S. plants) recognize that the rise in the yen has made moving operations to the United States more economically feasible.

More important, overseas companies recognize the advantage of automated manufacturing, which essentially places the low-cost labor issue on the back burner. Close proximity to the world's largest market for electronics products is another significant incentive for foreign manufacturers to move onshore.

ONSHORE PRODUCTION FACILITIES

Recently, both NEC and Toshiba announced the intention to open U.S. facilities for manufacturing and assembling computers. Specifically, NEC will begin assembling its 16-bit, APC-IV desktop computers at its Boxborough, Massachusetts, plant. Likewise, Toshiba plans to manufacture computers, printers, copiers, facsimile systems, and key telephone systems in its new Irvine, California, facility.

Other foreign firms involved with domestic manufacturing include:

- Brother International—In June, 1987, opened a typewriter manufacturing assembly plant in the United States, the first Japanese company to do so. The $8 million Bartlett, Tennessee, plant currently employs 150 workers and is expected to increase that number to 300 when the plant becomes fully operational in 1988.

- Canon—Currently is producing laser printers in its Newport, Virginia, plant. Canon is producing one-third of the 30,000 printers now being exported to the United States by its parent company in Tokyo.

- Epson America—After one year of operations, has begun Phase II of construction, during which 81,000 square feet will be added to its Portland, Oregon, facility. The construction is expected to be completed by spring 1988. The plant currently employs 300 people and manufactures Epson's 9-wire printers and personal computers.

- Facit—Recently formed a custom product design and enhancement center in Concord, New Hampshire. The center will make custom product enhancements of its laser, matrix, bar code, color, and letter quality printers.

- Fujitsu America—Began construction of its second 177,000-square-foot manufacturing facility. The $30 million Hillsboro, Oregon, plant, when completed in March 1989, is expected to employ an additional 500 employees at the 145-acre complex. Fujitsu plans to manufacture printed circuit board assemblies, computer tape drives, and other electronic products at the site.

- Kikusui International—Recently relocated to a new company-owned building to launch U.S. manufacturing in 1988. The Gardena, California, facility marks the fourth time that Kikusui has moved to larger U.S. headquarters since the Japanese-based company entered the U.S. market in 1978.

- Konishiroku Photo Industry—Began construction on its first U.S.-based manufacturing facility for photographic color paper, which is located in Greensboro, North Carolina. The facility will be in operation by 1989 and will employ approximately 300 people.

- Ricoh Corporation—Plans to build a new manufacturing plant in the Southeast before the end of 1987. Funding for the project, which is expected to cost $25 million, will come from the $100 million Ricoh has earmarked to build the plant and expand its existing facilities on the West Coast. Ricoh Electronics, Inc. (REI), a subsidiary of Ricoh Corporation, recently purchased a two-building complex in Tustin, California. The new 250,000-square-foot facility will be the company's third U.S. facility for manufacturing office machines and is expected to hire 600 employees.

According to Electronic Business, the top 10 companies, 6 of which are Japanese, each sold more than $1.00 billion worth of electronics in the United States. Japan's Matsushita Electric Industrial Company, Ltd., ranking 9th, alone achieved sales of $6.52 billion.

Korea has also followed Japan's footsteps by establishing overseas firms.

Korean companies have moved their operations not only to the United States, but to other countries as well. Last year, Samsung Electronics invested $25.0 million in a consumer electronics plant in England, and Goldstar began construction of a factory in West Germany, with an investment of $2.6 million for the production of video recorders and televisions. Domestically, Goldstar's factory in Huntsville, Alabama, is reported to be one of the company's most successful plants, producing 500,000 microwave ovens and more than 1 million color televisions.

Although these Korean firms are maintaining pace with overseas manufacturing, they are still adversely affected by currency issues. The high proportion of Japanese-made parts in Korean exports essentially counteracts the impact of devaluing the U.S. dollar against the yen since the Korean currency has been equally devalued.

FOREIGN INVESTMENT

Just six years ago, U.S. holdings abroad exceeded the value of foreign-owned assets in the United States by more than $100 million. Today, foreign-owned firms have reversed the positions. In total, foreigners owned approximately $1 trillion of U.S. assets at the end of 1986, with foreign governments investing primarily in U.S. Treasury securities. Foreign corporations, institutions, and individual investment in America was overwhelming: $80 billion in Treasury securities, more than $200 billion in corporate stocks and bonds, more than $180 billion in direct investments in U.S. companies, and more than $400 billion in bank deposits, agricultural land, and commercial properties.

Who are these top foreign investors? The British have long been the biggest direct investors in the United States, currently having invested more than $44 billion in U.S. assets, including start-up operations and purchases of more than 10 percent of U.S. companies.

In 1985, the British spent $6.0 billion in the United States, nearly one-third of the $19.5 billion of foreign direct investment. It surpassed that number in 1986, with foreign direct investment totaling a staggering $8.7 billion.

The Netherlands came in second, with foreign direct investment led by Royal Dutch Shell, whose U.S. holdings are valued more than $36 billion.

In the Asian arena, many companies have discovered U.S. investment as a lucrative long-term tool. Japan has led the pack by stockpiling more than $19 billion in direct investment, specifically in the area of U.S. real estate. Shuwa Corporation, one of Japan's largest real estate buyers, spent $620 million last year for land in California and New York alone. According to the Treasury Department, Japanese investors spent an astonishing $2.5 billion buying U.S. stocks during the first nine months of 1986.

The Japanese Economic Institute in Washington maintains that Japanese corporations own more than 50 percent of at least 400 U.S. manufacturing or assembly companies and employ approximately 110,000 people.

Korean companies have invested only $200 million in U.S. plants—a much smaller amount than the Japanese. However, the Korean Economic Institute of America predicts that Korean investment could swell to $5 billion over the next decade.

FOREIGN INVESTMENT INCENTIVES

A significant incentive for foreign investment in the United States, aside from the obvious advantage of the dollar's depreciation, is the prevailing American protectionist mood. Consequently, foreign manufacturers have quickly responded to U.S. protectionism by settling their companies and production products on U.S. soil before sales of their products are stilted by costly or insurmountable trade barriers.

Historically, the Japanese have been successful in avoiding the detriments of protectionism. Most evident are the popular Japanese automobile industries and semiconductor companies. Having been accused of dumping on American shores, semiconductor companies have invested nearly $200 million over the past year to open and expand a dozen U.S. product facilities.

With Japan's insatiable appetite for purchasing real estate, building on the property is the next step. Last year, Japanese construction companies landed close to $12 billion in U.S. contracts, 18 times the amount won just five years ago.

Hong Kong and Indonesian residents have also kept their foreign investments in the United States because they perceive America as the safest haven for their cash.

Table I provides a list of some foreign companies currently involved with financial investment in the United States.

Table 1

Partial Listing of Foreign Companies and Their U.S. Holdings

Foreign Investor	Country	U.S. Investment	Industry
L'Air Liquide	France	Big Three Industries	Chemicals
AKZO NV	Netherlands	Litton Bionetics	Research laboratory
BASF AG	Germany	BASF Wyandotte	Chemicals
Corbridge Company	Hong Kong	Innovative Media	Typesetting
James Goldsmith	United Kingdom	Crown Zellerbach	Paper products
Goldstar Group	Korea	Goldstar Semiconductor	Semiconductors, business computers
Korea Explosives Group	Korea	Koryo Systems	Computer products
Kudo Trading	Japan	Japan Forest Industry	Sporting equipment
Lucky Group	Korea	Goldstar of America	Refrigeration machines
Mezzanine Capital	United Kingdom	Dale Electronics	Electronics
Mitsubishi Heavy Industries	Japan	Diamond Star Motor	Motor vehicles
Mitsui and Company	Japan	Alumax	Aluminum manufacturing
Moore Corporation	Canada	Elite Software Systems	Software
Sampo	Taiwan	Sampo Corp. of America	Electronics
Samsung Electronics	Korea	Samsung International	Televisions
Shinshu Seiki Company	Japan	Epson Portland	Computers
Tatung	Taiwan	Tatung Science & Technology	Computer products
Toray Industries	Japan	Trea Industries	Plastics
United Microelectronics	Taiwan	Unicorn Microelectronics	IC design
VNU BV	Netherlands	Clarita's Cos.	Computer software

Source: Dataquest
January 1988

FOREIGN ELECTRONICS INVESTMENT

Currently, electronic investments in the United States stand at $80 million. Overseas electronics investment has primarily taken three forms:

- Research and development
- Marketing
- Production facilities

Taiwan's shift toward overseas electronics investment, for example, began in 1984 when the Taiwan Investment Commission of the Ministry of Economic Affairs approved $30 million worth of overseas investment. During 1981 to 1983, only $2 million was approved; however, of the $30 million approved in 1984, electronics manufacturers accounted for $25.3 million.

Today, with Taiwan's foreign-exchange reserve over the $40 billion mark, the government is actively encouraging local electronics firms to invest abroad. Dataquest believes that the Asian governments will continue to support and encourage more electronics companies to relocate their branch operations to U.S. soil.

If government support continues, more electronics firms are expected to reach to overseas markets for locating their branch operations.

DATAQUEST CONCLUSIONS

Dataquest believes that the growing trend for foreign companies to manufacture in the United States will continue despite the unstable and unpredictable economy. Issues such as the weak U.S. dollar, import restrictions, automated manufacturing, and economic advantages will remain as the major attractions for foreign companies to break ground on U.S. soil.

Since foreign firms have been competing, and are continuing to actively do so in worldwide markets, U.S. companies must understand more than a single market or region. Electronics decision makers need to plan for new manufacturing strategies that will produce quality products at low costs while maintaining a global perspective.

In short, the electronics industry has made the inevitable shift toward international interdependence, forcing worldwide manufacturers not only to accommodate the changing needs of the customers but also to realize that a global view is the ultimate key for survival.

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David Norman
Bhanu Bhattsasali

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Research Newsletter

SAM Code: 1987–1988 Newsletters: January–March
1988–01

JANUARY PROCUREMENT SURVEY AND 1987 REVIEW

As we march into 1988, there is a sense of balance in the air between semiconductor supply and demand. The equation is complex, however. For the time being, mixing the factors of moderately growing demand, sufficient but tightening supplier capacity, the trade agreement, just-in-time delivery, a stock market crash, and several other variables yields a balanced marketplace. In general, end-equipment growth is strong but has leveled somewhat in the last three months. Although moderately excessive inventories were built in the last half of 1987, semiconductor orders and shipments have eased, thus avoiding a pathological correction situation later on. Nonetheless, we will scrutinize our 1988 survey data to ensure that the balance continues.

STATE OF THE INVENTORIES

According to our January survey, the overall semiconductor inventory excess will narrow to 11 percent. As indicated in Figure 1, this represents the healthiest situation since June 1987, when inventories were at the desired levels relative to business activity (target). Actual January inventories of 32 days were at the lowest point since the survey began in May 1987.

Figure 2 breaks out the inventory data for computer OEMs. With actual and target inventories in January nearly equal at 31 days, a similar conclusion can be drawn regarding the sound health of that segment. This is an interesting result for a segment that saw an overdemand for components in early 1987 and, subsequently, an oversupply in the latter part of the year.

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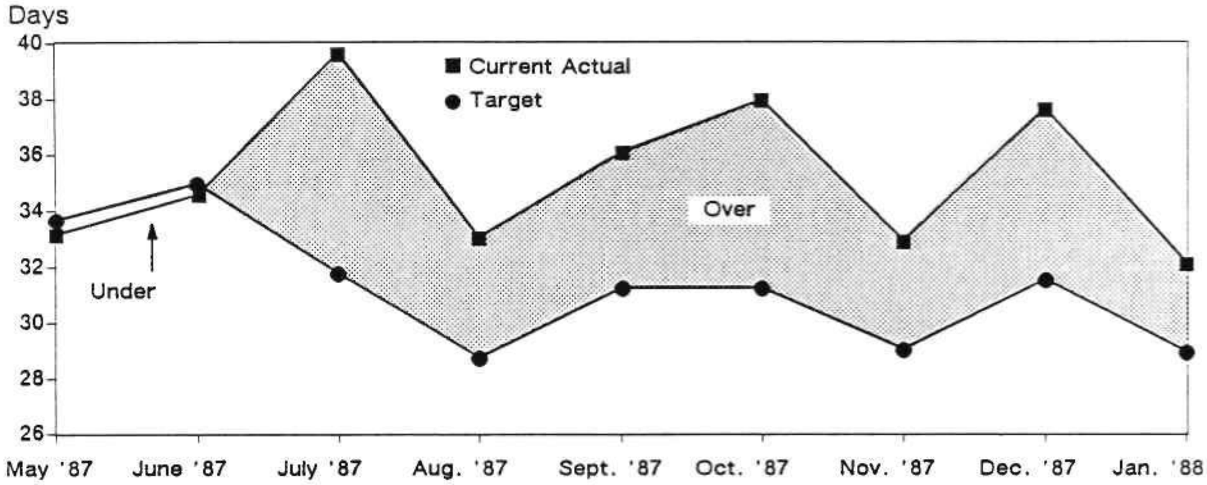
Figure 1

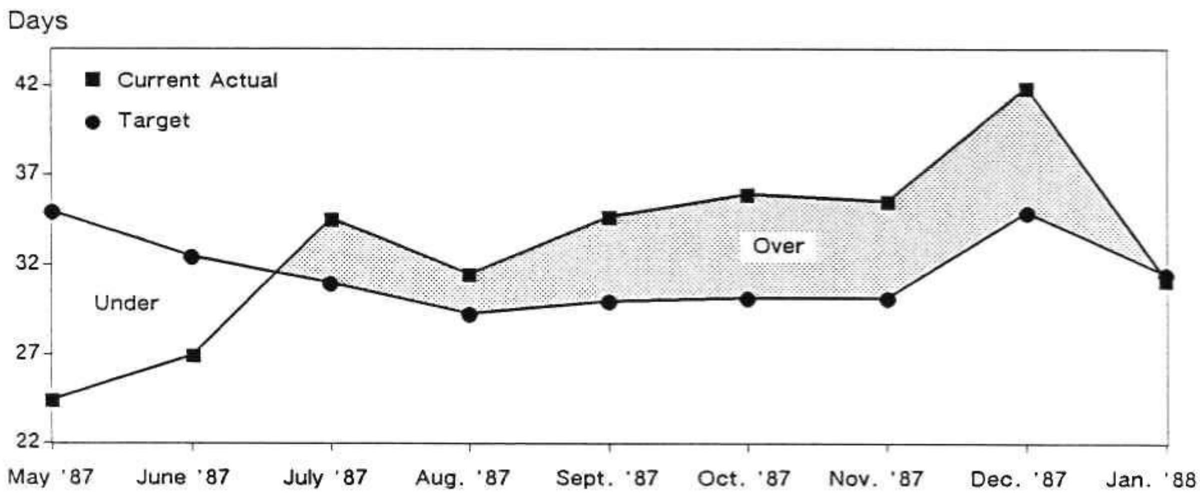
Current Actual versus Target Inventory Levels
(All OEMs)



Source: Dataquest
January 1988

Figure 2

Current Actual versus Target Inventory Levels
(Computer OEMs)



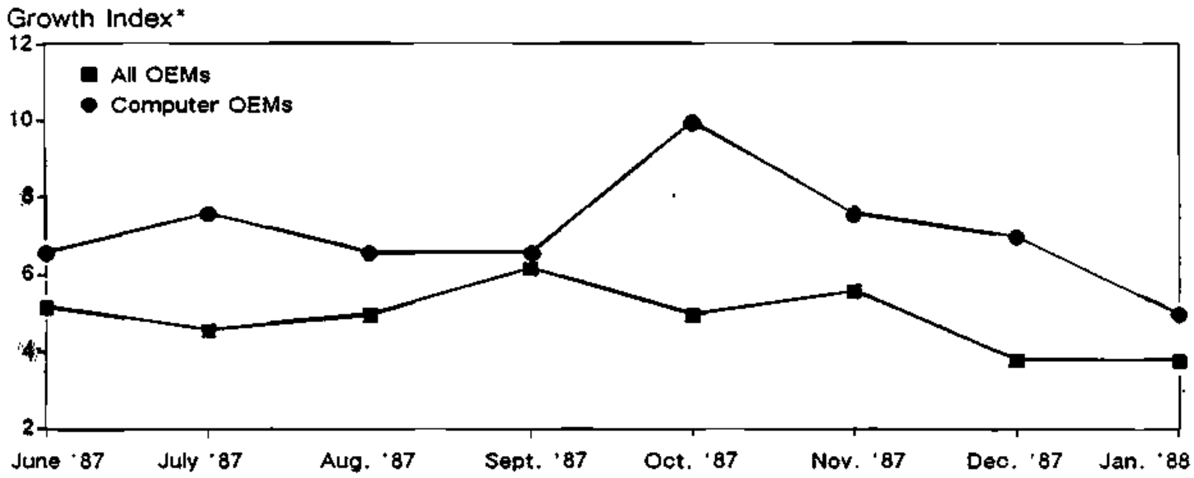
Source: Dataquest
January 1988

End-Equipment Sales Growth

On an index basis, the average OEM in our survey population has seen its end-equipment sales growth slowing since the third quarter of 1987. Sales are still growing, but the pace of growth has slowed. Detailed in Figure 3 are equipment sales growth index graphs for the total survey group and computer OEMs. Computer OEMs, on the average, have grown at a rate of 30 to 50 percent above the total group. While reflecting a higher degree of seasonality, January OEM sales growth has reached its lowest point since the index was started in June 1987.

Figure 3

Electronic Equipment Sales Growth



*Note: -10 through 0 = lower than last year
0 through 10 = higher than last year

Source: Dataquest
January 1988

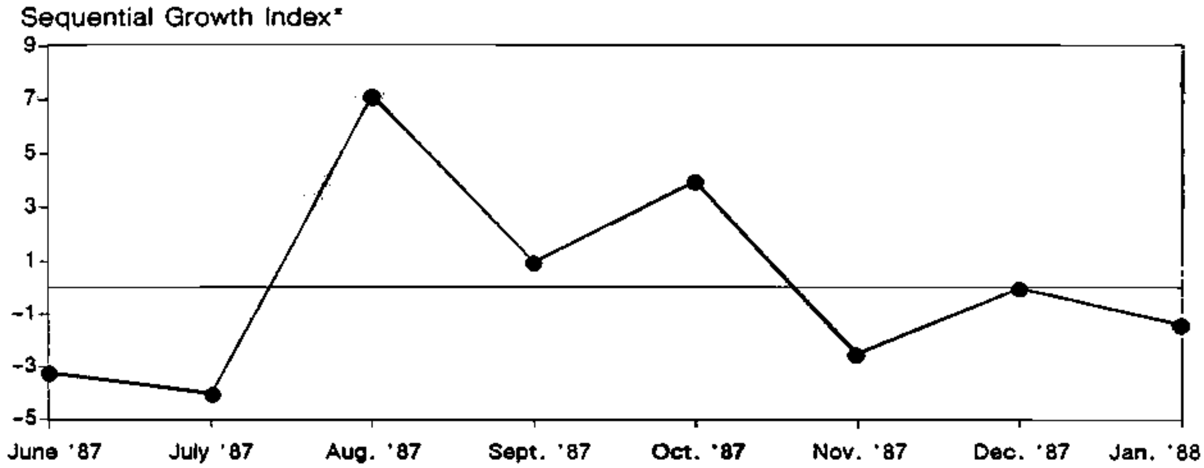
Slowdown in Semiconductor Orders and Shipments

Based on a similar index, semiconductor order placements will decline in January, compared with those in December (see Figure 4). This nonpositive order growth continues for the third straight month. As a lagged effect from slowing orders (see Figure 5), semiconductor shipments declined during January, for the second consecutive month. January shipments to all OEMs were noted to be down 9 percent, and down 7 percent to computer OEMs.

As in the past months, 256K and 1-megabit DRAMs continue to be hard to secure and are noted as still costing too much. Coupled with this is the observation of a raise in DRAM prices in the last month. Surface-mount logic and memory, and sole-sourced 32-bit MPUs are still hard to source for many. Discretes, especially transistors and most surface-mount varieties, are also in short supply.

Figure 4

Semiconductor Order Growth
(All OEMs)

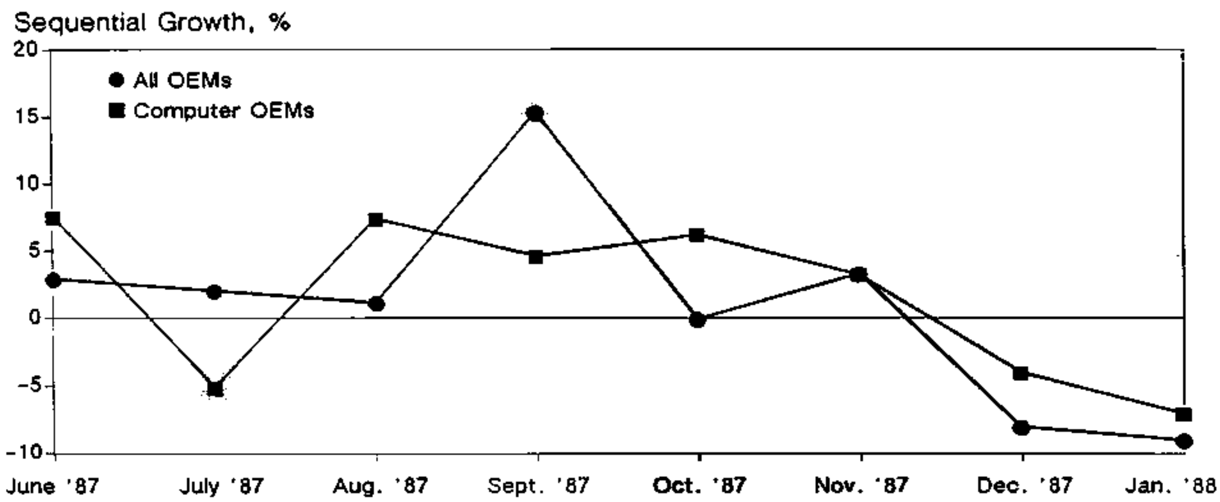


*Note: -10 through 0 = lower than previous month
0 through 10 = higher than previous month

Source: Dataquest
January 1988

Figure 5

Semiconductor Shipment Growth



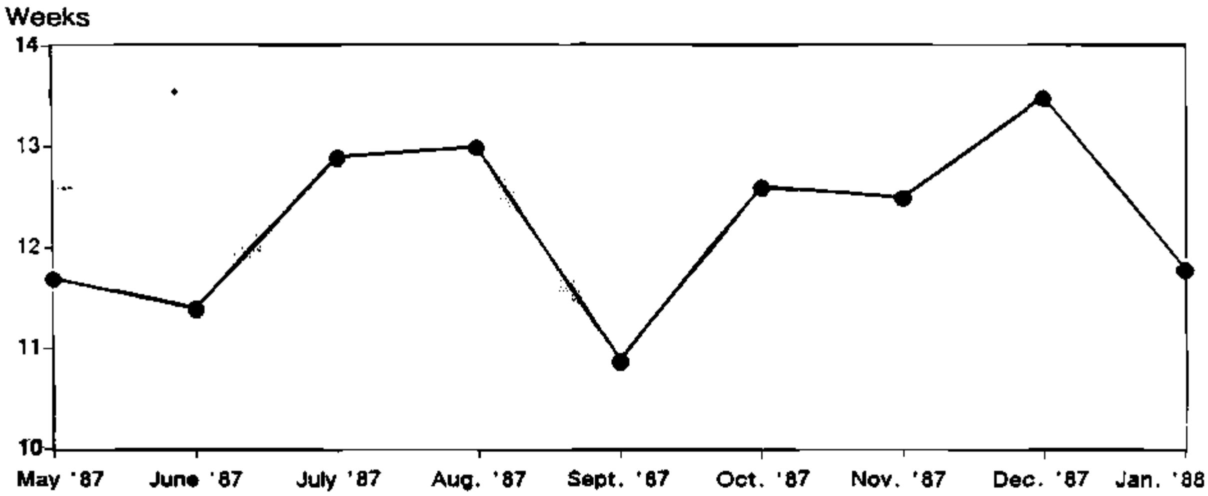
Source: Dataquest
January 1988

In general, there is a growing concern that sunset products are becoming unavailable. In order to preserve relationships with their customers, semiconductor vendors should approach obsolescence programs very carefully. It behooves semiconductor users to communicate their sensitivities early, so that surprises are avoided.

In spite of some hot spots, overall lead time dropped to 11.8 weeks in January, signifying an ongoing stable supply for the bulk of user needs (see Figure 6).

Figure 6

Lead Times—All Semiconductors



Source: Dataquest
January 1988

DATAQUEST CONCLUSIONS

The ultimate symbols of a healthy semiconductor industry are growing electronic equipment markets, coupled with proper levels of inventory to service that volume of business. Although not without a degree of underdemand in some product areas and overdemand in others, we are currently in a healthy situation.

The stability we are witnessing is best characterized by general price stability, as well as the continued relative shortness of lead times. So far, in this business cycle, semiconductor manufacturing capacity has more closely matched demand, and demand has not been driven by euphoric expectations of an equivalent PC boom. Probably just as important to creating this stability are the proactive efforts of suppliers and OEMs to form better relationships based on a degree of trust and improved inventory management. In this respect, maybe the electronics and semiconductor industries have grown up.

Gregory L. Sheppard

April–June

The following is a list of the newsletters in this section:

(Continued)

(Continued)

April-June

(Continued)

Dataquest
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Research *Bulletin*

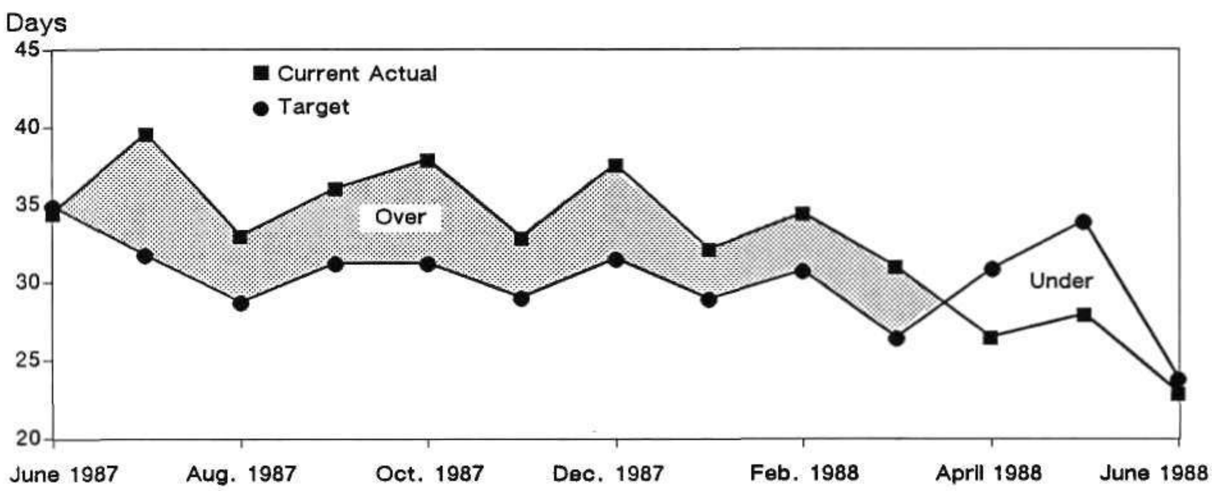
SAM Code: 1987–1988 Newsletters: April–June
1988–27
0000304

JUNE PROCUREMENT SURVEY: SALES UP, INVENTORIES DOWN

The majority of respondents to our procurement survey expect June sales of their electronic systems to increase over the levels set in May. Semiconductor orders to feed this demand will remain flat over the next month, not due to a lack of demand, but due to the shortage of key memory devices. The correction of overall inventory level decreases (both targeted and actual) have more than offset the increases seen in May by falling to 24 and 23 days, respectively, as shown in Figure 1. Memory availability continues to plague medium-size to small companies, but only for DRAMs and some slow SRAM products. Adequate supplies of these parts are being delivered to larger companies and those with long-term vendor agreements in place.

Figure 1

Current Actual versus Target Inventory Levels (All OEMs)

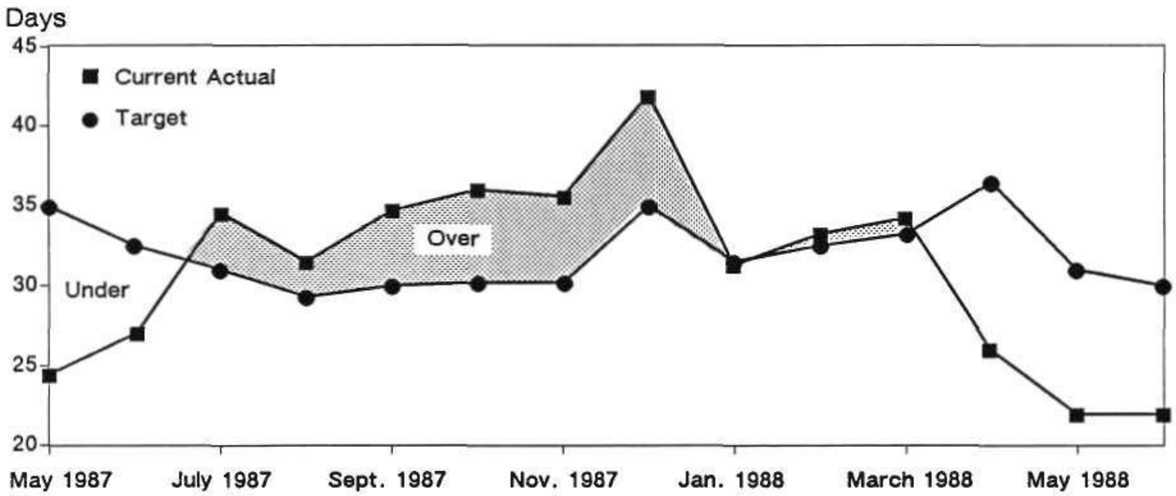


Source: Dataquest
June 1988

Computer OEMs continue to maintain stable inventory levels, with the target level coming down slightly from last month's 31 days. The flatness seen in Figure 2 is due in part to the shortage of DRAMs keeping supplemental semiconductor orders/inventories in check. Ancillary devices most affected have been slow microprocessors and some standard logic products.

Figure 2

Current Actual versus Target Inventory Levels (Computer OEMs)



Source: Dataquest
June 1988

Pricing and lead times have remained relatively stable compared with last month's survey. Distribution orders have also remained flat at 3 to 15 percent, reflecting the overall market dilemma of obtaining scarce parts at reasonable prices.

Mark Giudici

Dataquest
a company of The Dun & Bradstreet Corporation

Research Newsletter

SAM Code: 1987–1988 Newsletters: April–June
1988–26
0000252

SECOND-QUARTER UPDATE: DATAQUEST'S VIEW OF THE ELECTRONICS INDUSTRY

SUMMARY

Dataquest's coverage of more than 25 electronics industry segments puts it in a unique position to view the electronics industry as a whole and, more importantly, how the segments are interrelated. This newsletter gives Dataquest's view of the U.S. electronics industry, first by looking at the economy, then analyzing issues that cross industry boundaries or megatrends, then by looking at trends in each of the major electronics segments that Dataquest tracks.

THE ECONOMY

Our analysis of the economic outlook is the ground zero for all our forecasts. We rely heavily on the economic analysis of Dun & Bradstreet, our parent company, to help us develop our economic forecast.

As shown in Figure 1, we expect GNP growth in the United States to be approximately 2.8 percent in 1988 and 2.2 percent in 1989. However, 1989 will show some strength in the first half, with a slowdown in the second half of the year.

Two major uncertainties have been removed from the economic picture: What if there is a stock market crash, and what if the dollar declines in value? Both of these events already have happened and relieved at least some of the uncertainty.

The stock market crash had less effect than was anticipated. A Dun's 5000 survey at the end of 1987 showed that about 75 percent of the respondents said that their capital spending plans for 1988 were not affected by the crash. The quarterly Dun & Bradstreet Business Expectation Survey showed that the business sector expected only a slight decline in sales and profit and actually planned to increase employment in the same period.

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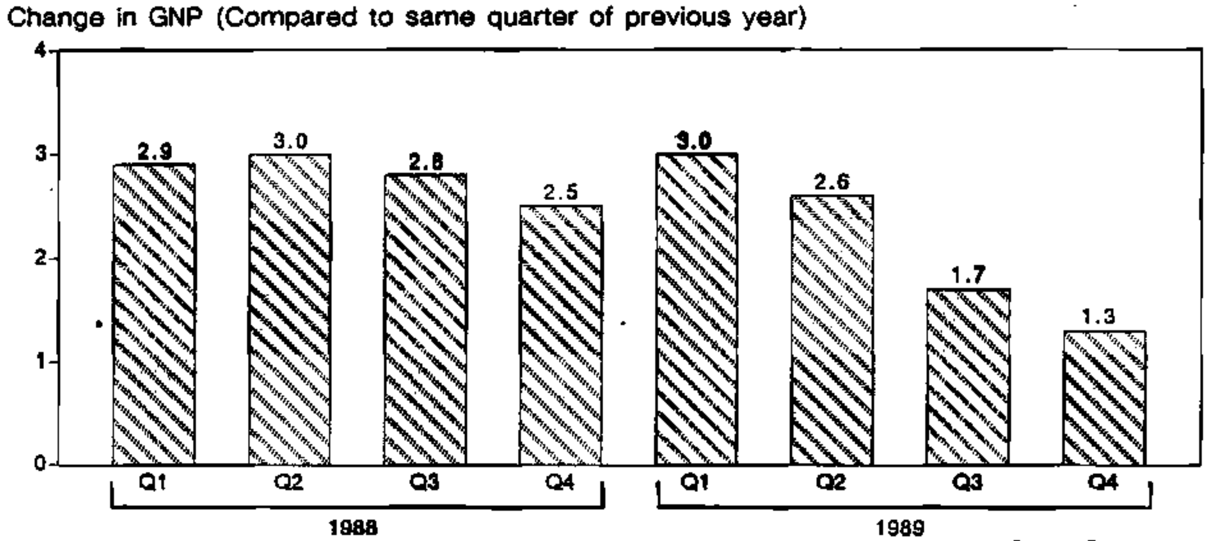
Figure 1

Estimated Change in GNP
Compared with Same Quarter of Previous Year



Source: Dataquest
June 1988

The United States is in its sixth year of economic expansion, and manufacturing capacity, at an average of 82 percent, is as high as it has been in the past two decades.

The current low value of the dollar has given a boost to manufacturing, and this, combined with the high-capacity usage typical of the later stages of economic expansion, is resulting in the addition of capacity and the resultant purchase of capital equipment. Such capacity expansion is good news for the electronics industry, which is enjoying the strongest market that it has seen since 1983.

Within this strong overall electronics market though, we see considerable fluctuations. These are caused by a number of factors including supply/demand relationships, product lifetime factors, and market saturation. Enhanced product capability also means that some products are encroaching upon others' territories. This is especially true in the computer market in which traditional definitions are rapidly becoming irrelevant.

Although economic growth is expected to slow in the second half of 1989, we still anticipate a relatively healthy electronics industry. The uncertainty factor is the value of the dollar. What effect will this have on world markets and the U.S. economy? The other major concern is the trade deficit. The lower-value dollar should do something to ease this problem, but the need exists for U.S. companies to recognize that they are operating in a global economy and expand further into overseas markets.

MEGATRENDS

Dataquest sees the following trends emerging throughout the electronics industry:

- Standardization
- Alliances
- Intellectual property
- Competitiveness

Standardization

End users are finally flexing their combined muscles and demanding product compatibility. They no longer want to be tied to one vendor's development plans or product lines. The concept of selling solutions instead of systems has finally moved from the realm of platitudes to reality.

The result is an increased emphasis on standardization. In the computer world, standards that were once confined primarily to communications protocols are now spreading to operating systems, hardware components, data management systems, document exchange protocols, and peripherals interfaces.

The successful electronics manufacturer must identify those standards that are important to his industry and cooperate in their development. This demands increased levels of cooperation between companies.

Alliances

We have seen a number of mergers (the ultimate alliances) of major companies in the electronics industry in the recent past. Burroughs' and Sperry's forming Unisys in the computer area, and the mergers of National Semiconductor and Fairchild and of Advanced Micro Devices and Monolithic Memories in semiconductors are good examples. In all of these mergers, each company possessed a strength that its partner did not, and the combination has promised a more effective company. The jury is still out on how successful some of these mergers will be. The ability of the two companies to merge their separate cultures and grow from their complementary strengths will be the most important factors in determining the winners and losers.

Another form of alliance that has become important is the industrial consortium. Sematech is, of course, the publicized example. Government easing of antitrust restrictions to enable companies to share the benefits of joint R&D should help the United States to become more competitive in world markets.

"Virtual vertical integration" is a term that we have been using at Dataquest to describe alliances between users and vendors to their mutual advantage. These alliances often cross national boundaries and enable buyers to form strong relationships with their vendors to assure supply of critical components in times of shortage. Many of these virtual vertical integration agreements are facing a real test in the current shortage of 1 Megabit DRAMs.

Intellectual Property

Paradoxically, this trend makes companies more aware of the importance of protecting their unique intellectual properties. The days of selling technology licenses to other companies just to make the quarter's numbers are over.

Protection of intellectual property is hampered by the lack of adequate relevant legislation. The short life cycle of today's electronic products means that a product can be obsolete by the time an intellectual property case reaches the courtroom. Defining intellectual property is also a problem, as cases such as the current Apple/Microsoft "look and feel" litigation show.

Increased concern with intellectual property rights is based on the following three major issues:

- Increased development costs. For example, the cost of developing a new generation of microprocessors can be as high as $80 million.
- Higher capital requirements. This is especially true in industries in which manufacturers are automating in order to compete effectively.
- Shorter product life cycles. The average lifespan of semiconductor logic families between 1965 and 1982 was 5.6 years. Microprocessor families, which were first introduced in 1972, have lasted an average of only 4 years, and application specific ICs can have lifespans that are measured in months.

Competitiveness

The falling value of the dollar has given U.S. manufacturers a brief respite in their efforts to conquer the global market. Enhanced productivity is one of the most important keys to competitiveness, and manufacturing automation may well give the U.S. electronics industry the opportunity to improve its position in world markets. Effectively implemented automation not only enhances productivity but can also improve the quality and consistency of the products manufactured.

THE MARKETS

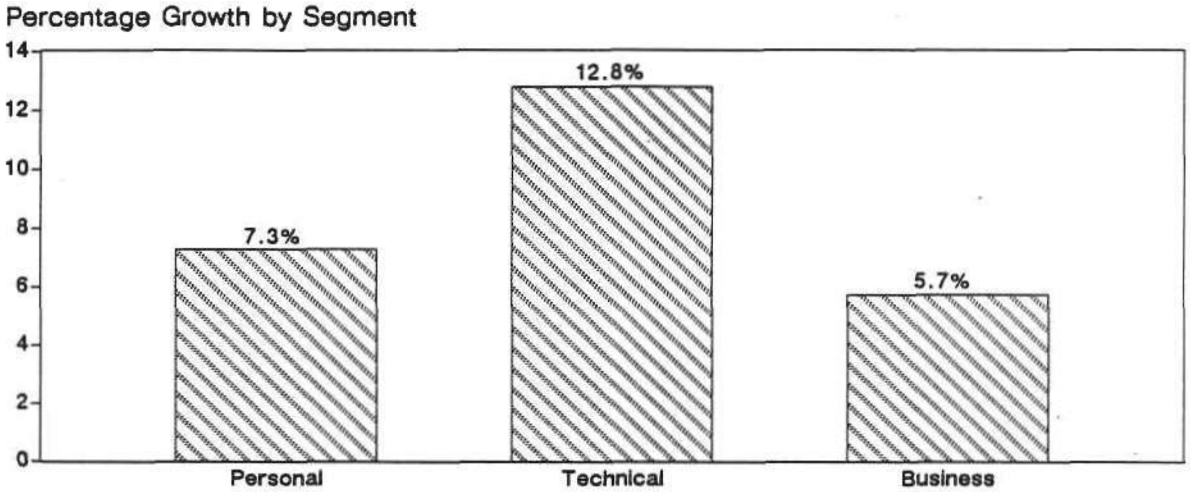
Computers

The DRAM shortage could have a significant impact on the growth of the computer industry in the coming year. We see continued growth in all segments of the computer industry. Figure 2 shows compound annual growth rates (CAGRs) for each segment over the period from 1988 to 1992.

The technical computer segment is the fastest-growing segment of the market, with a CAGR of 12.8 percent. Personal computers are forecast to grow at a relatively modest 7.3 percent and business computers at 5.7 percent. Forecasts for each of these markets are shown in Figures 3 through 5.

Figure 2

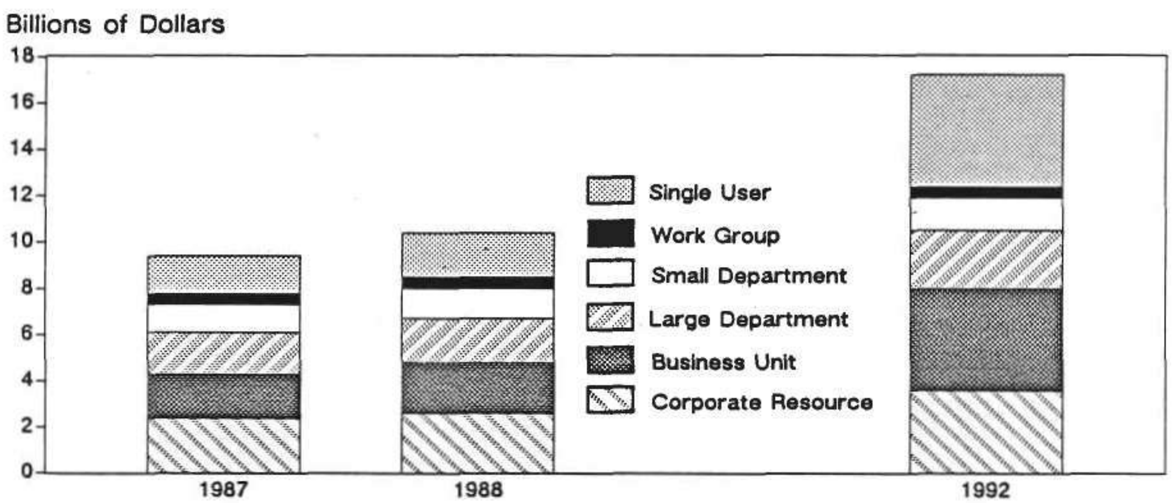
U.S. Computer Markets
Estimated Percentage Growth by Segment



Source: Dataquest
June 1988

Figure 3

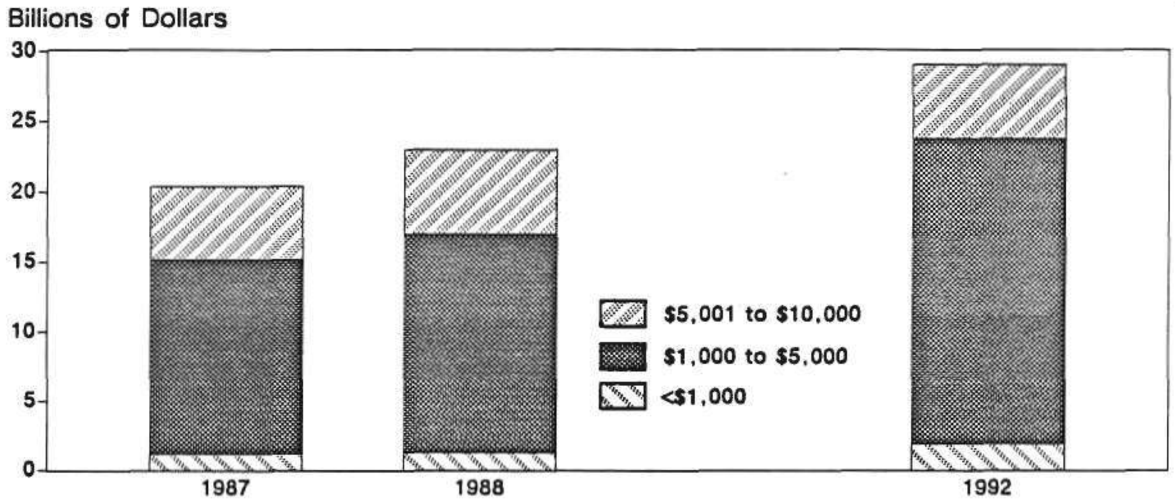
Technical Computer Market
Estimated U.S. Revenue



Source: Dataquest
June 1988

Figure 4

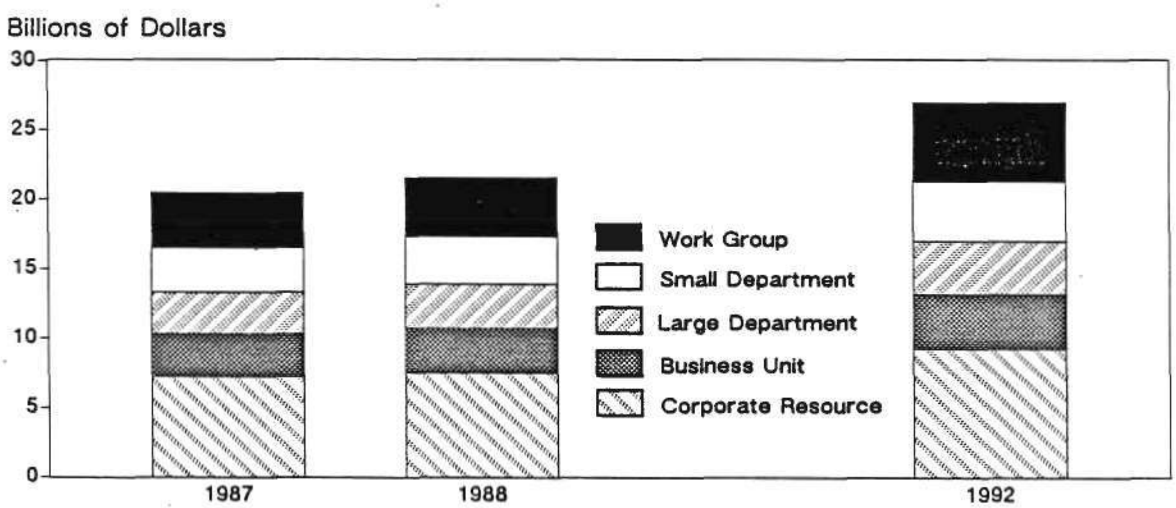
Personal Computer Market
Estimated U.S. Revenue
(Billions of Dollars)



Source: Dataquest
June 1988

Figure 5

Business Computer Market
Estimated U.S. Revenue
(Billions of Dollars)



Source: Dataquest
June 1988

We believe that the following are the most significant trends in the computer industry:

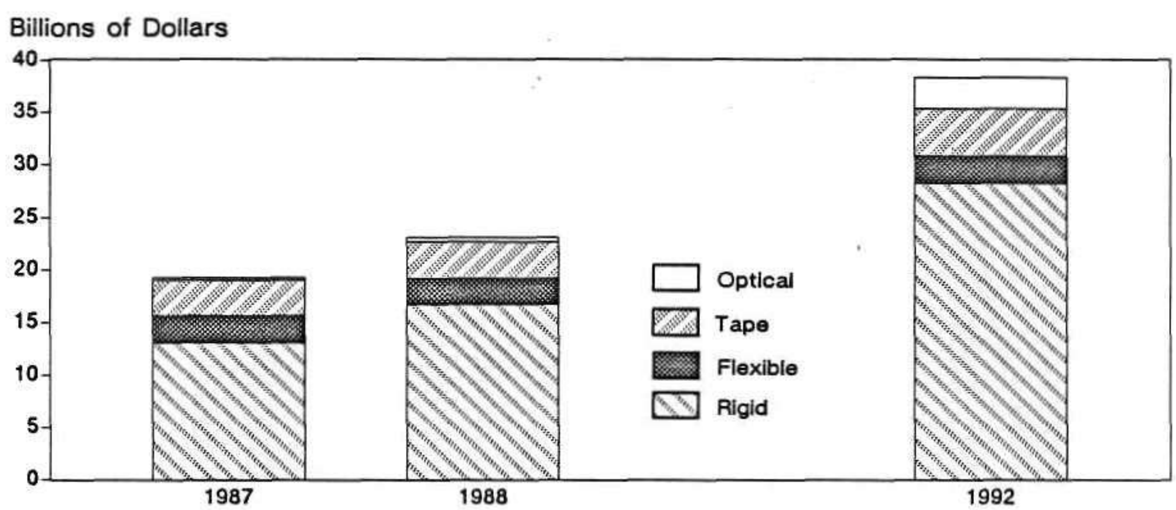
- Workstations are the fastest growing platforms.
- The style of computing is changing from host-based systems to server-based systems.
- RISC architecture is penetrating the technical computer industry.
- Competition between Digital Equipment and IBM is becoming fierce, as their product lines become more directly competitive.
- Continued need for connectivity is enhancing modular growth, whether this means adding more CPU boards or adding new peripherals.
- Continued integration of functionality by PC manufacturers onto the system board. Likely additions include networking, facsimile, and graphics.
- VGA graphics will become the new standard for PC graphics.

Storage

The computer storage market is forecast to grow from $19.3 billion in 1987 to $23.1 billion in 1988, an increase of 21.5 percent. The CAGR for the years 1988 through 1992 is expected to be 14.7 percent, reaching $38.4 billion by 1992. Figure 6 shows Dataquest's forecast for the computer storage market.

Figure 6

Computer Storage Market
Estimated U.S. Revenue
(Millions of Dollars)



Source: Dataquest
June 1988

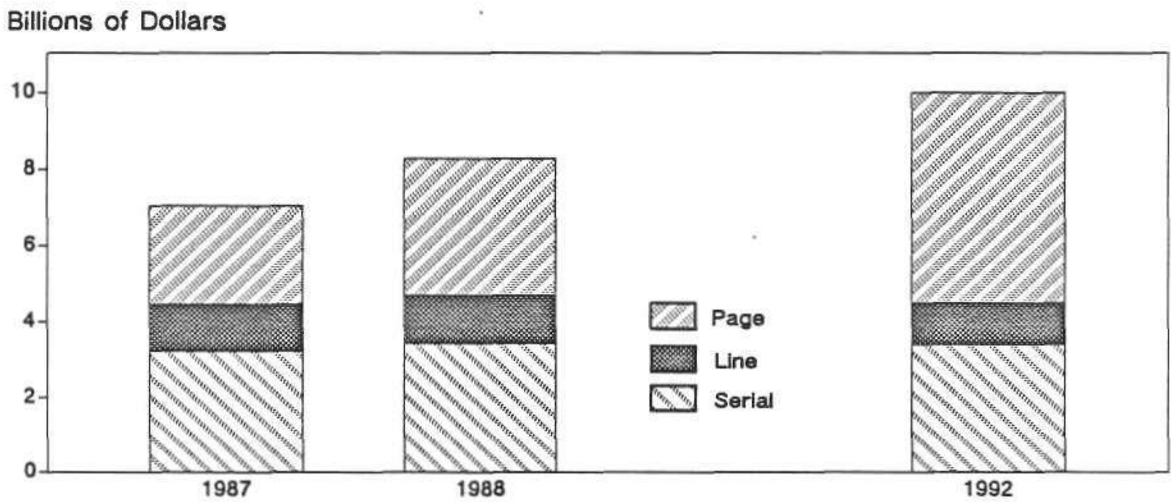
While the flexible disk drive market is almost static, the optical disk drive market is forecast to grow at an astounding 65 percent CAGR through 1992. Tandy's announcement last week of an erasable optical disk may make even that forecast conservative. The device that Tandy announced is expected to be available within 18 months to two years. Although a relatively slow data transfer rate means that it is unlikely to compete with the Winchester disk as the primary means of storage, its use as a backup medium could seriously impact the tape drive market.

Printers

In 1987, the printer market rebounded, and continued growth is expected up to 1992. Dataquest expects page printers to continue to increase market share at the expense of serial and line printers. Figure 7 shows Dataquest's electronic printer forecast.

Figure 7

Electronic Printer Market
Estimated U.S. Revenue
(Millions of Dollars)



Source: Dataquest
June 1988

An interesting about-face sees U.S. electronic printer manufacturers moving production back onshore. Japanese vendors are also setting up manufacturing plants in the United States to avoid prohibitive trade barriers. Extremely low labor content in printer manufacturing makes low labor rates overseas a less significant factor in production.

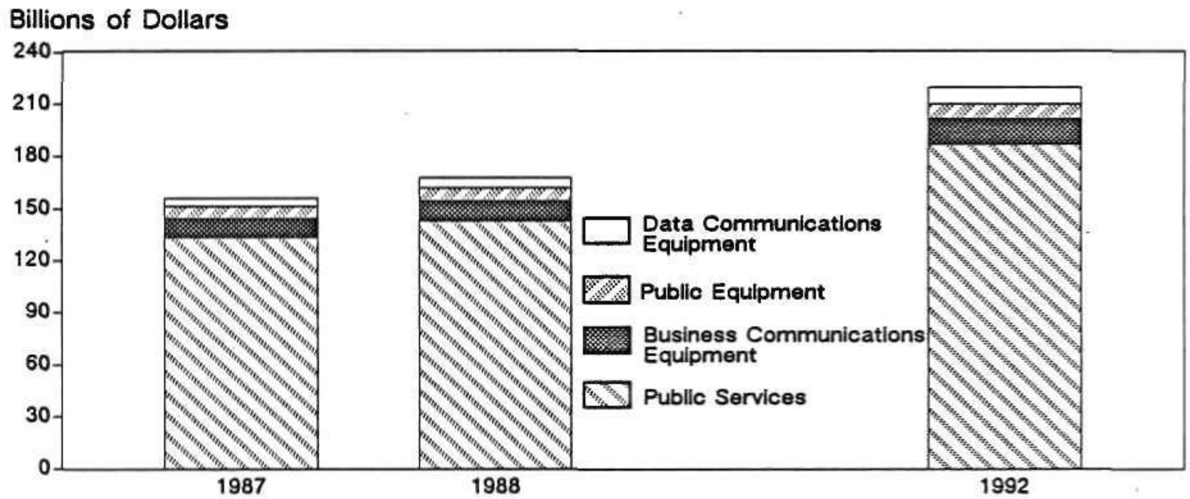
Laser printers continue to constitute the fastest-growing printer segment. This should continue as performance is enhanced due to new chip sets and controllers announced in 1988.

Telecommunications

The total telecommunications market is expected to grow from $156.1 billion in 1987 to $219.5 billion in 1992. By far the largest segment of this is the public services segment, which should grow from $133.3 billion in 1987 to $187.1 billion in 1992. The data communications segment is the fastest-growing part of the market, with a forecast CAGR of 12.7 percent. Figure 8 shows Dataquest's forecast for the telecommunications market.

Figure 8

Telecommunications Market
Estimated U.S. Revenue
(Billions of Dollars)



Source: Dataquest
June 1988

The generalization of these categories, however, makes for some spectacular growth in niche markets. The fax market, for example, grew a staggering 123 percent in 1987 over 1986; 1988 growth is expected to be 65 percent.

There is also a strong probability of integration of facsimile machines into other products such as copiers. The market is dominated by Japanese suppliers, with Sharp moving from number four to number one last year. Despite this domination, plenty of potential is still in the market. We estimate market penetration at less than 10 percent of the total available market, with an installed base of fewer than 1 million.

The major trends in telecommunications are those described earlier as megatrends. We are seeing substantial consolidation: the AT&T/Sun joint venture, DCA and Cohesive, Tandem/Ungermann-Bass, Unisys and Timeplex, to name a few. Even more significantly, we are seeing very few start-ups in the telecommunications arena.

Standards are a significant issue in telecommunications. Again, this is driven by the demands of the user who is unwilling to be tied to a single vendor. Customers, indeed, are the driving force in the telecommunications industry. So much technology is available that success is dictated not by being first, but by giving customers what they want.

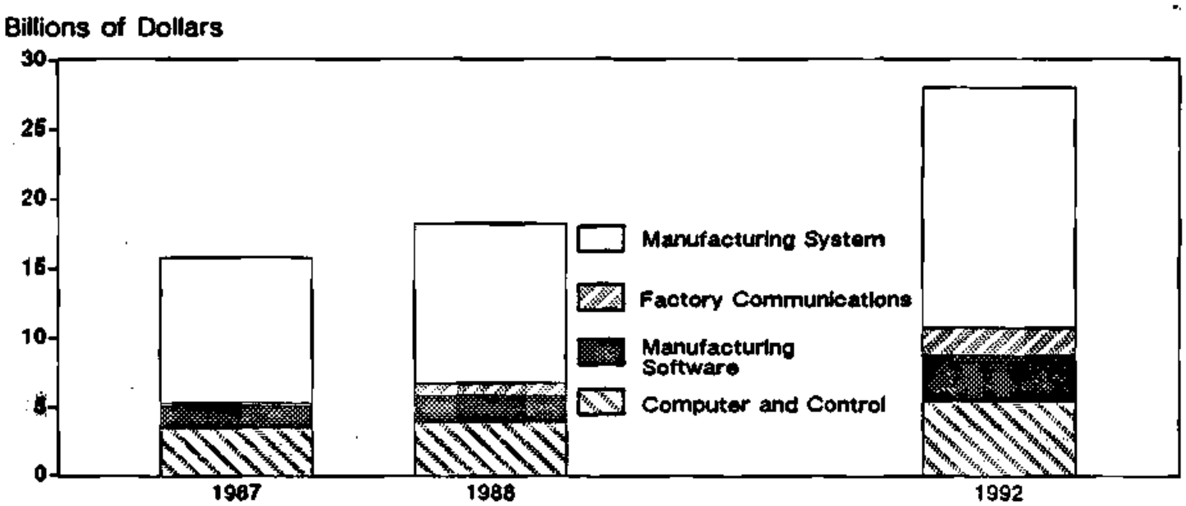
ISDN seemed in danger of being always about to happen, but the standards are now in place and we expect to see real growth in this area. The industry has settled into a period of slow but sustained growth, with areas of excitement including voice messaging, local area networks, and facsimile.

Manufacturing Automation

We estimate that manufacturing automation revenue in 1988 will be $18.3 billion, a growth rate of 15.8 percent over 1987. We forecast the market to grow to $28 billion by 1992, almost doubling from last year. In 1987, both the trade and business press focused on automation as critical to the ability of U.S. manufacturing companies to regain their competitiveness in the world market. This attention to competitiveness is largely a result of concern over the worst trade deficit in the history of the United States. So far, this has resulted in more tire kicking than actual purchases. Figure 9 shows Dataquest's manufacturing automation forecast for the U.S. market.

Figure 9

Manufacturing Automation Market
Estimated U.S. Revenue
(Billions of Dollars)



Source: Dataquest
June 1988

The United States is making product quality the primary goal, both to reduce costs due to rework and to improve customer relationships. For these reasons, U.S. companies are concentrating on the manufacturing side of the equation. Fewer companies are buying software to integrate their factories than manufacturers in Europe and Japan.

DATAQUEST CONCLUSIONS

Our broad coverage of the electronics industry has allowed us to see how all pieces of the industry are interrelated. From that knowledge, we have found recurring themes or megatrends in each segment of the electronics industry. These trends are: standardization, alliances, intellectual property, and competitiveness. All of these issues will continue to affect semiconductor users and manufacturers in the way that they compete in their own industries and operate as vendors and buyers.

David Norman

Dataquest
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U.S. FACSIMILE MARKET: TOP GUN IN TELECOMMUNICATIONS INDUSTRY GROWTH

SUMMARY

The facsimile market experienced unsurpassed growth in 1987 with U.S. placements exceeding 400,000 units, a 123 percent increase over 1986. In this newsletter Dataquest analyzes the dynamics of this market, including trends and issues, technological changes, alternative channels of distribution, new market entrants, and the Dataquest scorecard for the U.S. facsimile market.

GROWTH RATE

In order to put 1987 into perspective, it is important to understand what occurred in 1986, a year that experienced modest growth. Dataquest estimates that 187,500 units were placed in 1986, which was a 19 percent increase over 1985. This modest growth was largely due to the dollar-to-yen situation, which made facsimile machines more expensive to purchase for the U.S. market. Rather than pass the price increases on to dealers, vendors cut back on orders, lowering inventory levels and artificially creating a situation where demand exceeded supply. However, in 1987, the Japanese manufacturers geared up production and exported products to satisfy the demand of their offshore distributors. This pent-up demand, coupled with United States-based vendors' strategy of buying market share by aggressive pricing and discounting, led to a bumper-crop year. Table 1 reflects the total number of units shipped to the United States on a monthly basis.

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Table 1

Facsimile Machines Exported
to the United States from Japan—1987

Month	Number of Units*
January	23,341
February	26,373
March	30,432
April	27,561
May	35,400
June	47,097
July	57,752
August	41,652
September	52,020
October	66,790
November	64,113
December	81,423
Total	553,954

*Minus 10 percent for products shipped into the United States on their way into Canada

Source: Japanese Ministry of Finance
Dataquest
June 1988

Although the number of shipments was 553,954, total end-user placements in 1987 were 417,250, or 123 percent growth over 1986. Dataquest notes that the fourth quarter of 1987, which accounted for 212,328 units, represented the highest quarterly shipment level to the United States in facsimile history, further underscoring the effect of low prices and stifled demand. In addition to the suppressed demand and lower prices, Dataquest believes that the growing low-end segment of the fax market fueled this rapid growth. Dataquest estimates that 33 percent of all products placed in 1987 were priced at less than $2,000 (suggested list price).

Dataquest notes that the disparity between shipments and placements is the result of the following factors:

- Products in transit from Japan to the United States
- Inventory carried by dealers and some vendors
- Products shipped to the United States but with final destinations outside the United States, such as the Caribbean and Mexico.

TECHNOLOGY

In 1987, advances in fax technology included error correction mode and a new type of scanning method the contact image sensor. The CCITT recently approved the international error correction mode, a checking system that detects and resends information automatically if needed before it is printed at the receiving end. This checking system saves the cost of a phone call and potentially wasted paper.

Contact image sensor (CIS) technology also made its debut in 1987, with companies such as Fujitsu, Harris/3M, and Mitsubishi introducing low-end products with this new scanning method. The CIS system comprises a glass rod with a light array that actually comes into contact with the document. The current scanning method, charge-coupled device (CCD), uses lenses, a PC board, a fluorescent lamp, and mirrors that are susceptible to disturbance if the machine should get jolted. The CIS system is lighter, more compact, and less prone to damage because it has fewer moving parts.

Dataquest believes that this technology will become more prevalent on low-end and midrange products due to two factors: increased reliability and improvement in resolution. Although CIS technology is considerably more expensive than CCD technology, the tradeoffs are financially justified for the reasons cited above. Additionally, as the implementation of CIS technology is employed in mass production, its cost will decrease. As stated earlier, CIS technology offers increased reliability because it involves fewer moving parts and the units can be transported without causing injury. Frequently, CCDs slip out of alignment, which then requires a service call. CIS technology does away with this inconvenience. Improvement in resolution is another outcome of CIS technology. Because CIS technology uses no lenses, which can become dirty or dusty, the output quality is consistently better.

NEW MARKET ENTRANTS

Nineteen eighty-seven represented a window of opportunity for many office equipment and telephony companies interested in expanding their product offerings. In the office equipment arena, the following companies joined the fax market: Brother, Gestetner, Medbar Enterprises, Minolta, and Savin. Facsimile was also viewed as an opportunity for key telephone system vendors, the regional Bell operating companies (RBOCs), and other communications vendors. Extel, Galaxy Communications, Iwatsu, Nitsuko, Northwestern Bell, PacTel Products, Panasonic, Teli USA, TIE Communications, and Trans-Lux Corporation are some telephony companies that joined the facsimile fray. We believe that the presence of communications companies in the fax market will continue to increase to the point where communications companies outnumber all other company types as participants in this rapidly growing market.

Distribution Relationships

Table 2 indicates the OEM suppliers for these new market entrants and how the products are distributed.

Table 2

Facsimile Distribution Structure

Competitor	OEM Supplier	Distribution Channels
Brother	Brother	Dealers, distributors, retail
Extel	Teco	Dealers, distributors
Galaxy Communications	Sanyo	Telephone supply houses
Gestetner	Sanyo	Dealers, branches
Iwatsu	Murata	Telephone supply houses, interconnects
Medbar Enterprises	Nissei Opto	Dealers, retail
Minolta	Mitsubishi	Dealers
Nitsuko	Ricoh	Distributors
Northwestern Bell	Toshiba	Distributors, retail
PacTel Products	Canon, NEC	Dealers, distributors, retail
Panasonic	Matsushita	Telephone supply houses, interconnects, retail
Savin	Ricoh	Dealers, branches
Teli USA	Tokyo Electric	Dealers
TIE Communications	Nitsuko	Branches, telephone supply houses, interconnects, independent telcos
Trans-Lux Corporation	Sanyo	Branches

Source: Dataquest
June 1988

DISTRIBUTION CHANNELS

Retail, Dealers, and Vendors

Office equipment dealers view facsimile machines as a natural extension of their current product lines of copiers, typewriters, and dictating machines. However, the vendors and dealers that will survive in the face of extreme competition are those that continue to maintain separate sales forces and dedicate salespeople to fax. An example of such a commitment is Savin Corporation, which entered the fax marketplace at NOMDA 1987. It has not transferred copier salespeople or management to its newly created fax division, but instead has hired people from the fax industry to manage the group.

Dataquest research has indicated that dealers who compete on the basis of price only are not thoroughly trained about fax machine features and also do not offer products that have features that match end-users' needs and benefits. In order for dealers to compete against the growing retail channel, they need to promote midrange and high-end units to their prospects. Therefore, dealers need to fully understand applications and features so that they can sell as close to list price as possible. Aftermarket revenue for fax supplies is marginal, so it becomes imperative that dealers sell at list price.

Telephone Channel

The telephony distribution channel also gained momentum during 1987. Facsimile is a communications product whose basic function is to send time-vital information over a telephone line via a modem. Key telephone system vendors that are well positioned in the marketplace have picked up fax equipment as a value-added enhancement to their product line. Their primary distribution channel, the interconnects, act in a role similar to that of office equipment dealers, except that they sell telephone systems. However, the target market is virtually the same: the small to medium-size companies in rural or suburban areas of the United States. Two RBOCs (PacTel and Northwestern Bell Phones) also view fax as a logical addition to their residential, cordless, and answering machine telephone product lines. Panasonic was the first company to fully integrate the fax machine with a telephone answering device. Although some technical problems have occurred, interconnects and telephone supply houses have been selling this model well.

Alternative Channels

Facsimile sales in the past few years have traditionally gone through two distribution channels: the vendor's direct sales force and the office equipment dealer. In 1987, Dataquest notes that the retail channel gained importance, with 6.3 percent of total placements. The retail channel consists of mass merchandisers, consumer electronics stores, department stores, warehouse clubs (i.e., Price Club), catalog houses, and phone centers (AT&T). As shown in Table 3, the definite shift from the direct to dealer sales force became noticeable during 1986 and 1987. However, the latter part of 1987 is when retailers, distributors, and interconnects began to carve away at the dealer and direct channels. Table 3 reflects this gradual shift in distribution channels for the years 1985 through 1987.

Table 3

Facsimile Distribution Channel Mix

	1985 Units	Percent	1986 Units	Percent	1987 Units	Percent
Dealer	41,050	26.1%	84,330	45.0%	244,055	58.5%
Direct	115,950	73.9%	103,170	55.0%	131,545	31.5%
Retail	N/A	N/A	N/M	N/M	28,790	6.9%
Others*	N/M	N/M	N/M	N/M	12,860	3.1%
Total	157,000	100.0%	187,500	100.0%	417,250	100.0%

*Others include telephone interconnects and Comdex dealers.
N/A = Not Applicable
N/M = Not Meaningful

Source: Dataquest
June 1988

DATAQUEST SCORECARD FOR THE U.S. FACSIMILE MARKET

Nineteen eighty-seven was a year for significant market share shifts, as reflected in Table 4 and 5, which list market shares for 1986 and 1987. Many companies that placed significantly more units in 1987 than 1986 nonetheless lost market share because they did not keep pace with the market growth rate. The numbers in Tables 4 and 5 reflect the 1986 and 1987 market share by new, end-user placements.

Table 4

1986 Estimated Market Share
(Based on End-User Placements)

Company	Rank	Placements	1986 Percent
Ricoh	1	29,500	15.7%
Canon	2	23,500	12.5
Pitney Bowes	3	22,500	12.0
Sharp	4	19,500	10.4
Fujitsu	5	13,500	7.2
Panafax	6	12,500	6.7
NEC	7	12,000	6.4
Xerox	8	11,500	6.1
Harris/3M	9	11,000	5.9
Murata	10	10,500	5.6
Telautograph	11	9,500	5.1
AT&T	12	5,000	2.7
Sanyo	13	3,000	1.6
Others		4,000	2.1
Total		187,500	100.0%

Source: Dataquest
June 1988

Table 5

1987 Estimated Market Share
(Based on End-User Placements)

Company	Rank	Placements	1987 Percent
Sharp	1	79,000	18.9%
Ricoh	2	67,000	16.1
Canon	3	48,000	11.5
Pitney Bowes	4	27,500	6.7
Fujitsu	5	24,000	5.6
Xerox	6	23,000	5.5
Harris/3M	7	22,500	5.4
Telautograph	8	16,500	4.0
Murata	9	16,000	3.8
Panafax	10	14,500	3.4
Toshiba	11	14,000	3.4
AT&T	12	11,500	2.8
NEC	13	10,000	2.4
Sanyo	14	9,000	2.2
Others		34,750	8.3
Total		417,250	100.0%

Source: Dataquest
June 1988

MARKET SHARE ANALYSIS

Prior to 1987, no dominant leader existed in the quickly evolving fax market. Consequently, 1987 saw industry participants trying to buy market share to further establish their market positions even at the risk of lower margins. Also discussed below are those participants who exceeded or lagged behind market expectations.

Sharp

Sharp climbed from fourth place in 1986 to market dominance in 1987. Sharp's clever approach to marketing and distribution, its organizational changes, and its two low-end products the FO-210 and FO-150, were their keys to success.

Marketing and Distribution

Sharp is known in the facsimile industry for its pricing aggressiveness. Its discount program for dealers is typically steeper than the industry average. In May 1987, Sharp took a strategic marketing step by developing the concept of "master" or "convenience" dealers. These 15 master dealers who were part of Sharp's authorized network were given the authority to sell any volume of its low-end units (the FO-210 and FO-150, list priced at $1,895 and $1,495, respectively) to anyone including end users and other dealers. This differs markedly from Sharp's other dealers, which can sell only to end users. These quasi "distributors" literally opened up the market and greatly fueled the price wars that developed in 1987, yet ensured Sharp's success.

Organizational Changes

In August 1987, Sharp's Personal Office and Personal Electronics Divisions were merged to form the Personal Home Office Electronics Division. This bold move by Sharp reflected its serious commitment to the growing office-at-home and small business marketplace. Dataquest believes that as the retail channel of distribution grows, Sharp's dealers will ultimately be forced to pursue the midrange and higher-end fax sales where the margins are greater, leaving the retail sector to concentrate on the low end. With the home office division in place, Sharp's Facsimile Division can more effectively promote the midrange and high-end units to its dealers, thereby increasing its proportion of midrange to high-end revenue in 1988.

Ricoh

Ricoh realized a loss in market share primarily because it did not have its low-end unit, the FAX 07 (list price $1,750), until September. Although it had an extensive network of 350 dealers, Ricoh was not well positioned for the emerging low-end market that accounted for one-third of the total placements in 1987. Most of Ricoh's business was in the midrange and high end, which were experiencing severe pricing pressures. In addition, Ricoh lacked a low-end product for most of the year, which prevented it from taking advantage of the low-end growth.

Canon

Canon, number 2 in 1986, lost market share in 1987 primarily because of one major factor. It underestimated the demand for its FaxPhone 10, a low-end product that was sold by retailers and dealers. Due to an insufficient supply of a low-end product it was unable to take advantage of the rapid market growth at the low end. However, what helped Canon maintain its foothold in this price-sensitive market was the FAX-230. This product, with a suggested list price of $2,295, but selling for less than $2,000 on the street, was offered to dealers in lieu of the FaxPhone 10, which assuaged the dealers until they could obtain more FaxPhone 10 units later in the year.

Fujitsu

Although Fujitsu lost market share, the number of units it shipped in 1987 was almost twice the number shipped in 1986. After overcoming difficulties during its acquisition of Burroughs in 1986, Fujitsu has proven to be a strong player in the major account arena and through the dealer channel. In fact, Fujitsu's nonstandard selection of dealers has helped the company's unit shipment numbers. It purposely selects successful dealers in remote regions of the United States that act in a role very similar to a manufacturer's direct sales channel. Dataquest believes that Fujitsu is well positioned as a high-end, major-account-focused company. It also offers its dealers low-end products to successfully penetrate the small and very small business establishments. We believe that Fujitsu can be the major high-end facsimile networking supplier with its dex 7800 product, as well as a market leader in the high end of the fax market.

Murata

Murata continued to persevere despite its single-product focus (facsimile only). Murata's competitors carry a broader product line, such as copiers, fax, and telecommunications equipment, thereby leveraging their brand-name recognition across multiple markets. Murata lost market share; however, the number of machines it placed in 1987 increased 52 percent over 1986. The major setback Murata experienced in 1987 occurred in June when it restructured its sales force. Murata assigned its direct representatives to train and assist dealers in an attempt to penetrate major business and government accounts. This job-function change resulted in significant turnover of its direct sales representatives. However, Murata offset this blow somewhat by introducing a much-needed low-end model, the F-20, which, at $1,695, satisfied demands from dealers for a price-competitive product.

NEC

NEC lost market share despite significant overall market growth. Although its products have been heralded as technologically superior, its marketing and distribution has held the company back. In a market where meeting demand is essential, NEC has not been able to react quickly and provide products. Some of NEC's middle-management personnel left, causing some turmoil and inconsistency in marketing tactics. NEC's dealers have not been able to compensate for this organizational turnover.

However, NEC's activity in the OEM side of the facsimile business did well in 1987. The OEM agreements that NEC signed during 1987 helped to pick up some of the sales slack that its direct and dealer organization could not offload. The two OEM agreements NEC signed were with Telautograph and PacTel Products.

Toshiba

Toshiba America fared well in 1987 despite its parent company's political problems with respect to the Soviet Union. Toshiba entered the fax marketplace in 1986 with three strong advantages:

- It had a well-known name in the telecommunications/office equipment market
- It had solid distribution channels
- It had been supplying fax products to Pitney Bowes and Telautograph, so its knowledge of the fax market was firmly entrenched

Toshiba's approach to the fax market during 1987 was to sell its midrange and high-end products (TF 221 and TF 341) through its copier dealer channel. Additionally, in January 1987, Toshiba announced the 30100, a low-end product slated for distribution through three different channels:

- Dealers—used by Toshiba's Copier Division
- Telephone interconnects—used by Toshiba's Telecommunications Division
- Retail outlets—also used by Toshiba's Telecommunications Division.

Toshiba's two-pronged sales approach and its addressing of the low-end market enabled it to grab a representative piece of the market.

DATAQUEST CONCLUSIONS

The facsimile market growth is just beginning. The installed base at the end of 1986 exceeded 500,000 units. This represents less than a 10 percent penetration rate in the business environment and even less in the home office arena. It is clear that the potential for facsimile is just being realized. However, despite the growth in 1987, some companies did not experience market momentum because they failed to understand fully what the factors for success were. Dataquest notes that, in order to succeed in the next few years, companies must invest in advertising and must offer comprehensive training and support tools, point-of-purchase displays, and 800 numbers with diagnostic centers to ensure their market positions. Additionally, marketing and distribution will continue to play a critical factor in the fax market.

Dataquest believes that 1987 was a landmark year in areas other than total placements. The dramatic market share shifts, as discussed previously, underscore both the market's volatility and its growth potential.

From a distribution perspective, companies must generate brand awareness in the retail segment to attract consumers. At the dealer level of distribution, support in the form of training, promotional literature, and incentive programs must be a standard offering to dealers. The retail channel of distribution, though small in 1987, garnered quite a bit of interest due to the surge of new players and media exposure. Dataquest does not believe retail unit placements will exceed 15 percent of total placements in 1988, but this channel has begun to redefine how the industry will have to do business. NOMDA dealers will be forced to more fully understand the features and applications of fax machines and compete on that basis rather than just price. Vendors, in many cases, will have to choose what segment of the market they want to target and position themselves accordingly. Will it be low-end units sold through retail channels, midrange and high-end units sold by dealers, or high-end, Group IV units sold by manufacturers' direct sales forces targeting the major or national accounts?

Dataquest believes that some companies have already begun to make these choices. At the low end, Brother, Northwestern Bell, PacTel Products, Panasonic, and Sharp are vying for the market share. At the midrange to high end, Canon, Fujitsu, Konica, Panafax, Toshiba, and Xerox are examples of companies competing in this predominantly dealer-driven channel. At the high end, Canon, Fujitsu, Pitney Bowes, Ricoh, and Savin are the companies specifically targeting the major or national accounts where the potential of multi-unit sales and additional placements is greater and also more profitable. Dataquest will continue to closely monitor and report on this volatile market. The watershed year that was 1987 also portends of things to come.

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David Norman
Greg Carlsted

Dataquest
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Research Newsletter

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1988–24

SEMICONDUCTOR PRICE SURVEY: SUPPLIES TIGHT, PRICES FLAT TO RISING

SUMMARY

Pricing of semiconductors during the first quarter of 1988 has ranged from the ridiculous to the sublime. The situation has ranged from a balanced supply-demand situation for many standard logic products to a very unbalanced DRAM supply crunch. The DRAM shortage has caused like-process SRAMs to be affected, as vendors convert SRAM capacity to more profitable DRAMs, reducing overall SRAM supplies. Microprocessor prices have remained flat in the face of steady demand, while supply increases of high-speed microprocessors have come on-line. This newsletter will cover highlights of the latest price survey and forecast.

STANDARD LOGIC TRENDS

Prices for standard logic products have remained relatively stable over the past three months, with lead times ranging from 6 to 12 weeks. Demand for the high-volume LS and HC families has kept prices firm, yet there is a wider spread in the price range for the LS products, reflecting a softness in this area. Lead times are between six and eight weeks for these parts. The newer ALS and AS families lead times range from 8 to 10 weeks and also reflect a firm price trend. Figure 1 compares a similar product of all four families to illustrate this trend.

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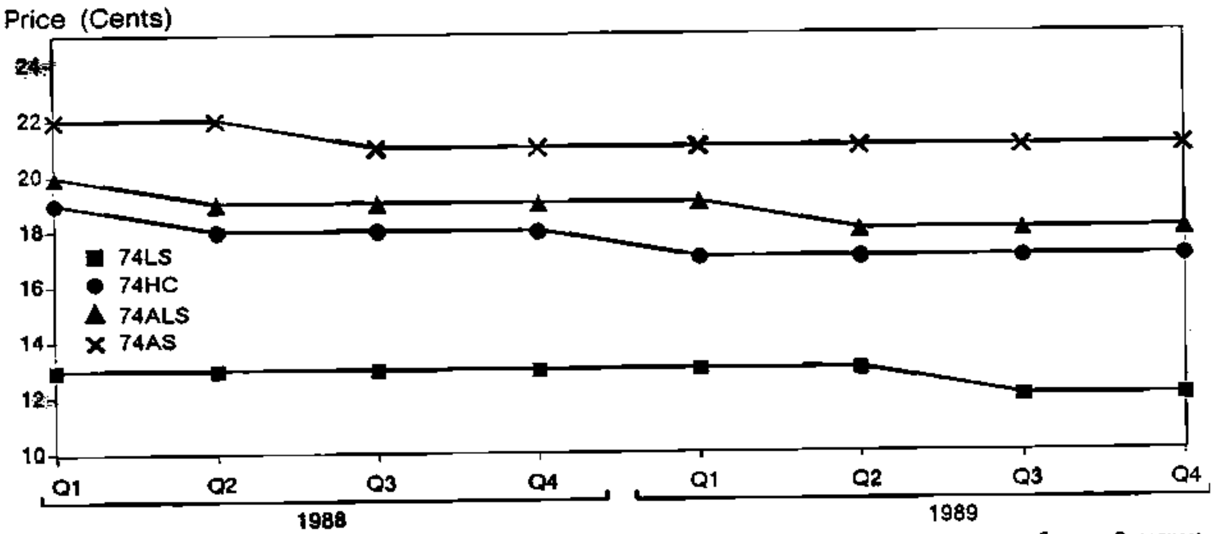
Figure 1

Standard Logic Price Trends



Source: Dataquest
June 1988

MICROPROCESSOR TRENDS

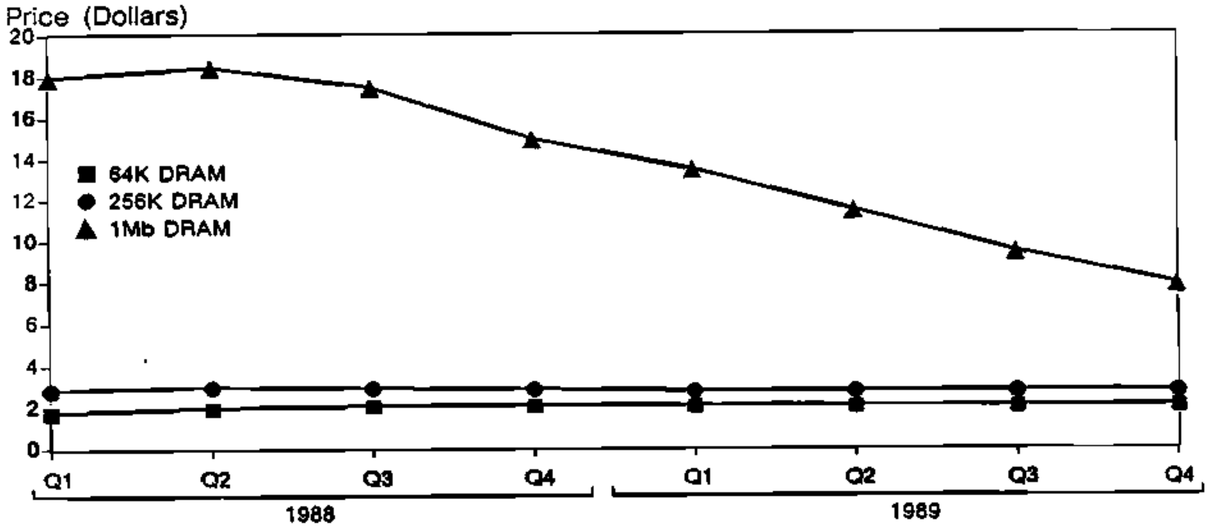
Microprocessor prices have remained steady, as the demand for 10-MHz and higher than 12-MHz, 16-bit parts has begun to increase. The demand for 32-bit microprocessors has kept prices firmer than we forecast last quarter. Strong demand for new-generation personal computers and workstations that these parts require will keep prices flat for the remainder of this year. The DRAM shortage has affected demand for microprocessors, as lower memory supplies have constrained shipments of some systems utilizing these microprocessors. Supplies for all microprocessors are expected to be adequate, as capacity put in place late last year has now come into production.

MEMORY TRENDS

The memory market is still being influenced by decisions made in the second quarter of 1987. That was when MITI resorted to production "advisories," reducing supplies and propping up prices above constructed Foreign Market Value (FMV) levels. DRAM products have been affected directly by past controls, but the scramble for capacity to meet demand has crimped video and static RAM capacities, as vendors have shifted some capacity to more profitable DRAMs. The 256K DRAM will rise slightly in price, as seen in Figure 2, then will flatten out by the end of this year, as demand shifts in response to the increasing supplies of 1Mb densities. The 1Mb parts will begin their price declines late this year, once yields and the number of large-volume competitors increase. The prices shown in Figure 2 reflect data collected in the first quarter. Due to the volatile nature of this market, overall prices for DRAMs may rise, pending the outcome of our current survey. However, the trend for the 256K and 1Mb DRAMs remains the same. Any radical departure from this trend will be analyzed in a research bulletin.

Figure 2

DRAM Price Trends



Source: Dataquest
June 1988

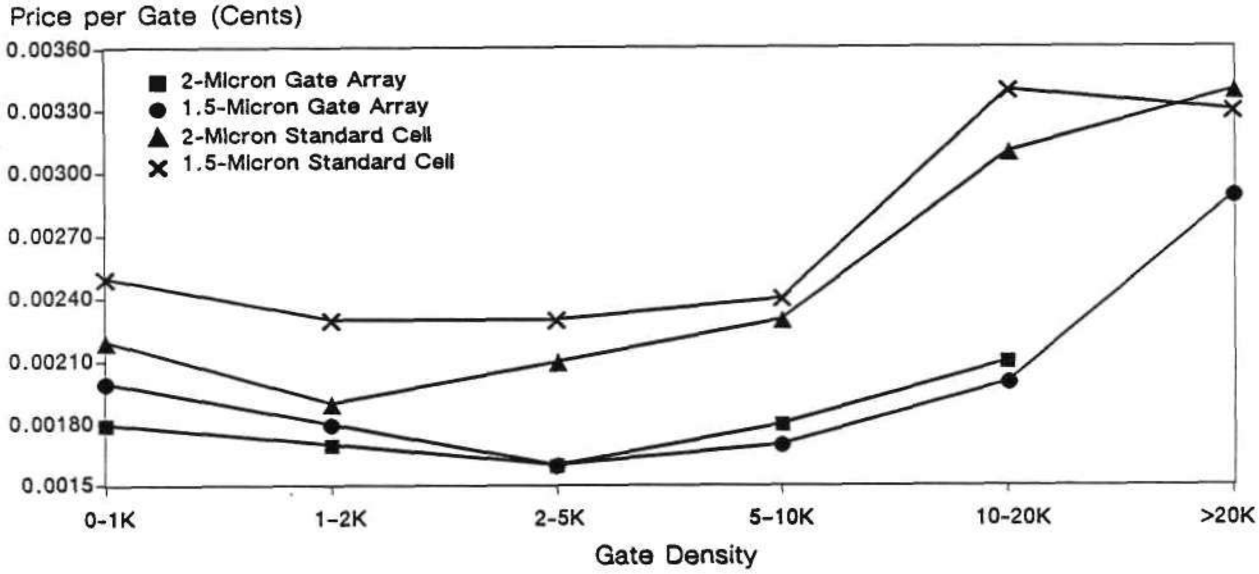
Fast static RAM prices will continue to be flat in the face of strong demand and increased competition. Low-density (lower than 16K), slow SRAMs are being phased out. Users of these older products should communicate their long-term needs to their suppliers while redesigning newer parts into their systems. EPROMs have remained comparatively plentiful in the 256K and higher densities. The reduced vendor base of sub-256K-density EPROMs has led to increases in prices and long lead times, especially for the 128K device.

ASIC TRENDS

Prices for ASIC parts have remained relatively unchanged since our last price survey. This is in response to strong demand and a shift of vendor competition to variables other than price alone. Service and availability have taken precedence as primary factors in determining the top vendors, now that prices per gate have stabilized somewhat. As seen in Figure 3, gate arrays continue to hold a price edge over cell-based designs. This is due primarily to the CAD and production work that are intrinsically more costly for these high-speed/density devices. We expect to see increased competition from Japanese vendors in the ASIC arena over the next two to five years. Although the Japanese are currently viable suppliers, improvements in Japanese software packages and design verification tools will enhance their positions in this high-growth market.

Figure 3

1988 ASIC Price Trends



Source: Dataquest
June 1988

DATAQUEST RECOMMENDATIONS

The current strong demand for electronic hardware is expected to continue through the first half of next year. Semiconductor supplies put in place to meet this demand, in aggregate, will begin to improve the current shortages by early in the fourth quarter of 1988. Overall supply is expected to be in balance with demand by mid-1989, as memory yields and volumes increase in the absence of government intervention. Semiconductor prices for the remainder of this year will remain flat for the most part, and in some cases will rise slightly (i.e., 256K DRAM, slow SRAMs, 64K/128K EPROMs). Availability of key products depends on close involvement of buyers with vendors, with each communicating accurate long-range forecasts and availability schedules, respectively.

Mark Giudici

Dataquest
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Research Newsletter

SAM Code: 1987–1988 Newsletters: April–June
1988–23

THE 3.5–INCH RIGID DISK DRIVE MARKET BLASTS OFF

SUMMARY

The last Dataquest forecast for sales of 3.5–inch rigid disk drives was made in May 1987. The results anticipated a swing toward this form factor as a result of IBM's April 1987 announcement of the PS/2 product family, but we had no idea how quickly the industry would adopt this new trend in desktop computers. Recent surveys show that worldwide total sales of 3.5–inch products increased 240 percent in 1987 over 1986. Dataquest anticipates that 3.5–inch disk drive sales will be 9.8 million units in 1988, an increase of nearly 190 percent over 1987.

This newsletter looks at the producers, their products, and the probable winners in this exciting new product opportunity.

A QUICK HISTORY

Dataquest has reviewed all of its archived documents to arrive at a clear picture of how this form factor got started. The first mention of a 3.5–inch diameter disk was presented by Sony at Dataquest's Computer Storage Industry Service conference in October 1981. The primary thrust of the paper was Sony's announcement of the 3.5–inch floppy disk drive and media, which are now the industry standards. A forecast of 3.5–inch rigid drive shipments began in 1983 and capacities ranging from 3MB to 100MB were discussed. This prediction proved to be one of the most accurate in our industry's history.

Rodime actually announced and shipped first production volumes of such a product in 1983. However, Control Data's 3.5–inch drive Cricket never saw the light of day after its 1983 announcement. It took Quantum's subsidiary, Plus Development, to make a market for these small drives.

Plus Development introduced the 10MB Hardcard in 1985 and was promptly upstaged by clever marketers like Mountain Computer, which quickly lashed a 20MB 3.5–inch drive and a Western Digital or Scientific Micro Systems IBM PC XT half–slot controller onto a frame. These drive–on–a–card (DOAC) devices were offered with twice the capacity and at lower retail prices than Plus had introduced. It took two years, but Plus persevered and now owns the DOAC market because of its continuing presence with high-performance, high-quality products.

The 1986 worldwide 3.5-inch drive sales of nearly one million units were mostly configured as DOACs, but Apple Computer's Macintosh paved the way for system utilization of the small form factor drives. Compaq found a novel way to use small drives by suspending the Rodime drive in a 5.25-inch enclosure for ruggedization. Laptop computers cried out for rigid drives but none were low enough in power consumption to preserve battery life in true portables.

IBM's April 1987 announcement of PS/2 Models 35 and 50 with 20MB 3.5-inch drives was the stamp of approval the industry needed and the race began.

DATAQUEST FORECASTS

Normally considered conservative, Dataquest estimated the demand would accelerate more slowly than it did. Since the computer industry appeared at a loss as to how to package these little drives, the June 1987 forecast would have been accurate except for IBM's PS/2 success. In fact, there is still little evidence of dealers carrying desktop computers with 3.5-inch rigid drives; a few high-end laptops and the IBM desktops are the only ones using these drives.

Miniscribe captured the worldwide resale market leadership early, and its production output will be challenged in 1988 only by IBM's Fujisawa factory, which is a captive supplier of files to IBM. JVC's low-power drive has been popular in laptops and Tandon's 3.5-inch products often find their way onto retail shelves as DOACs. Along with Plus Development, these companies were the only ones that sold reasonable quantities of 3.5-inch rigid drives in 1987.

Table 1 shows Dataquest's historical data and current forecast of total worldwide demand for 3.5-inch rigid drives of all capacities. These figures include numbers from captive producers like IBM and Olivetti.

Figure 1 illustrates unit sales through 1992 broken out by capacity ranges. The average capacity per drive will be 35MB in 1988 due to the rapid movement away from the 20 to 25MB capacities and the availability of 40MB drives from multiple vendors. The use of run-length-limited (RLL) data encoding and variable zone bit density recording techniques that increased the capacity of ST-412 MFM encoded drives led to the technology breakthroughs needed to push capacity upper boundaries to higher figures.

Dataquest's research indicates that the low-capacity, 20 to 25MB drives will dominate worldwide sales through 1989 due to their popularity in laptop computers and low-cost desktop PS/2 copies. The 31 to 100MB capacity category was pioneered by Conner Peripherals with its 40MB SCSI drives and most new entrants in the 3.5-inch market offer a 40MB file. Quantum's 80MB product will ship in quantity in 1988 but the predominant capacity will be 40MB.

Table 1

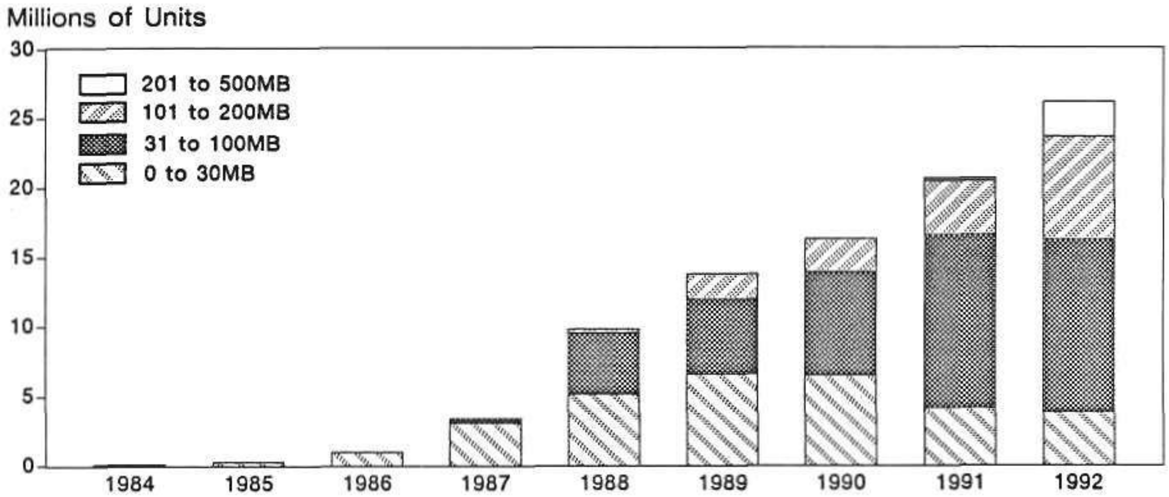
Total Worldwide 3.5-Inch Rigid Disk Drive Demand

	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	CAGR 1987-1992
New Shipments (K)	0.04	14.03	120.64	281.17	996.59	3,383.60	9,776.10	13,708.00	16,267.00	20,660.00	26,138.00	50.51%
ASP Factory ($K)	0.46	0.46	0.40	0.34	0.33	0.27	0.30	0.35	0.35	0.37	0.48	12.49%
Revenue Factory ($M)	0.02	6.45	48.34	96.19	331.85	904.73	2,892.23	4,846.96	5,668.52	7,700.20	12,590.40	69.32%
ASP End User ($K)	2.50	2.50	2.75	2.91	2.94	2.56	2.59	2.44	2.50	2.70	2.65	0.69%
Revenue End User ($M)	0.05	16.13	132.97	280.11	974.12	2,319.10	7,478.47	11,807.94	14,168.96	20,754.72	33,398.00	70.48%
Retirements (K)	0	0	0	0	0.42	2.62	47.93	142.21	259.87	479.63	821.20	215.67%
End Installed Base (K)	0.04	14.07	134.71	415.88	1,412.05	4,793.03	14,521.20	28,086.99	44,094.12	64,274.49	89,591.29	79.61%
Average MB/drive	6.10	6.10	12.08	17.11	22.10	23.79	35.31	46.52	56.26	70.76	97.77	32.67%
Cost/MB Factory ($)	75.41	75.41	33.17	20.00	15.07	11.24	8.38	7.60	6.19	5.27	4.93	(15.21%)
Cost/MB End User ($)	409.84	409.84	227.73	170.22	132.81	107.77	73.23	52.37	44.43	38.09	27.13	(24.11%)
Total GB Shipped (K)	0	0.09	1.46	4.81	22.03	80.48	345.17	637.72	915.21	1,461.86	2,555.49	99.69%

Source: Dataquest
May 1988

Figure 1

Total Worldwide 3.5-Inch Rigid Drive Demand



Source: Dataquest
May 1988

The greater than 100MB category has seen only a few sample drives shipped so far, and there may be some difficulty in finding homes for the 300,000 units forecast for 1988. This goal could become a reality, however, if Control Data and Maxtor actually start volume shipments into their OEM customer bases. We believe that 3.5-inch disk drives with greater than 200MB capacity are unlikely to show up in volume until as late as 1991, echoing the slow start of the much-heralded 760MB 5.25-inch products. By then, the demand will be in place and 1992 sales will be heavy.

QUICK SUPPLIER PROFILES

Miniscribe

As we pointed out earlier, Miniscribe has been the volume leader since 1986 and its production capacity and experience will keep it in the forefront of the resale market. Solid OEM contracts such as for the Apple Computer Macintosh SE provide Miniscribe with a stable growth plan and consistent profitability. We estimated that Miniscribe sold nearly a million 3.5-inch drives in 1987 and that it will manufacture nearly 1.5 million units in 1988.

IBM

IBM is soon to become the largest producer of 3.5-inch products. Estimates for 1987 show that Fujisawa provided 750,000 drives for use in the PS/2 Models 30 and 50. IBM sold a total of 1.2 million PS/2s in 1987, including 740,000 of the desktop models. A portion of Fujisawa's 1987 production is now showing up in the stores as part of IBM's products, and Dataquest estimates that IBM will sell 2.5 million PS/2 machines in 1988. The total output of this 3.5-inch drive factory could exceed 1.5 million units this year.

Seagate

Seagate is the sleeper in this market, and the current hot topic of conversations and rumors involves Seagate's plans and customers for its family of 3.5-inch drives. Already shipping 1,000 units per day as we entered 1988, this manufacturing powerhouse could well be nearing 2,000 units per day by now. Few outsiders have seen any of these drives, however, leading to the speculation that a good portion of them are being sold to IBM. Seagate's 1987 IBM business increased from 17 percent in the third calendar quarter to 24 percent in the fourth quarter. Development projects with Cirrus Logic, a Milpitas, California, chip designer, point to some embedded controller technology that could well be a Micro Channel interface.

Conner Peripherals

Conner Peripherals, a Seagate alumni, made a considerable splash in the 3.5-inch market during its first year of shipping. Dataquest estimates that Conner sold in excess of 250,000 40MB units in 1987. Compaq Computer took 90 percent of these drives and maintained an ownership of almost 50 percent of the company.

Conner was able to hold its average selling price at nearly $450 because of the uniqueness and reliability of its product. The 100MB Conner drive will begin volume shipments in 1988. In a recent announcement, Conner revealed a 20MB, 1-inch high 3.5-inch product with a standby 2-watt power requirement. Designed specifically for laptops, this is not a drive positioned to battle the low-cost, low-performance products. Its 27-millisecond average access time and exceptional ruggedness should make this another high-price device.

JVC

JVC's 1-inch high, low-power disk drives have long been popular in DOAC applications and, recently, in laptop computers. Conner's entrance into this market could impact JVC's position in the market.

Quantum

Quantum has entered the battle with a flurry of new 3.5-inch drives, some of which will be manufactured by Matsushita Kotobuki in Japan (the same factory where the Plus Hardcards are made). The SCSI versions of its 40 and 80MB drives were ready to ship when the announcement was made. An AT-bus interfaced version of each will be available soon. Quantum's 19-millisecond average access time coupled with 64KB of cache memory brings most file accesses down to 13 milliseconds. An attractive 50,000-hour MTBF specification and prices lower than those of Conner will likely be just the shot in the arm Quantum needs to regain its status as a premier disk drive maker. Higher-capacity products will be available late in the year.

Kalok

Kalok, a start-up in Sunnyvale, California, could actually be a survivor in this business. A family of low-cost products has been designed by the same folks that gave us the Seagate ST-225 and the Lapine Spartan, both good illustrations of low manufacturing-cost devices. Oriental Precision is building the drives in Korea and the goal of the company is to offer a 20MB file at prices below $150 in the U.S. resale market.

Other Suppliers

Control Data announced a strong series of drives at Fall Comdex 1987, but it is unlikely that the company will be able to produce production volumes in 1988. Maxtor's 170MB product has been scrapped in favor of a higher-capacity product that is likely to show up in small volumes this year. There is still no accurate word regarding a Micropolis 3.5-inch program. There are many more producers of 3.5-inch drives (34 total), each with a potential piece of this growing market.

DATAQUEST CONCLUSIONS

Fueled by IBM's rapid move toward smaller form factor products, the 3.5-inch rigid drive market is about to become the fastest rising star in the history of the storage business. As PS/2 desktop copies and look-alikes show up in the next few months, the OEM and dealer upgrade demand for small drives will increase dramatically.

Faced with a probable overcapacity in the less than-100MB rigid drive market, the smart market participants are heading for niche markets with highly reliable, very fast access, and higher-capacity drives to differentiate them from the highly price-competitive market of the 20MB to 30MB products.

The winners appear to be the U.S. companies that already have a good hold on the small rigid disk drive market. Conner Peripherals is the only real newcomer likely to be in the top five producers of 3.5-inch products in 1988.

It was only five years ago when newsletters were being published proclaiming the meteoric rise of 5.25-inch disk drives and hinting at a 3.5-inch first shipment date. Today, we are forecasting shipments of massive numbers of 3.5-inch drives and anticipating initial shipments of 2-inch products. One can only speculate about what will happen in this industry in the next five years.

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David Norman
Phil Devin

Dataquest
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Research Bulletin

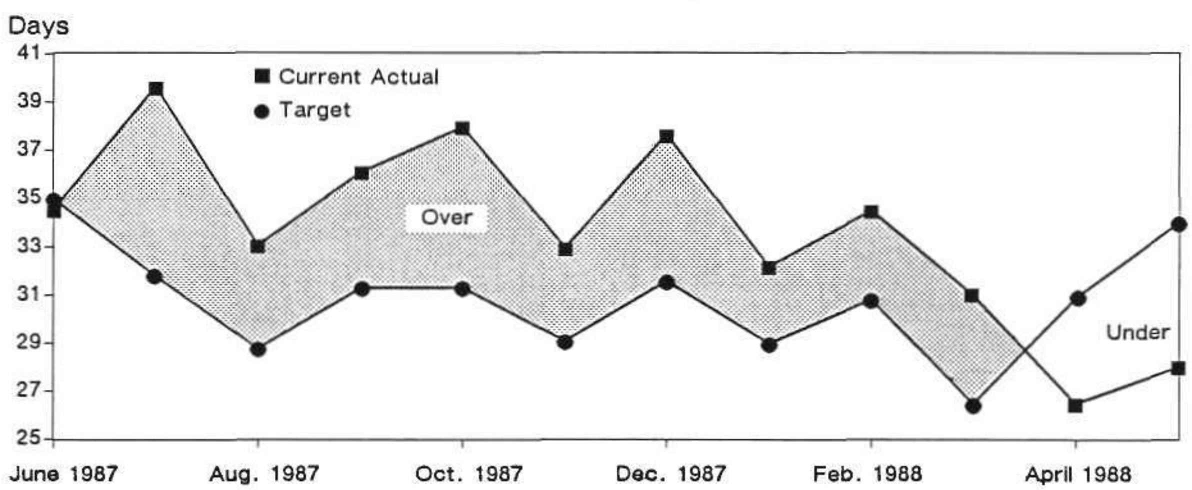
SAM Code: 1987–1988 Newsletters: April–June
1988–22

MAY PROCUREMENT SURVEY: SALES ARE UP, BUT INVENTORIES ARE MIXED

Sales of North American electronic systems are expected to continue rising throughout the month of May. Overall inventories, both targeted and actual, rose by three and two days, respectively (see Figure 1). DRAM availability has become worse since our last survey. SRAMs, video RAMs, and some discrete parts (diodes, in particular) are still in short supply and are expected to remain difficult to procure through the rest of this year. Long-term supplier agreements should straighten some of the curves in the procurement pipeline, however. The increases in inventory levels reflect shipment restraints due to DRAM shortages and the reaction of companies to increase inventories where possible to better weather upcoming shortages of raw materials.

Figure 1

Current Actual versus Target Inventory Levels (All OEMs)



Source: Dataquest
May 1988

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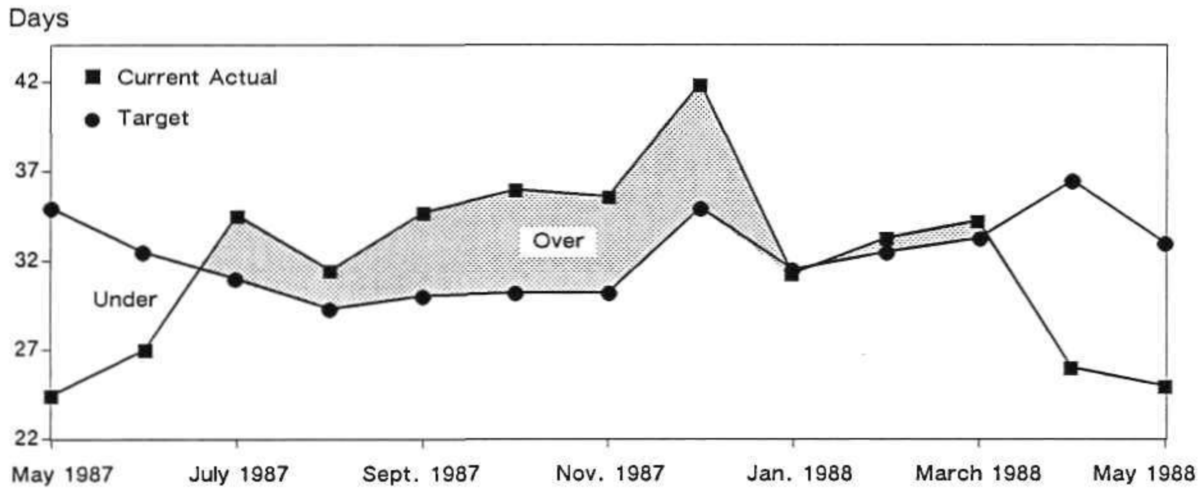
Figure 2 reflects the trend that began last month with low actual inventories in the face of component shortages for computer manufacturers. Targeted inventories also have declined somewhat since our last review.

Figure 2

Current Actual versus Target Inventory Levels (Computer OEMs)



Source: Dataquest May 1988

Overall, pricing has risen approximately 3 percent since our last survey, and lead times have remained stable. Distribution sales are expected to increase slightly in May due to shortages of key components.

Mark Giudici

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Research Newsletter

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1988–21

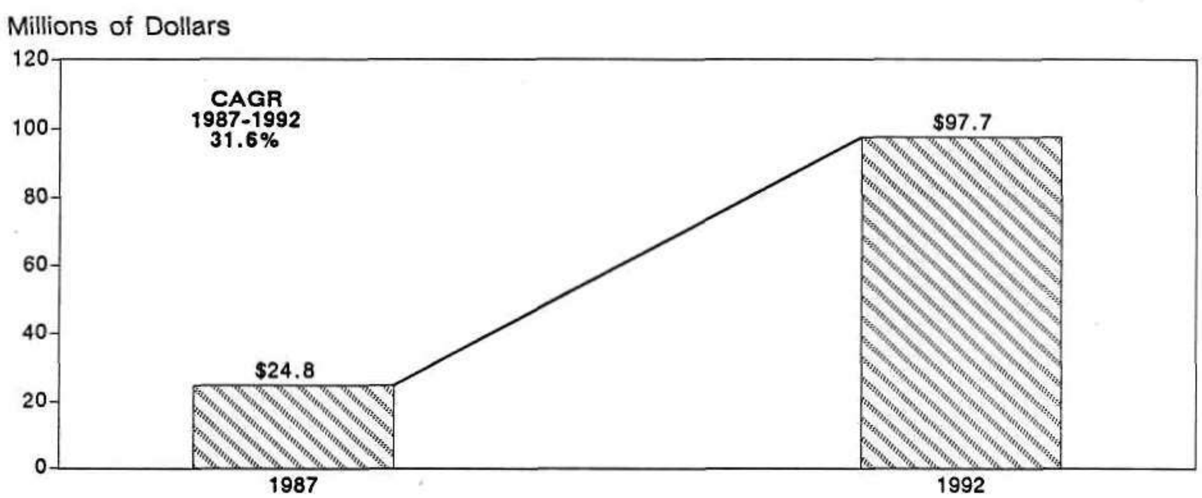
THE $100 MILLION HYBRID HEDGE IN THE INTELLIGENT POWER ARENA

SUMMARY

This third and final newsletter in Dataquest's series on intelligent power products looks at the hybrid segment. Suppliers of intelligent power hybrids should emerge as winners in this marketplace. Why? Because the history of the semiconductor industry has always been marked by user demand for high levels of performance that can only be met through hybrids. Figure 1 shows Dataquest's forecast of consumption of intelligent power hybrids as supplied by North American and European vendors. We expect the intelligent power hybrid market to approach $100 million by 1992. Thus, Dataquest foresees a profitable niche for vendors that supply intelligent power hybrids.

Figure 1

North American and European Suppliers
Intelligent Power Hybrid Revenue
1987 and 1992



Source: Dataquest
May 1988

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

Many suppliers will be competing fiercely for a share of a business that we expect to expand at a 31.6 percent compound annual growth rate during the 1987 through 1992 period.

SUPPLIERS OVERVIEW

Table 1 provides information on current and prospective suppliers of intelligent power hybrids. GE Solid State, International Rectifier, and Unitrode are among the leaders as measured in revenue in the intelligent power hybrid marketplace. IXYS, National Semiconductor, Rifa, Silicon General, and Silicon Power Cube also supply these hybrids. Siliconix and Powerex plan to enter this market.

Table 1

North American and European Suppliers*
Intelligent Power Hybrids

1987 Ranking	Supplier	1987 Revenue ($M)
1	GE Solid State	N/S
2	International Rectifier	N/S
3	Unitrode	N/S
4	Silicon General	N/S
5	Rifa	N/S
6	IXYS	N/S
7	Silicon Power Cube	N/S
8	National Semiconductor	N/S
	Total Revenue	$24.8

*Future entrants: Powerex and Siliconix
No ranking is available for Motorola and Siemens
N/S = Not Specified

Source: Dataquest
May 1988

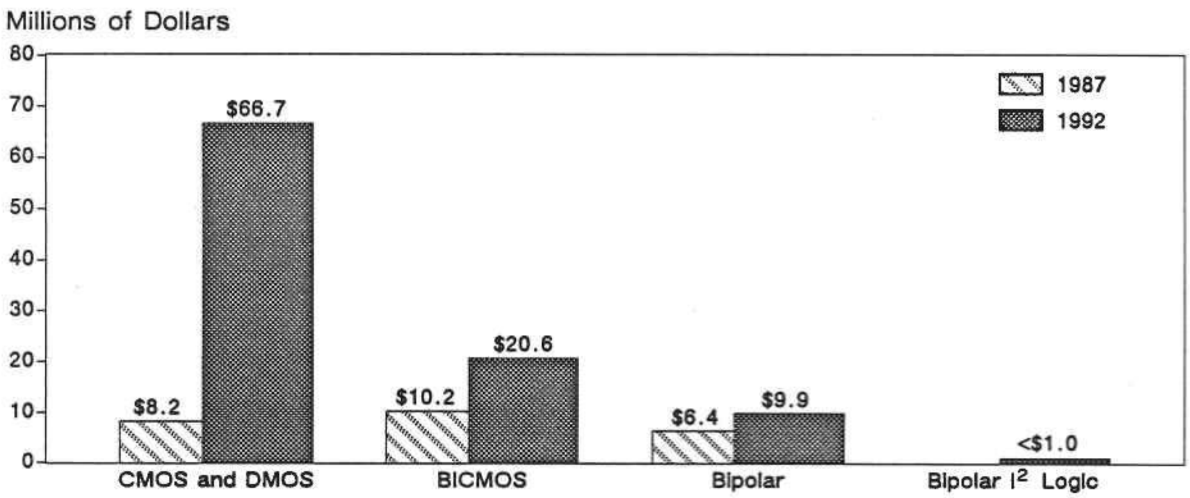
HYBRID TECHNOLOGY OVERVIEW

Figure 2 shows 1987 consumption of intelligent power hybrids by technology and illustrates Dataquest's hybrid technology forecast for 1992.

As shown in Figure 2, users can anticipate that the CMOS+DMOS approach will be a major technology of choice in the hybrid marketplace. In fact, Figure 2 reveals that intelligent power hybrids will be based on three technologies: CMOS+DMOS; BICMOS; and Bipolar. The CMOS+DMOS and BICMOS technologies should predominate in this market.

Figure 2

North American and European Suppliers Intelligent Power Hybrids by Technology 1987 and 1992



Source: Dataquest
May 1988

SEMICONDUCTOR APPLICATIONS MARKETS

Users must track suppliers of intelligent power hybrids as part of their supply base management programs. Table 2 provides information on current and prospective vendors of hybrids by the major semiconductor application markets to which they sell.

Table 2

North American and European Suppliers*
Intelligent Power Hybrids
1987 through 1992

	Semiconductor Application Market (SAM)					
1987 (Actual)	DP	Comm.	Indus.	Consumer	MIL/Aero.	Trans.
GE Solid State	O	O	C	O	O	O
International Rectifier	C	C	C	O	O	F
Unitrode	C	C	C	O	C	O
Silicon General	O	O	C	O	C	C
Rifa	O	O	C	O	O	F
IXYS	O	F	C	O	C	O
Silicon Power Cube	O	O	C	F	F	O
National Semiconductor	C	O	F	O	O	F
Powerex	F	O	F	F	F	O

*Excludes Motorola and Siemens; Siliconix also plans to supply intelligent power hybrids

C = Current supplier
F = Future entrant
O = Does not plan to supply

Source: Dataquest
May 1988

Data Processing Application

As shown in Table 2, intelligent power hybrid vendors expect industrial and military/aerospace applications to require hybrid solutions more often than other applications.

Three firms—International Rectifier, National Semiconductor, and Unitrode—supply intelligent power hybrids for use in data processing applications. We expect Powerex to enter this semiconductor application market in the future.

Hybrids produced for data processing functions will be based on the CMOS+DMOS technology and, to a lesser extent, on the bipolar approach.

Communications Applications

Two vendors—International Rectifier and Unitrode—produce intelligent power hybrids for communications applications. Users should anticipate IXYS participation in this arena.

Because of the suitability of one version of the DMOS process in high-voltage applications, users can expect that derivatives of the DMOS technology will play an important role in intelligent power hybrids geared for this market.

Industrial Application

GE Solid State, International Rectifier, IXYS, Rifa, Silicon General, Silicon Power Cube, and Unitrode supply intelligent power hybrids for use in industrial applications. National Semiconductor and Powerex are also expected to produce hybrids for the industrial community.

Hybrids produced for industrial applications will be based on all three technologies: CMOS+DMOS, BICMOS, and bipolar.

Consumer Application

No firm supplied intelligent power hybrids during 1987 for use in consumer applications. Powerex and Silicon Power Cube plan to do so in the future.

Military and Aerospace Application

Three firms—IXYS, Silicon General and Unitrode—supply intelligent power hybrids for use in military and aerospace applications. Unitrode ranks as the leading supplier to military users. Users in this arena can expect Powerex and Silicon Power Cube to enter this business.

Hybrids produced for military and aerospace applications will be based on the CMOS+DMOS and bipolar technologies.

Transportation Application

Silicon General is the only firm that supplied intelligent power hybrids to users in the transportation arena during 1987. Manufacturers of automobiles and other transportation equipment should expect additional firms to enter this business, namely, International Rectifier, National Semiconductor, and Rifa.

During 1987, hybrids for transportation equipment applications were based on the BICMOS process, with a long-term trend toward increasing use of the CMOS+DMOS technology.

HYBRIDS: A HEDGE STRATEGY FOR USERS

Systems manufacturers experience considerable risk whenever system life cycles are tied to the availability of undeveloped or unproven devices (here, power ICs). This is especially true when the number of suppliers is limited.

The intelligent power hybrid approach can be used as an alternative for getting systems into the marketplace should the IC approach prove infeasible. Even so, hybrids cost more and do not lend themselves to volume production, so the user's total system costs ultimately increase and profits decline.

DATAQUEST CONCLUSIONS

Current and prospective users and vendors of intelligent power products can look to hybrids as a hedge strategy. For North American and European suppliers, Dataquest expects the intelligent power hybrid arena to approach a $100 million business by 1992. For users, hybrids will always fill a need in systems either by user choice—given the extremely high performance requirements of systems—or by default, namely, the failure of power IC vendors to deliver. For suppliers, production of hybrids provides either a straightforward strategy—to focus on hybrids—or, given the challenge of packaging and technical constraints, a hedge strategy for responding to setbacks in the IC side of their intelligent power business.

Ronald A. Bohn

Dataquest

a company of The Dun & Bradstreet Corporation

Research Newsletter

SAM Code: 1987–1988 Newsletters: April–June
1988–20

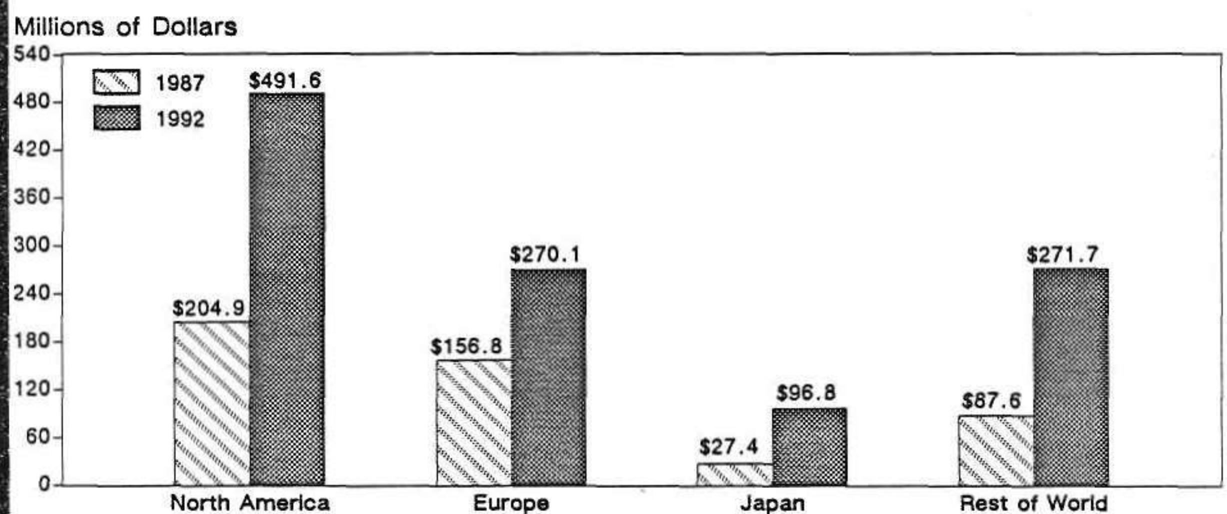
INTELLIGENT POWER SPELLS DOOM AND BOOM IN THE ELECTRONICS INDUSTRY

SUMMARY

Growth in the intelligent power marketplace means tremendous challenge and opportunity for players in the electronics industry. Figure 1 shows the dimensions of the opportunity on a global basis. This newsletter (the second in a series) examines the issue of prospective winners and losers from developments in this arena. Dataquest recommends that users migrate to the use of intelligent power products in electronic systems in order to win. Dataquest also recommends that close user-vendor relations be formed to facilitate this migration. Dataquest warns vendors of power semiconductors against underestimating the trend toward intelligent power ICS and hybrids in order to avoid losing.

Figure 1

**North American and European Suppliers
Intelligent Power Products
by Region of World**



Source: Dataquest
April 1988

WORLDWIDE CONSUMPTION OF INTELLIGENT POWER PRODUCTS

Figure 1 shows that the North American and European regions provided the lion's share of 1987 revenue for North American and European vendors of intelligent power products. Revenue from Rest of World (ROW) countries for these vendors more than tripled the amount of sales into Japan.

As revealed in Figure 1, North American and European vendors and users of intelligent power products should not expect a drastic change regarding the Japanese slice of the global pie. A focus on Japan will not be a winning strategy for most non-Japanese vendors. Sales by North American and European vendors to customers in Japan are not expected to break the $100 million barrier by 1992. Certainly, suppliers like Motorola plan to do well by selling intelligent power products that are suitable for use by Japanese manufacturers (e.g., consumer electronics); however, most of these vendors should foresee greater opportunity in North America, Europe, and the ROW countries.

LONG-TERM WINNERS AND LOSERS

Rapid expansion of the intelligent power marketplace into a $1.1 billion arena for North American and European vendors by 1992 means that there will be big winners and losers throughout the electronics industry. Dataquest expects at least three displacements to occur as this market expands between 1987 and 1992. Each displacement gives rise to sets of winners and losers.

Table 1 presents Dataquest's preliminary 1987 worldwide rankings of suppliers of linear ICs and discrete semiconductors. Succinctly, vendors of these two products stand to make the greatest gains and to risk losing the most ground from the advance in intelligent power ICs and hybrids.

Three Displacements

Electromechanical Systems Manufacturers

Manufacturers of electromechanical equipment and components stand to lose market share by the development of electronic solid-state equipment. Intelligent power products will play a key role in the acceleration of the trend toward electronic equipment and subassemblies.

Manufacturers of electromechanical equipment are likely to be hard hit by developments in three main markets: data processing (printers, disk drives, and other peripherals); industrial (solid-state motor controls and drives, switch mode power supplies, and factory automation systems); and transportation (motor control and regulation). In a related development, Japanese manufacturers of consumer electronic equipment plan to ward off Korean and other ROW competition by incorporating intelligent power products into consumer equipment ranging from household appliances to cameras.

Table 1

Preliminary Worldwide Linear and Discrete Market Share Rankings (Based on Revenue)

Linear Market 1987 Rank	Linear Market Supplier	Discrete Market 1987 Rank	Discrete Market Supplier
1	National/Fairchild	1	Motorola
2	Toshiba	2	Toshiba
3	Matsushita	3	Hitachi
4	NEC	4	NEC
5	Philips-Signetics	5	Philips-Signetics
6	Texas Instruments	6	Matsushita
7	Sanyo	7	Mitsubishi
8	Motorola	8	Rohm
9	Hitachi	9	Sanyo
10	SGS Thomson	10	Fuji Electric
11	Mitsubishi	11	SGS Thomson
12	Analog Devices	12	International Rectifier
13	Sony	13	Siemens
14	Rohm	14	Sanken
15	Harris	15	ITT
16	Fujitsu	16	GE Solid State
17	GE Solid State	17	General Instrument
18	Burr-Brown	18	Powerex
19	Siemens	19	Telefunken Electronic
20	Sanken	20	Semikron
21	New JRC	21	National/Fairchild
22	Sprague	22	Sony
23	Silicon Systems	23	Fujitsu
24	Precision Monolithics	24	Texas Instruments
25	AMD/MMI	25	KEC
26	Telefunken Electronic	26	Hewlett-Packard
27	Siliconix	27	Siliconix
28	Sharp	28	ASEA-BBC
29	ITT	29	TRW
30	Samsung	30	Unitrode
31	Linear Technology	31	Solitron
32	Mitel	32	Samsung
33	Exar/Exel	33	Ferranti
34	Plessey	34	New JRC
35	Ferranti	35	TAG
36	Fuji Electric	36	VQSI (Varo)
37	Gold Star	37	MEDL
38	Cherry Semiconductor	38	Sprague
39	Raytheon	39	Acrian
40	Unitrode	40	Raytheon
41	Oki		
42	KEC		
43	TRW		
44	General Instrument		
45	Interdesign		
46	Solitron		
47	Teledyne		
48	Seiko Epson		
49	VTC		
50	Micro Power Systems		

Source: Dataquest
April 1988

Discrete Semiconductor and Linear IC Manufacturers

Most vendors of discrete semiconductors and linear voltage regulators plan over the long term to enter or expand participation in the market for intelligent power products. Not all vendors will successfully make the migration, however. Those firms that do not weather the transition face lost market opportunities or even extinction. The first shakeout should occur by 1990.

Regarding the bipolar linear segment, the giants of the semiconductor industry, as shown in Table 1 (Motorola, National Semiconductor, and SGS-Thomson, among others), will fight a bruising battle to maintain and expand shares in a maturing marketplace. These firms face another fierce battle: The world is moving toward digital technology and away from analog technology in its pure form, as marked by the trend toward switch-mode power supplies and away from linear supplies.

Vendors of discrete semiconductors face the same intense pressure. Discrete semiconductor products, such as bipolar power transistors and power MOSFETs, are precisely the kinds of devices that intelligent power ICs intend to displace from system applications. Giants like SGS-Thomson and Motorola are everywhere in these markets—bipolar voltage regulation, power transistors, and intelligent power ICs—which creates a stiff long-term challenge for other suppliers of discrete semiconductors.

Pitfalls of Technological Nonmigration. In terms of intelligent power technologies, some vendors naturally tend to stay with the technology with which the firm is most familiar. There is a clear potential problem with the "one technology for all application markets" strategy: the technology that best serves one set of applications (for example, data processing) might be unsuitable for other applications such as industrial or transportation usages. Vendors like International Rectifier, Linear Technology, and Supertex, which plan to concentrate on one technology, run the risk of limiting future market opportunities.

Pitfalls of Technological Migration. Conversely, vendors that develop multiple technologies for a given semiconductor application market (SAM) run the risk of misallocating engineering resources. These firms could miss the mark by targeting the SAMs with the wrong technology. Broad-based vendors like SGS-Thomson, Motorola, GE Solid State and Sprague face time-critical decisions in determining which technology best serves which SAM.

Linear Power Supplies Manufacturers

A major trend in the power supply business that directly relates to the trends in equipment (from electromechanical to electronic) and semiconductors (from power discretes/bipolars to newly evolving power ICs) involves the displacement of linear power supplies in system applications with switch mode power supplies.

Specifically, many systems manufacturers keep a power supply expert on staff to interact with linear power suppliers regarding the custom design and production of power supplies. Essentially, manufacturers of data processing equipment and other electronic systems become drawn into the power supply manufacturing process. Furthermore, linear power supplies are bulky and unreliable devices vis-à-vis switch mode power supplies.

In turn, intelligent power ICs play a key role in the enhanced convenience and reliability of standard switching mode power supplies. For systems manufacturers the trend toward increasing consumption of switching mode power supplies (and intelligent power products) converts the power supply "make or buy" decision into a decision to "buy." For users, the former involved decision to "custom make" linear supplies through a so-called private-label manufacturer becomes the less-complicated decision to buy and connect them.

Linear power supplies manufacturers stand to lose as a result of the developments in the intelligent power arena.

PROSPECTIVE WINNERS

For every loser there will be a winner. Growth in the intelligent power arena, however, is more than a zero sum game. For every loser, there stands to be multiple winners, including consumers who will pay less for more efficient and convenient products. Even so, the following players stand to gain a great deal by development of the intelligent power marketplace.

Systems Manufacturers that Migrate to Solid State Electronics

Systems manufacturers that migrate to solid state electronics will be winners from the development in intelligent power products. The new systems should operate more reliably, offer more functions, use energy more efficiently, cost less to produce, conserve space, and thus remain competitive against systems from low-cost manufacturing sources.

Seagate Technology

The data processing market provides a cogent example. Seagate Technology's fortunes ride on the efficient and competitive production of computer peripherals. This equipment used to be largely electromechanical systems that incorporated a lot of discrete semiconductors and standard logic devices. Through the former Integrated Power Semiconductors (IPS), Seagate began the migration to solid state electronics. Seagate fully realizes the vital role that intelligent power products play in its current and future systems. When IPS's existence became threatened, Seagate responded by acquiring its former supplier.

Automobile manufacturers now stand where Seagate stood just a few years ago: in the process of converting from less-reliable electromechanical systems into more-reliable solid-state electronic systems. Manufacturers in the transportation Semiconductor Application Markets that make the transition to intelligent power products could zoom to technological leadership in the 1990s.

General Electric

Another way of looking at possible winners is to examine a lost past opportunity that could be converted to a future success.

General Electric (GE) has ranked among the leaders in consumer electronics equipments, including household appliances. GE also enjoyed an early leadership role in intelligent power. However, the vertically integrated supplier never fully coordinated these twin advantages. Even so, GE now stands in an excellent position to exploit the firm's long years of experience in consumer/household electronics and intelligent power.

Key to this prospect is GE's recent aggressive and successful effort to acquire Roper Corporation. In terms of intelligent power, the acquisition gives GE an expanded position in the appliance motor business including outdoor power appliances. In turn, GE Solid State could develop an outlet in the consumer application market for motor control ICs that are now being developed and targeted for industrial applications.

Vendors of Discrete Semiconductors that Migrate to Intelligent Power

All manufacturers of discrete semiconductors (see Table 1)—ranging from giants like GE Solid State, Motorola, Philips-Signetics, SGS-Thomson, and Siemens; through formidable competitors like International Rectifier, Sprague Electric, and Unitrode; to start-ups like Powerex—must make the move to intelligent power products. These firms know this reality and though disagreement exists as to the time frame for full migration—now or the early 1990s—they can read the writing on the wall. Discrete semiconductors will not disappear; however, with a few exceptions like power MOSFETs, discretes are becoming products of the past.

An emerging consensus that derives from the participants in the power semiconductor industry holds that the intelligent power leaders of tomorrow will emerge directly from the ranks of the power technology leaders of today. Undoubtedly, firms like Motorola and SGS-Thomson will be formidable competitors over the long term. Nevertheless, the marketplace remains wide open and includes room for new entrants.

Growth in intelligent power consumption represents both a challenge and an opportunity for suppliers of standard logic and application-specific integrated circuits (ASICs). The challenge: that intelligent power products will displace these logic products in selected applications. The opportunity involves a migration by vendors of standard logic and ASICs to intelligent power over the long term.

IC Vendors that Migrate to Power ICs

Many of the linear IC vendors listed in Table 1 will also win by migrating to the newly evolving segments of the intelligent power market.

Clearly, some of the winners of tomorrow will have had more experience in IC manufacturing than in discrete semiconductors. For example, the primary strength of National Semiconductor and Texas Instruments has been in ICs. Although these vendors face a stiff technical challenge, either or both could emerge as leaders in the intelligent power marketplace.

Many other firms—Cherry Semiconductor, Harris Semiconductor, IXYS, Linear Technology, Micrel, Silicon General—bring a lot to the marketplace. Rifa already wins a favorable reputation among users, although the firm is not yet well known outside of Europe. As noted, Seagate Microelectronics' future now looks favorable after its past travails.

Manufacturers of Switch Mode Power Supplies

Manufacturers of switch mode power supplies will be winners from and will contribute to the move from bipolar linear regulators to intelligent power products. One of the most likely winners will be Cherry Semiconductor, which produces both switch mode power supplies and intelligent power ICs that are incorporated into these supplies.

Manufacturers of Intelligent Power Hybrids

Producers of intelligent power hybrids should also emerge as winners in this marketplace. The prospect for vendors of intelligent power hybrids will be the topic of the third newsletter in this series.

DATAQUEST'S RECOMMENDATIONS

Dataquest makes the following recommendations to market participants that are now being affected by developments in the intelligent power market:

- Systems manufacturers must schedule now for the replacement of the electromechanical systems with electronic systems.

- Systems manufacturers should use supply base management techniques to assess the flow of products and technologies from the vendor base.

- Vendors of discrete semiconductors and bipolar power ICs must prepare for the shift by users from these mature products to newly evolving intelligent power ICs and hybrids.

- Users and vendors should remain committed to forming close long-term alliances to facilitate in tandem incorporation of intelligent power products into systems.

DATAQUEST'S CONCLUSIONS

North American and European vendors of intelligent power products should aim at local markets as well as ROW countries in their efforts to secure a share of a business that Dataquest expects to grow to $1.13 billion by 1992.

Three displacements are expected: manufacturers of electronic systems should displace producers of electromechanical systems; vendors of discrete semiconductors and bipolar power ICs are expected to lose ground to vendors of newly developing intelligent power products and technologies; and suppliers of linear power supplies face displacement by suppliers of switch mode power supplies.

A possible winning hedge strategy will be the production of intelligent power hybrids. Dataquest examines this issue in the third and final newsletter in this series.

Ronald A. Bohn

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Research *Newsletter*

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SUPPLY BASE MANAGEMENT IN ACTION

SUMMARY

This newsletter illustrates the use of supply base management as a semiconductor procurement technique in the context of a practical example—tracking developments in the 4–, 6–, and 8–bit video digital–to–analog converter (DAC) marketplace. Supply base management (defined below) offers the prospect of long–term benefits for both users and vendors of semiconductors. Dataquest recommends that semiconductor users institute a supply base management program, and points out that failure to do so can result in a host of long–term problems including costly and avoidable system redesigns.

INDUSTRY MEGATRENDS

Dataquest identifies the move by semiconductor users and their vendors toward closer partnerships as a major trend in the semiconductor industry. Strategic alliances, including those with start–ups, are corollaries to this trend. Since 1985, in fact, Dataquest has recommended that users and suppliers form these expanded relationships, and industry trends since then confirm the recommendation's validity.

SUPPLY BASE MANAGEMENT

Users are under great pressure (given the constraint of shorter system product life cycles) to more quickly and efficiently identify the best semiconductor product, vendor, and price for use in their electronic systems. A powerful tool for achieving this goal is a strong commitment by users to developing a supply base management system.

A supply base management system can be defined as any systematic approach for collecting and using information on semiconductor products, vendors, and pricing toward the goal of designing and procuring parts on a dependable, cost–effective basis. The ultimate goal of a supply base management system is the production of electronic systems that are competitive in terms of cost and performance in international markets.

The Challenge of Managing Conflicting Goals

A constant organizational challenge for users is bringing design engineers and procurement managers into agreement regarding semiconductor content for system designs and redesigns. Design engineers need to be creative and freewheeling when selecting prospective vendors—or putting them "on the board"—and in designing parts into systems. Conversely, semiconductor buyers and materials managers must be relatively aggressive in terms of taking vendors "off the board" and in keeping nonviable newer parts out of systems. Materials managers must also remove older devices from systems prior to device obsolescence through the "design-out" process.

Supply base management, which enables users to coordinate system life cycles with semiconductor life cycles, can be a practical tool for bridging the often conflicting aims of design engineers and procurement managers toward the goal of building competitive systems at competitive costs. Component engineers also play a key role in this process.

A Practical Example of Supply Base Management

The development of closer user-vendor relationships and of an effective supply base management program requires patience and persistence. Events in the video DAC world provide a practical example of the realities and benefits of this procurement strategy.

The First Issue: Product Choice

The first issue in supply base management concerns the identification of the right product. In the following example, any semiconductor product could have been used as an illustration of the system in action. In effect, the choice of product in this case (video DACs) is a given. (The third issue in supply base management—semiconductor price—is not discussed in this newsletter).

The main point of the video DAC example is that supply base management enables users to effectively track semiconductor product availability and vendor qualifications, especially in the case of start-up suppliers and second-source alliances.

The Second Issue: Vendor Qualification

By early 1986, Brooktree, a start-up firm, had emerged as a technological leader in the video DAC business. Brooktree's stature as a start-up, however, instantly generated concern in users' minds regarding the second issue in supply base management—vendor qualification. Design engineers had included Brooktree on their list of suppliers. Now, procurement managers faced the question of whether the start-up firm should remain on the board or be removed because users needed to know whether Brooktree was a viable long-term supplier. Could this start-up, in fact, fill the bill? A significant subissue centered on second sources.

The second-source issue was tentatively resolved by mid-1986 with the announcement of a second-source alliance between Brooktree and what was then the Fairchild Semiconductor Corporation. Essentially, Brooktree's technical expertise in video DACS would be buttressed by Fairchild's fab strength. Because of the alliance, then, most procurement managers made the supply base decision to keep Brooktree on the board.

Vendor Qualification Continued: Tracking the Second-Source Alliance

For semiconductor users working with Dataquest on supply base management issues since the mid-1980s, tracking the evolution of the Brooktree-Fairchild alliance has been a challenging but manageable task. For prospective users that failed to use supply base management techniques, however, the practical challenge turned into a torturous and confusing headache.

Specifically, during 1987, Fujitsu's proposed acquisition of Fairchild completely overshadowed the Brooktree-Fairchild alliance. Indeed, the controversial Fairchild-Fujitsu deal generated uncertainty in the minds of North American and Japanese users of Brooktree's video DACs as to whether the second-source arrangement would survive. During this period, Dataquest responded to a series of inquiries regarding the status and future prospects of this alliance.

National Semiconductor's ultimate acquisition of Fairchild added to the confusion. In fact, users' worst fears materialized during 1987 with the lapse of the Brooktree-Fairchild alliance as National Semiconductor absorbed the former Fairchild entity into the fold.

NEW INFORMATION ON VIDEO DACS FOR SUPPLY BASE MANAGERS

For users who are tracking suppliers of 4-, 6-, and 8-bit video DACs through a supply base management program, a constant update is required.

First, a Brooktree-National Semiconductor second-source arrangement exists regarding 4- and 8-bit video DACs. Second and separately, National Semiconductor plans to introduce a line of 6-bit video DACs by mid-1988.

For current and prospective users of video DACs, this news translates into the following supply base management information: Brooktree should remain on the board as a supplier of 4- and 8-bit video DACs, with National Semiconductor as a second source. IDT also supplies users of 8-bit devices.

Next, National Semiconductor will soon emerge as an alternative to Inmos as a supplier of 6-bit video DACs. Most of Inmos's output will flow to IBM; however, Dataquest expects other firms to enter this marketplace.

The constant flow of product and vendor information like this keeps a supply base management system operating smoothly and effectively by keeping all parties aware of the key issues.

RECOMMENDATION

To restate the recommendation that was made at the beginning of this newsletter, Dataquest strongly recommends that semiconductor users institute a supply base management program in order to efficiently track semiconductor products, vendors, and prices. Furthermore, vendors must work with users so that users can efficiently coordinate electronic system life cycles with semiconductor product life cycles.

DATAQUEST CONCLUSIONS

Supply base management benefits both users and vendors of semiconductors. For users, it converts the tension between design engineers and semiconductor buyers into a program for coordinating system product life cycles with semiconductor product life cycles. Supply base management provides users with a path not only for designing the right semiconductor product into systems at an early stage of the system life cycle, but also for choosing the right vendor and the right price. In essence, supply base management enables manufacturers of electronic systems to design and produce systems that can compete in global markets in both price and performance.

Semiconductor vendors should also benefit from users' adoption of supply base management techniques. Supply base management mandates closer user-vendor relations. For semiconductor vendors, this trend means that vendors should expect to supply a fewer number of customers over the long term. However, vendors can also anticipate that the streamlined customer base will buy larger quantities of semiconductors for a longer duration (typically, the full length of the system life cycle) from any single vendor. The upshot for semiconductor vendors is the long-term prospect of more predictable, manageable, and profitable semiconductor production that is geared for a smaller number of key accounts.

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"INTELLIGENT" ICS POWER THEIR WAY INTO $1.1 BILLION SEMICONDUCTOR APPLICATION MARKET

SUMMARY

A Dataquest survey shows that North American and European vendors, led by SGS–Thomson, garnered more than $476 million in revenue during 1987 from sales of intelligent power products. This newsletter covers major trends in this vibrant marketplace. Table 1 provides product definitions, supplier rankings, and 1987 market size. The following are highlights of this newsletter:

- We believe that a dramatic 47 percent compound annual growth rate (CAGR) in the consumption of newly evolving bipolar/MOS technologies will push the market to $1.1 billion by 1992.

- Vendors must quickly translate newly developed technologies into reliable and cost–effective products, while users must ascertain which vendors, if any, offer viable products for their systems of the 1990s.

A SERIES OF NEWSLETTERS

This newsletter is the first in a series of newsletters being prepared by Dataquest on the issue of intelligent power products. Future newsletters focus on prospective winners and losers and on intelligent power hybrids. A main point of these newsletters is that Dataquest has developed a critical mass of information and insight regarding long–term trends in the intelligent power products marketplace in terms of supplier base, technologies, and semiconductor application markets (SAMs).

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Table 1

North American and European Suppliers*
Intelligent Power Products

1987 Ranking	Supplier	1987 Revenue ($M)
1	SGS-Thomson	$150.0
2	Motorola**	114.0
3	National Semiconductor#	100.0
4	Texas Instruments	42.0
5	Sprague Electric	10.3
6	GE Solid State	10.0
7	Unitrode	9.0
8	International Rectifier	7.5
9	Seagate Microelectronics	7.0
10	Silicon General	5.6
11	Cherry Semiconductor	5.5
12	Supertex	5.0
13	Linear Technology	4.0
14	Siliconix	3.0
15	Rifa	2.9
16	IXYS	<1.0
17	Micrel	<1.0
17	Silicon Power Cube	<1.0
	Total Revenue	$476.7

*Excludes Harris, Siemens, and Japanese vendors
**Estimated
#Estimated as to bipolar voltage regulator revenue

Definitions: An intelligent power integrated circuit (power IC) is a monolithic IC that incorporates a power element (with current of 1 amp or greater or with 100 volts or more) with a control/logic circuitry elements.

An intelligent power hybrid device contains two or more semiconductors in order to incorporate a power element and control-logic circuitry element, as specified for a power IC.

Source: Dataquest
April 1988

THE SURVEY METHODOLOGY

The information in Table 1 results from a survey conducted during the first quarter of 1988. Seventeen North American and European semiconductor vendors provided detailed information. Three firms (Harris Semiconductor, Motorola, and Siemens) would not reveal complete financial information. As cited in footnotes, Dataquest developed estimates for the total revenue of Motorola and National Semiconductor, respectively. The survey did not extend to Japanese vendors. By definition, the survey excluded all discrete semiconductors.

NORTH AMERICAN AND EUROPEAN VENDORS: SUPPLIER BASE

As shown in Table 1, the North American and European supplier base for intelligent power integrated circuits (ICs) and intelligent power hybrids includes a host of familiar and unfamiliar firms. Suppliers like SGS-Thomson, Motorola, National Semiconductor, Texas Instruments, GE Solid State (which includes the former GE Semiconductor, RCA, and Intersil), and Siemens rank as giants in the global semiconductor industry. Producers such as Harris Semiconductor, International Rectifier, Siliconix, Sprague Electric Company, and Unitrode are well recognized as manufacturers of linear ICs and/or power semiconductors.

The following vendors aim to win a share in the intelligent power marketplace: Seagate Microelectronics (formerly Integrated Power Semiconductor), Silicon General, Cherry Semiconductor, Supertex, Linear Technology, and Rifa. At least three of the newer firms—IXYS, Micrel, and Silicon Power Cube—seek a share of the business. In addition, Dataquest expects other suppliers, such as Powerex, to enter the marketplace.

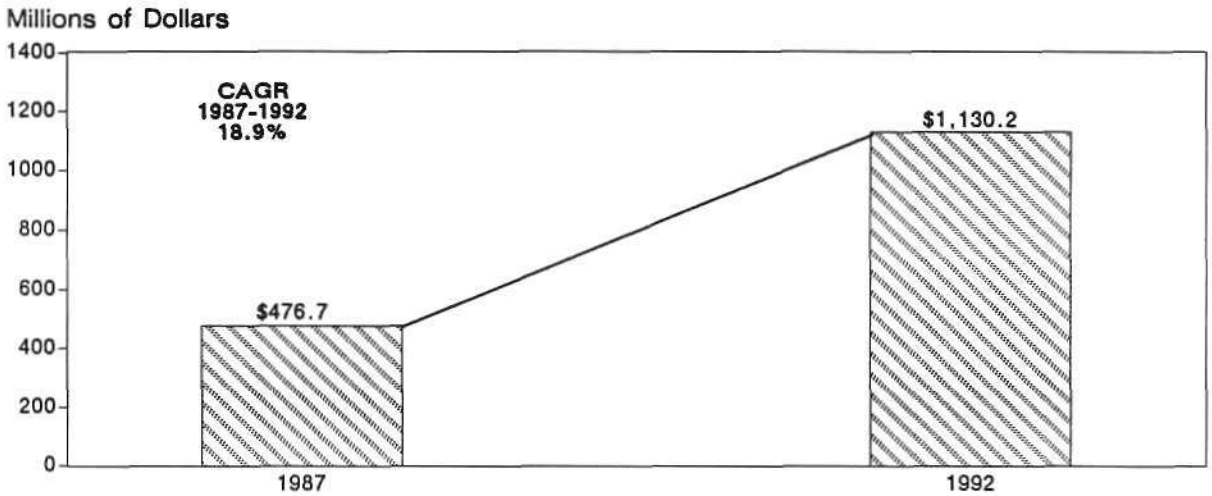
$1.1 Billion Marketplace by 1992

Figure 1 presents Dataquest's forecast for growth in intelligent power product consumption.

As shown in Figure 1, vendors should expect users' consumption of intelligent power products to expand at a healthy 18.9 percent compound CAGR during this period. Demand from users in the data processing, industrial, and transportation application markets drives growth.

Figure 1

1987 and 1992 Intelligent Power Product Revenue



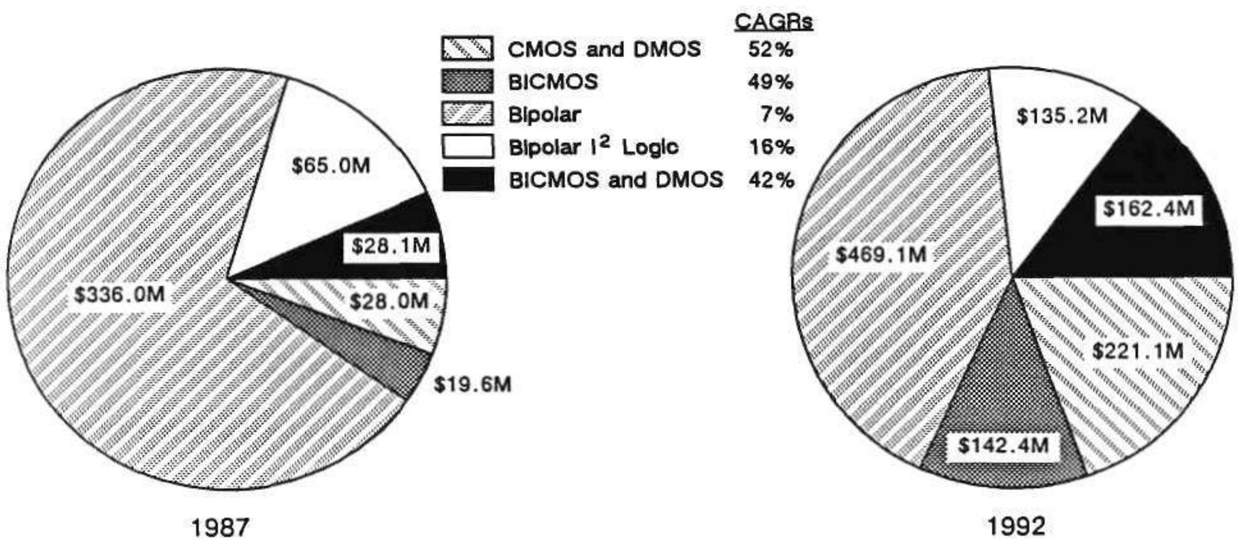
Source: Dataquest
April 1988

The Trends by Technology

Figure 2 presents Dataquest's 1987 through 1992 forecast for growth by technology in this marketplace. The figure clearly reflects the predominant trend in terms of intelligent power technologies: a shift from pure bipolar technology to mixed bipolar-MOS or mixed MOS technologies.

Figure 2

1987 and 1992 Intelligent Power Technologies (Millions of Dollars)



Note: CAGR covers 1987 through 1992.

Source: Dataquest
April 1988

The Mature Bipolar Technology

Table 2 provides information on suppliers of pure bipolar devices. As noted in Figure 2, the bipolar technology segment accounted for $336 million in revenue during 1987, with growth expected at a CAGR of 7 percent from 1987 through 1992.

For users, many of these firms listed in Table 2 are quite familiar, because voltage regulators that draw more than 1 amp of current meet the definition of a power IC. Table 2 shows that several smaller firms--Cherry Semiconductor, Linear Technology, Rifa, Seagate Microelectronics, Silicon General, Harris Semiconductor, and Silicon Power Cube--also have stakes in this segment.

Table 2

North American and European Suppliers
Bipolar-Technology Intelligent Power Products

1987 Ranking	Supplier	1987 Revenue
1	SGS-Thomson	N/S
2	Motorola*	N/S
3	National Semiconductor*	N/S
4	Texas Instruments	N/S
5	Unitrode	N/S
6	Seagate Microelectronics	N/S
7	Cherry Semiconductor	N/S
8	Silicon General	N/S
9	Sprague Electric	N/S
10	Linear Technology	N/S
11	Rifa	N/S
12	Silicon Power Cube	N/S
	Total Revenue	$336

N/S = Not Specified
*Estimated ranking
Note: Harris and Siemens also produce these devices.

Source: Dataquest
April 1988

The Newly Evolving Technologies

Table 3 provides information on suppliers whose product portfolios include devices that are based on the newly evolving technologies (BICMOS, CMOS+DMOS, BICMOS+DMOS).

Users should anticipate that one or more of the technological leaders of tomorrow will emerge from the ranks of these suppliers listed in Table 3. By 1992, these technologies should represent a $525 million marketplace (47 percent CAGR).

Table 3

North American and European Suppliers*
Intelligent Power Products
1987 through 1992

	Technology			
Supplier	CMOS +DMOS	BICMOS	Bipolar I^2Logic	BICMOS +DMOS**
SGS-Thomson	F	F	C	C
National Semiconductor	F	O	O	O
Texas Instruments	F	F	O	O
Sprague Electric	F	O	O	C
GE Solid State	F	C	O	F
Unitrode	F	O	O	F
International Rectifier	C	O	O	O
Seagate Microelectronics	O	F	F	O
Silicon General	O	F	O	O
Cherry Semiconductor	F	O	F	O
Supertex	C	O	O	O
Linear Technology	O	O	O	O
Siliconix	C	O	O	C
Rifa	C	F	O	O
IXYS	C	F	O	O
Micrel	C	O	O	C
Silicon Power Cube	F	O	O	O
Harris	O	O	O	O
Powerex	F	F	O	O

*Excludes Motorola and Siemens
**See Table 2 regarding bipolar products. BICMOS+DMOS includes Bipolar-MOS and Bipolar+DMOS.
C = Current supplier
F = Future entrant
O = Does not plan to supply

Source: Dataquest
April 1988

CMOS+DMOS Technology

International Rectifier, Siliconix, and Supertex are establishing leadership positions in the CM0S+DMOS technology area. As depicted in Figure 2, consumption of intelligent power products based on the newly developed CMOS+DMOS technology is expected to expand into a $221 million marketplace at a 52 percent CAGR from 1987 through 1992.

Users should closely track the performance of Rifa, IXYS, and Micrel, because these firms could emerge as significant players in the CM0S+DMOS arena. The following vendors plan to migrate to this segment: Cherry Semiconductor, GE Solid State, National Semiconductor, Powerex, SGS-Thomson, Sprague Electric, Texas Instruments, and Unitrode.

BICMOS Technology

As depicted in Figure 2, the BICMOS segment is expected to expand at a 49 percent CAGR into a $142 million marketplace by 1992.

Table 3 reveals that GE Solid State supplies intelligent power products that are based on the BICMOS process technology. (Motorola also targets BICMOS as a key technology in its product portfolio.) Users can expect the following vendors to migrate to the BICMOS technology: IXYS, Powerex, Rifa, Seagate Microelectronics, SGS-Thomson, Silicon General, and Texas Instruments. Users can also look to GE Solid State and Powerex (and to a lesser extent, Rifa) as suppliers of BICMOS intelligent power hybrids.

BICMOS+DMOS Technology

As shown in Figure 2, consumption of intelligent power products that utilize the newly developing BICMOS+DMOS technology should grow at a 42 percent CAGR into a $162.4 million segment by 1992.

Table 3 shows that SGS-Thomson, Siliconix, and Sprague Electric Company are advancing to leadership positions in this marketplace. Micrel's ASIC product portfolio includes the BICMOS+DMOS technology. Users can also expect GE Solid State and Unitrode to enter this segment.

THE FUNDAMENTAL FORCE DRIVING GROWTH

The need for systems manufacturers to replace systems' electromechanical assemblies with electronic circuity is the fundamental force driving long-term growth. The incorporation of intelligent power products into users' systems should translate into enhanced reliability, greater functionality, new applications, space savings, efficient energy management, and reduced system-production costs.

Overcoming Barriers to Growth

Nevertheless, formidable barriers threaten to stall progress in this business. Vendors of intelligent power products face an engineering challenge in terms of building bridges between technologies. Similarly, a tremendous challenge remains in terms of packaging technologies. Vendors also confront a stiff challenge in accommodating users. A predominant trend in the global semiconductor industry is toward closer user-vendor relationships. Consequently, users are becoming more dependent on (and demanding of) the streamlined supplier base.

Given two specific forces—namely, vendors' high costs of developing intelligent power ICs and users' aims of streamlining the supplier base—strategic alliances have evolved as a major vehicle in the business.

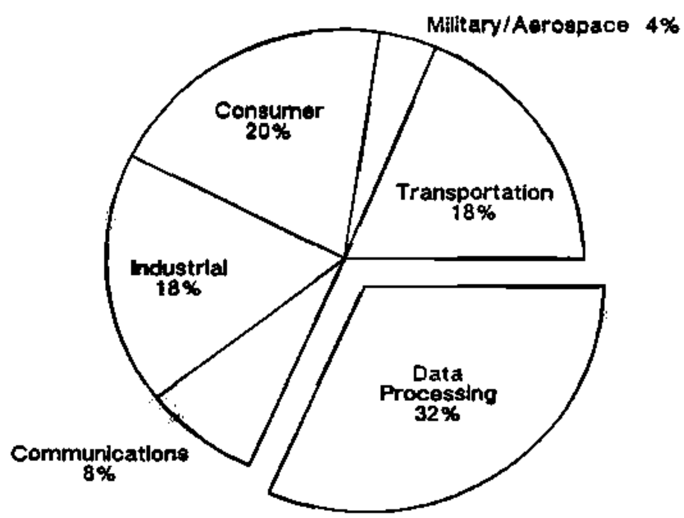
Perhaps the greatest barrier to growth in this marketplace could be a basic failure of vendors and users to communicate. Vendors must communicate to prospective users the potential benefits of intelligent power products. On the user side, system design engineers must work closely with procurement managers and vendors in assessing the relative benefits, costs, and applications of intelligent power products.

THE USER BASE: THE WORLDWIDE SEMICONDUCTOR APPLICATION MARKETS

As shown in Figure 3, data processing ranked as the leading SAM for intelligent power products (32 percent share) during 1987.

Figure 3

Intelligent Power Products by Semiconductor Application Market (Millions of Dollars)



Source: Dataquest
April 1988

Figure 3 shows that other leading application markets during 1987 were consumer (20 percent), transportation (18 percent), and industrial (18 percent). The communications and military/aerospace markets are just starting to use intelligent power products.

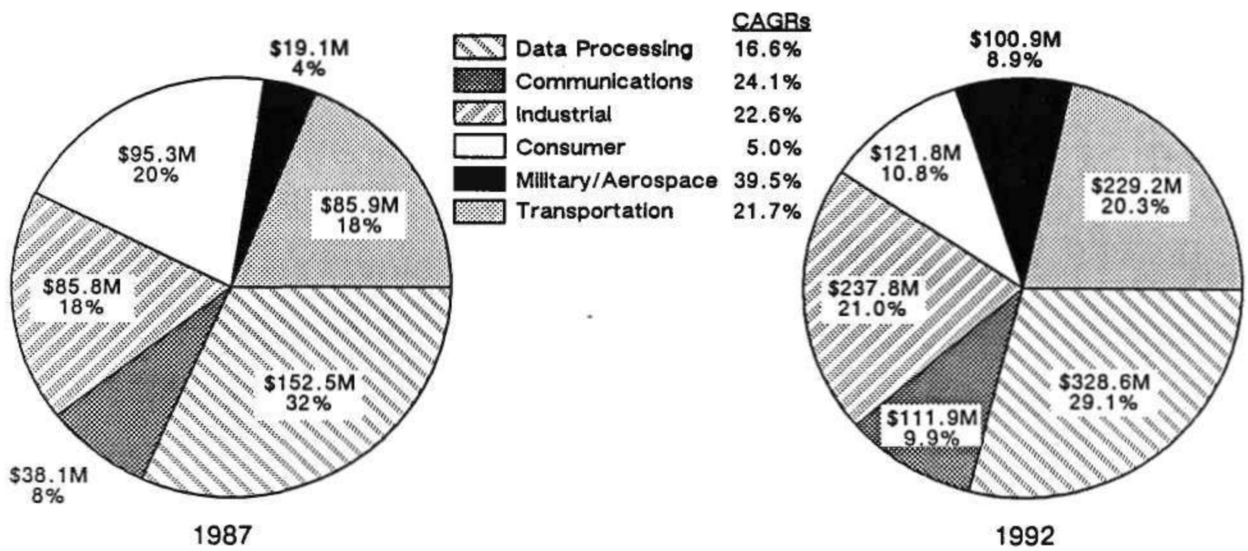
Figure 4 depicts the anticipated rate of growth in consumption of intelligent power products by SAM from 1987 through 1992.

As shown in Figure 4, data processing should remain the largest SAM ($328.6 million by 1992); however, other SAMs are expected to increase consumption of power products at faster rates.

Along with data processing applications (16.6 percent CAGR for an already big segment), the industrial and transportation SAMs should drive the intelligent power marketplace during the 1987 to 1992 time frame, to exploding into $200 million-plus segments by 1992.

Figure 4

1987 and 1992 Growth in Intelligent Power Products by Semiconductor Application Market



Note: CAGR covers 1987 through 1992.

Source: Dataquest April 1988

The Semiconductor Application Markets by Technology

A critical but unresolved issue concerns which technology or technologies will prove most suitable for which applications. As a "sanity check" on the future flow of intelligent power products by technology into the six SAMs, the Dataquest survey asked responding vendors the following question regarding actual 1987 revenue and anticipated 1992 sales:

> "To which semiconductor application market did your company sell the most CMOS+DMOS-based, BICMOS-based, Bipolar-based, Bipolar I^2 Logic-based, and BICMOS+DMOS-based intelligent power products?"

Table 4 presents the results.

As shown in Table 4, manufacturers of data processing equipment should expect vendors of intelligent power products to use at least five technologies over the long term in an effort to serve users' needs in computer and related applications. Two technologies are expected to flow to the industrial SAM, while three technologies should meet the needs of users in the other SAMs.

Table 4

Vendors' Estimate of Leading Intelligent Power Technology by SAM

	Semiconductor Application Market (SAM)					
1987 (Actual)	DP	Comm.	Indus.	Consumer	MIL/Aero.	Trans.
CMOS+DMOS	3	0	2	0	2.0	0
BICMOS	0	0	2	0	0.5	0.5
Bipolar	3	1	0	1	0	4.0
Bipolar I^2 Logic	1	0	0	0	0	0
BICMOS+DMOS	1	0	0	0	0	0

	Semiconductor Application Market (SAM)					
1992 (Expected)	DP	Comm.	Indus.	Consumer	MIL/Aero.	Trans.
CMOS+DMOS	4	1	3.5	0.5	0.5	4.5
BICMOS	1	1	2.0	0	0.5	2.5
Bipolar	2	1	0	1.0	0.5	4.5
Bipolar I^2 Logic	2	0	0	1.0	0	0
BICMOS+DMOS	4	0	0	0	0	0

Note: Several firms did not respond to this question. Some firms specified two leading SAMs for a few technologies.

Source: Dataquest
April 1988

The Semiconductor Application Markets by Supplier

Table 5 shows prospective users of intelligent power products that vendors are serving or expect to serve in the six semiconductor application markets (as reported to Dataquest by survey respondents).

Table 5 tells users that numerous firms plan to enter or expand their roles in the intelligent power business over the long term. Table 4 signals the shift by suppliers from the pure bipolar technology to the mixed bipolar/MOS technologies, while Table 5 shows the anticipated move by suppliers to the transportation SAM (seven new entrants expected), consumer SAM (six entrants), and other SAMs (five to six entrants) over the long term.

Users should expect suppliers that serve data processing applications to expand their reliance on the CMOS+DMOS technology over the long term. The "dielectrically isolated" bipolar process technology should find use in high-voltage communications applications. Another approach for communications applications will be hybrid circuits based on the CMOS+DMOS technology.

Users in the industrial SAM can anticipate that suppliers will base intelligent power products for this SAM on the CMOS+DMOS or the BICMOS technology. Users should expect the bipolar technology to continue as the technology of choice in consumer electronics applications. As shown in Table 4, users of intelligent power products in the military and aerospace arena can expect devices based on either the CMOS+DMOS technology or the BICMOS process from suppliers specified in Table 5.

Users in the transportation equipment marketplace should expect the newly developed technologies (CMOS+DMOS and BICMOS), along with bipolar products, to flow their way over the long term.

Table 5

Suppliers of Intelligent Power Products by Semiconductor Application Market 1987 through 1992

	Semiconductor Application Market (SAM)					
	DP	Comm.	Indus.	Consumer	MIL/Aero.	Trans.
SGS-Thomson	C	C	C	C	C	C
National Semiconductor	C	O	F	F	O	F
Texas Instruments	C	C	C	C	C	C
Sprague Electric	C	C	C	C	C	C
GE Solid State	F	F	C	F	F	O
Unitrode	C	C	C	C	C	F
International Rectifier	C	C	C	F	F	F
Seagate	C	O	O	O	O	O
Silicon General	O	O	C	O	C	C
Cherry Semiconductor	C	F	C	O	O	C
Supertex	C	C	C	C	C	O
Linear Technology	C	C	C	O	C	C
Siliconix	C	C	C	O	C	C
Rifa	C	O	C	O	O	F
IXYS	F	F	C	F	C	F
Micrel	F	F	F	O	C	F
Silicon Power Cube	O	O	C	F	F	O
Harris	F	C	F	O	F	F
Powerex	F	F	F	F	F	O

Note: Excludes Motorola and Siemens data. National Semiconductor's 1987 presence in these SAMs is per bipolar voltage regulators.
C = Current supplier
F = Future entrant
O = Does not plan to supply

Source: Dataquest
April 1988

DATAQUEST CONCLUSIONS

The intelligent power marketplace is a large business for North American and European vendors—$476 million in revenue during 1987—with several segments poised to push total revenue to $1.13 billion by 1992. The newly evolving technologies (CMOS+DMOS, BICMOS, and BICMOS+DMOS) are expected to generate rapid rates of growth (47 percent CAGR) during the 1987 to 1992 period. By SAM, data processing leads the way and continues as the largest segment over the long term; however, the industrial and transportation SAMs are also expected to boom during the 1987 to 1992 time frame.

As noted at the outset, this newsletter is the first in a series of Dataquest newsletters on the vital topic of intelligent power. This newsletter lays out the critical mass of 1987 historical and 1992 forecast information regarding supplier base, technologies, and SAMs. The next newsletter examines the prospective winners and losers from developments in the intelligent power arena. The newsletter includes specific Dataquest recommendations on the strategic response for prospective and current users and vendors of intelligent power products. The third newsletter looks at the vendors that view intelligent power hybrids as a possible winning strategy.

Ronald A. Bohn

Dataquest
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Research *Bulletin*

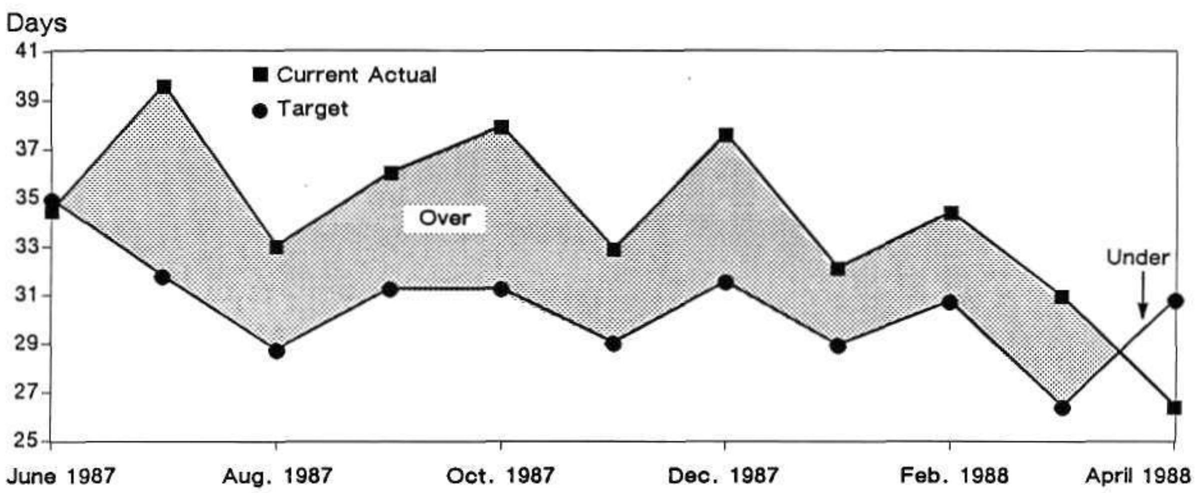
SAM Code: 1987–1988 Newsletters: April–June
1988–17

APRIL PROCUREMENT SURVEY: INVENTORIES DROP AS EQUIPMENT SALES RISE

North American electronic systems manufacturers expect rising sales during April, which should eat into current component inventories. DRAMs remain on allocation, and users report difficulty in obtaining other semiconductor products like SRAM, video RAM, linear ICs, discrete semiconductors, and optoelectronic devices. As shown in Figure 1, actual inventory levels are at their lowest level since we began this procurement survey. Figure 1 shows that manufacturers want to maintain or even increase inventory levels in order to meet projected high-growth rates.

Figure 1

Current Actual versus Target Inventory Levels (All OEMs)



Source: Dataquest
April 1988

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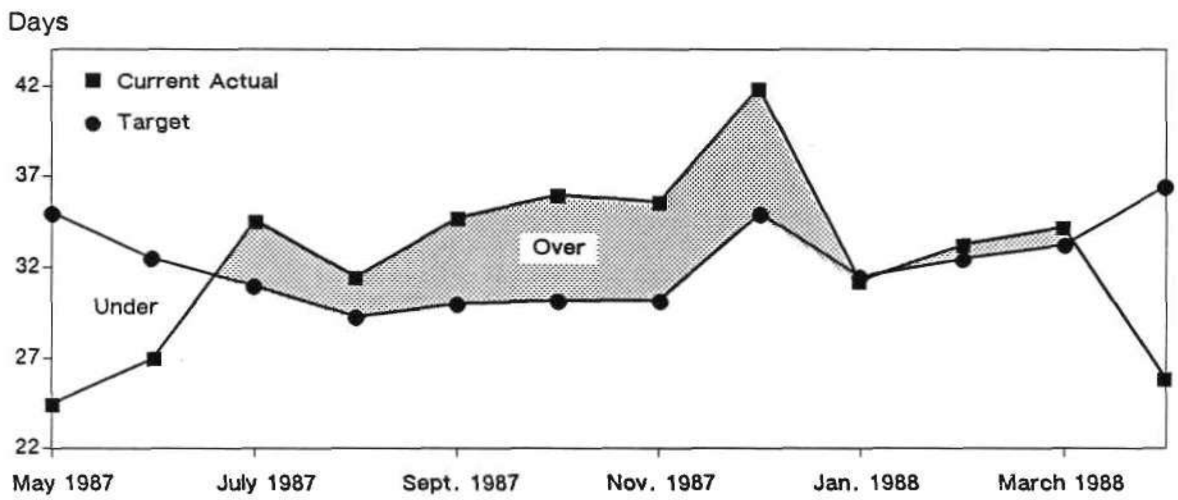
Figure 2 reveals that the same trends in actual and target inventories hold true in the computer OEM market. Indeed, actual inventories of computer OEMs fell to 26.0 weeks versus 26.5 weeks for all OEMs. Computer OEMs target 36.5-week inventory levels whereas all electronic OEMs aim at a 30.9-week level, a considerable difference.

Figure 2

Current Actual versus Target Inventory Levels (Computer OEMs)



Source: Dataquest April 1988

Overall, pricing has been stable and has firmed slightly upward. No changes are expected in terms of sales to OEMs from distribution.

DATAQUEST CONCLUSIONS

OEMs must make sure to not over order during this boom period. The greatest threat to market prosperity at this time would be poorly synchronized supply and demand.

Ronald A. Bohn
Gregory L. Sheppard

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Research Newsletter

SAM Code: 1987-1988 Newsletters: April-June
1988-16

U.S. MANUFACTURING AUTOMATION: DISAPPOINTING IN 1987, UPTURN PREDICTED IN 1988

SUMMARY

How did the manufacturing automation industry in the United States perform in 1987? What factors contributed most to this performance? And how will current trends influence the future of this complex, growing industry?

This newsletter reviews the U.S. manufacturing automation industry in 1987 and previews future directions. It covers the following subjects:

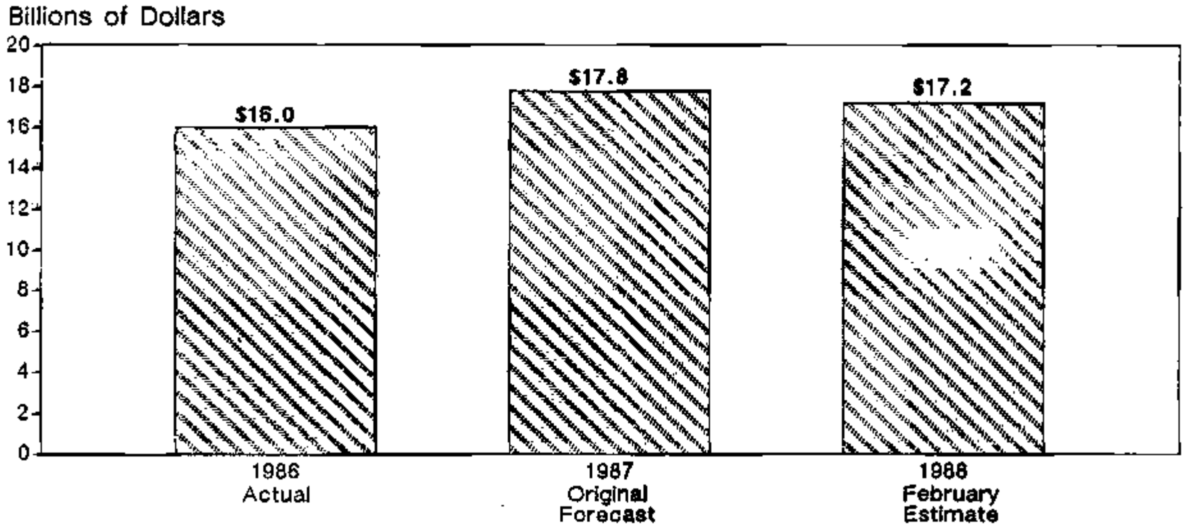
- A comparison of Dataquest's original forecast for 1987 with our current preliminary estimate of industry performance
- A recap of important events—both positive and negative
- An assessment of vendor performance—the current market share leaders, and companies that exhibited the largest market share gains and losses
- An analysis of major industry trends and how they influence future directions
- Dataquest's preliminary forecast for 1988 through 1992

1987 INDUSTRY PERFORMANCE

For the first three quarters of 1987, manufacturing automation industry revenue grew more slowly than expected. Business picked up significantly in the fourth quarter, largely due to an increase in exports by U.S. companies. Fourth quarter revenue contributed greatly to total 1987 revenue—but not enough to reach Dataquest's earlier forecast of 11.3 percent growth to $17.8 billion. As Figure 1 illustrates, we believe that the 1987 revenue total was closer to $17.2 billion—only 8 percent growth over 1986 revenue of $16.0 billion. This is a preliminary estimate based on ongoing research throughout the year; Dataquest will publish the final 1987 revenue estimates and forecast in mid-1988.

Figure 1

Forecast Update: U.S. Manufacturing Automation Industry (Billions of Dollars)



Source: Dataquest April 1988

Dataquest defines manufacturing automation as comprising specific industry segments, which are included in Dataquest's estimates of market size. These segments are as follows:

- Information systems
  - Computer hardware
  - Manufacturing software
  - Manufacturing networks
- Manufacturing systems
  - Automated material handling equipment
  - Electronic automatic test equipment
  - Factory data collection
  - Machine vision and industrial sensors
  - Mechanical inspection and test equipment
  - Process control systems

- Programmable machine tools
- Robotics
- Special manufacturing machinery

1987 EVENTS

The past year had its share of surprises, both positive and negative. Major positive events include:

- The awareness of and focus on automation as a key to manufacturing competitiveness grew.
- Manufacturing application software experienced healthy growth.
- Digital Equipment Corporation had an increase in market share.
- U.S. manufacturing firms had record-breaking productivity.

Negative developments include:

- The overall growth rate was slower than expected.
- General Motors' cutback in capital investment continued its negative impact.
- The development of Manufacturing Automation Protocol (MAP) faced more haggling by participating companies.

In 1987, both the trade and business press focused on automation as critical to the ability of U.S. manufacturing companies to regain their competitiveness in the world market. This attention to manufacturing competitiveness is largely a result of the growing concern over the worst trade deficit in the history of the United States—$170 billion, 80 percent of which is manufactured goods that we buy overseas for the quality and price advantages they offer. The need for U.S. companies to improve manufactured goods so that they are competitive in a world market has attracted enough attention to become a political campaign issue in 1988.

The ongoing publicity both mirrors and creates the awareness that automation has important benefits, and has contributed to the growing interest and inquiries concerning automation projects by new companies, including small and medium-size manufacturers. This interest has not yet led to sales, so the overall growth rate for automation sales in 1987 was slower than expected. Manufacturing application software is the area that has showed the most growth.

Growth in the U.S. automation market has been slowed by several factors. One major factor is that companies cut back their 1987 capital spending for plants and equipment, of which manufacturing automation is a subset. General Motors reduced its 1987 capital expenditures from a planned $9.6 billion down to $7.9 billion (approximately 17 percent). This caused other manufacturers in general industry to reexamine their strategies for automation—and frequently companies require little incentive to postpone projects that involve spending money and taking the risks associated with innovation.

Two other factors that contributed to the slowing growth in manufacturing automation are worth separate mention. One is the penetration of the U.S. market by non-U.S. machinery imports. U.S. buyers turned to European and Japanese imports for their superior quality and functionality, lower prices, better service, and faster delivery.

The second factor is a spirit of controversy in the development of MAP standards, which has slowed the progress of MAP's adoption in the United States. The committee of about 700 users is finding the road to agreement a slow one. In fact, Dataquest believes that European companies are implementing MAP more readily than in the United States. European manufacturers are motivated by cost reductions to automate and network their machinery using MAP. The primary reason is that the declining value of the U.S. dollar forces the prices of non-U.S. products to rise. Many European companies use a strategy of dropping their product prices to remain competitive in the U.S. market. Some companies see automation as the means to new manufacturing cost efficiencies to achieve their targeted product prices and profit margins.

The predominant area of healthy growth is in manufacturing applications software. This includes software used for factory floor control, maintenance packages, and especially for applying artificial intelligence (AI) and expert systems to solve manufacturing problems. Digital Equipment alone has 7,000 expert systems installations in its own and its customers' factories.

Digital Equipment Corporation rose to the forefront of manufacturing automation in 1987. Dataquest believes that it gained market share partly at the expense of IBM Corporation. Digital achieved much of its growth through penetration of the international marketplace, with half its 1987 sales coming from outside the United States. This figure is up from its previous 38 percent of sales attributed to international markets. DECWorld, Digital's exposition in Boston, was well-attended and enthusiastically received. Digital showed working applications, simulating the operations of fully integrated corporations. Theory was put into practice by networking Digital computers with products from numerous systems integrators using third-party application software. DECWorld illustrated Digital's capability for installing fully networked systems today.

Finally, 1987 was the year of a record-breaking 4.5 percent increase in productivity in U.S. manufacturing. Productivity is the output (dollar value of goods) per hour worked. Although some of this increase was due to the dollar devaluation, there was nevertheless real and dramatic growth in productivity. The United States led the world in productivity with its first big gain since 1972. This achievement was accompanied by very high factory utilization, with 82 percent of manufacturing capacity being used in 1987, the highest in approximately 10 years.

MANUFACTURING AUTOMATION COMPETITION STATUS

Nineteen eighty-seven's top U.S. market share leaders in the highly fragmented manufacturing automation marketplace are:

- IBM Corporation
- Digital Equipment Corporation
- Hewlett-Packard
- Allen-Bradley Co. (a division of Rockwell International)

The diverse needs of the market make it an extremely difficult one to sell into, and, as a result, no competitor has a large share—greater than 10 percent—even among the leaders. Note that all four top shareholders are computer-related firms, including Allen-Bradley, whose major product line is programmable logic controllers (a type of microcomputer).

The top three companies in 1987 in terms of market share gains were Digital Equipment, GEFanuc Automation Corp., and Honeywell, Inc. At the opposite end of the spectrum, the three biggest market share losers were Cross & Trecker Corp., IBM, and Schlumberger.

Digital Equipment, the leader in market share gains, obtained much of its growth from sales into international markets. GEFanuc, the joint venture between General Electric of the United States and Fanuc of Japan, dominated the computer numerical control (CNC) world market for the second largest gain in share. Honeywell achieved much of its gain through acquisitions, developments in sensors, and by applying process control to the discrete piece manufacturing area.

Schlumberger led in market losses. It has sold some of its divisions, including automatic test and inspection equipment, and appears to be retrenching into its traditional focus on the oil business. Cross & Trecker, the world's largest machine tool builder, has suffered from foreign competition in machine tools as well as cutbacks in machine tool purchases by General Motors. IBM also suffered a slight market share loss, even though it retained its position as the largest U.S. automation vendor. Dataquest believes that IBM needs to develop and introduce new products to maintain its competitive status.

Companies to Watch

Dataquest believes that the following companies have a bright future in manufacturing automation:

- The Foxboro Co.—This process control manufacturer has introduced its Intelligent Automation Series of modular control systems and process control applications based on expert systems technology. Foxboro has also made acquisitions in machine vision and sensors, and is offering a challenge to Honeywell.

- Adept Technology, Inc.—This robot and machine vision company has continued its rapid pace of market share gains through a strategic focus on mechanical/electronic assembly and small parts material handling applications, particularly in nonautomotive markets.

- Epic Data Inc.—This company has achieved growth and market leadership in the rapidly growing area of factory data collection systems.

Companies with disappointing performances in 1987 include:

- Electronic Data Systems Corp. (EDS)—This data processing company has not yet achieved its stated intention of being a major force in systems integration, particularly on the shop floor.

- Gleason—This company attempted to enter the assembly systems business through its Alliance Automation Systems unit, which it later sold to Cross & Trecker. Gleason is refocusing its commitment to gear-systems manufacturing and revamping its manufacturing operations to increase production and recover lost ground.

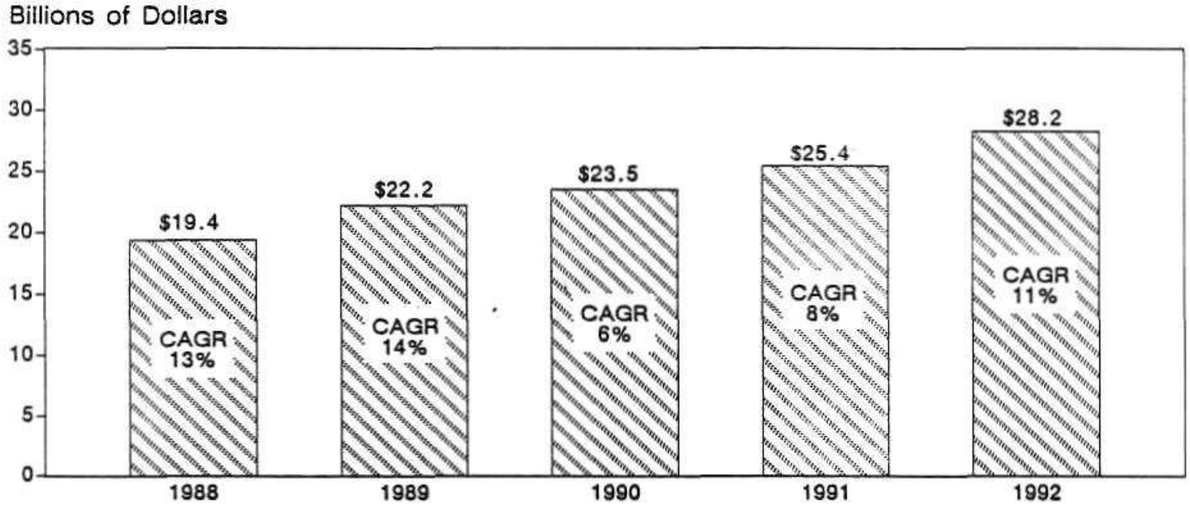
- Eaton Corp.—Subsidiary Eaton-Kenway was a former material handling leader that has experienced deep revenue losses in the past two years and was first offered for sale in October 1986. Eaton also plans to sell all defense electronics operations—part of its core business—in 1988.

DATAQUEST FORECAST—1988 THROUGH 1992

Dataquest expects 1988 to be an outstanding year—partly influenced by the economic buoyancy typical of election years—for manufacturing automation investment in the United States, with 13 percent growth over 1987. We believe that 1989 will show still stronger growth of 14 percent, but that toward the end of the year a recession will begin as the nation grapples with the overwhelming trade deficit. We predict that this recession will start showing its effects in the following two years, with growth rates of 6 to 8 percent annually. Because of the slowed growth in 1990 and 1991, the total compound annual growth rate (CAGR) for 1988 through 1992 is a little less than 10 percent, notwithstanding Dataquest's forecast for a healthy growth rate of 11 percent from 1991 to 1992. Figure 2 is a graphical representation of our forecast.

Figure 2

Forecast U.S. Revenue from Manufacturing Automation (Billions of Dollars)



Source: Dataquest April 1988

FUTURE TRENDS

Dataquest predicts that automation penetration, expressed as a percentage of total capital expenditures, will increase from a 3.9 percent penetration in 1987 to 4.6 percent in 1988. Despite expected slowdowns in the economy in 1989 and 1990, we believe that automation spending penetration may reach as high as 10 to 15 percent in the next 5- to 10-year period. What are the trends that lead to this optimistic prediction?

With continued focus on manufacturing competitiveness as a hot topic in the press and emphasis on it in the upcoming elections, we expect to see a resurgence in U.S. competitiveness through upgrading of manufacturing capabilities. This will lead to increasing penetration of export markets for the United States, led by such companies as Digital Equipment and Hewlett-Packard, and bolstered by the declining value of the U.S. dollar.

An important indication that manufacturing competitiveness is moving beyond talk into the action phase is that some U.S. companies are now moving their offshore manufacturing operations back to the United States. They are realizing that direct labor accounts for only 5 to 15 percent of total manufacturing costs. The cost of labor may be lower offshore, but this advantage is outweighed by other factors favoring onshore manufacturing. For example, many companies find that local, consolidated operations promote tighter control of the logistics of manufacturing and delivery. Another reason is to link design engineering directly with manufacturing engineering, which Dataquest believes is a growing trend.

Other influences that will promote automation include the resurgence of interest by the federal government in developing a strong manufacturing capability for defense purposes. In conference sessions at Autofact '87, Department of Defense programs for weapons systems procurement were emphasized, with indications that funds are available for upgrading manufacturing.

A growing number of industry consortia are concerned with manufacturing automation R&D, including Sematech and approximately a dozen other centers for manufacturing technology research. These consortia allow companies to contribute jointly to R&D programs of interest to their industries, and to spread the risks and costs of such programs.

A final trend to watch for in the next few years is the emergence of decision support systems as an important part of factory control. Despite the current emphasis on the automation of equipment, Dataquest believes that the real growth opportunities are in automation of information systems—software and communications. Decision support systems will increase in use for monitoring and control of the factory, and the linking of design to manufacturing (CAD and CAM) within a manufacturing company. Beyond that, they will also link manufacturers and their suppliers in just-in-time environments, and ultimately provide electronic communications links between manufacturers and their customers.

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Dave Norman
Melinda S. Pyle
David C. Penning

July–September

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July–September

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Research Newsletter

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PSST—WANT TO BUY A HARD DISK?
OR
OVERCAPACITY DOESN'T ALWAYS MEAN TOO MANY MEGABYTES

SUMMARY

The financial statements just issued by the top producers of 5.25-inch rigid disk drives (RDDs) are showing the first indication of industry overcapacity. All of the major producers except Miniscribe are showing dramatic decreases in profits due to severe pricing pressures. Inventories for the industry as a whole have soared to levels that recall similar problems in 1985.

The RDD industry was prepared to manufacture more than 17 million small-diameter drives in calendar 1988, but market demand is forecast at only 14 million even from the most optimistic viewpoint. This production increase of 70 percent over the 1987 sales figure far exceeds the projected personal computer market gain of 20 percent. The retail sales of rigid disk drives could even be reduced this year due to the large number of drives bundled in systems from Apple, Compaq, IBM, and Tandy.

This bulletin reviews some of the likely occurrences due to the current situation.

THE PROBLEM

As early as October 1987, it was apparent to Dataquest computer storage analysts that the anticipated small rigid disk drive production capacities were moving toward overcapacity. (See SAM newsletter 1987–38 entitled, "The Rigid Disk Drive Industry—Preparing for the Future.") Industry growth had been spectacular in the past two years due to the expanded retail market and strong PC sales. In an enthusiastic effort to gain worldwide market share, all vendors built production capacity and expanded their product lines.

Miniscribe produced the majority of the 3.5-inch drives in 1987 and has expanded capacities to nearly 4 million drives for 1988. Miniscribe has wisely moved out of the 5.25-inch low-end market (0 to 30 MBytes) and into the 3.5-inch drive arena. Dataquest predicts that Miniscribe will soon discontinue all stepper motor 5.25-inch products and offer only 3.5-inch drives to this market.

Seagate, the world's premier producer of 5.25-inch drives produced nearly 3.5 million units in calendar 1987 and built new facilities in Singapore and Thailand to produce at twice that rate in 1988. In the second calendar quarter of 1988, Seagate was building drives at a rate of 30,000 per day with a goal of 50,000 per day by the end of the year.

Seagate found itself with an excess inventory of ST-4096 drives in early 1988 as a result of the loss of an IBM order. Producers of these 80- to 85-MByte drives enjoyed a profitable business in 1987, with an average OEM selling price of $700. They soon found Seagate's inventory sales forcing the price of these drives as low as $450 by June 1988. The loss of this revenue was damaging to all suppliers of these drives and caused further price pressures up through the 380-MByte products.

With DRAM and SRAM shortages slowing controller and system sales, and PC vendors, such as Apple, Compaq, IBM, and Tandy, selling higher storage content in their PCs, the market cannot possibly absorb the 17 million drives anticipated by the drive industry production planners.

WHAT LIES IN STORE FOR US?

Looking ahead, one possible scenario is an immediate industry throttling of the production rates of 3.5- and 5.25-inch drives with less than 100 MBytes of capacity. A reduction of output to last-half 1987 levels would solve the problem.

Current inventories appear to be high. If Seagate liquidates its inventory of 5.25-inch products, many disk drives will be available for Christmas gifts this year. A second possible scenario would be that the low-end 5.25-inch market would collapse and absorb some of the anticipated 3.5-inch requirements due to the anticipated low prices.

We believe that the latter case is the more likely of the two. Seagate has already announced possible losses over the next two quarters. Why not take a bigger loss and dump the 5.25-inch products, switching to 3.5-inch drive production in 1989?

It appears that we should hang on to our hats. The "fun" has just begun.

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Dave Norman
Phil Devin

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Research *Bulletin*

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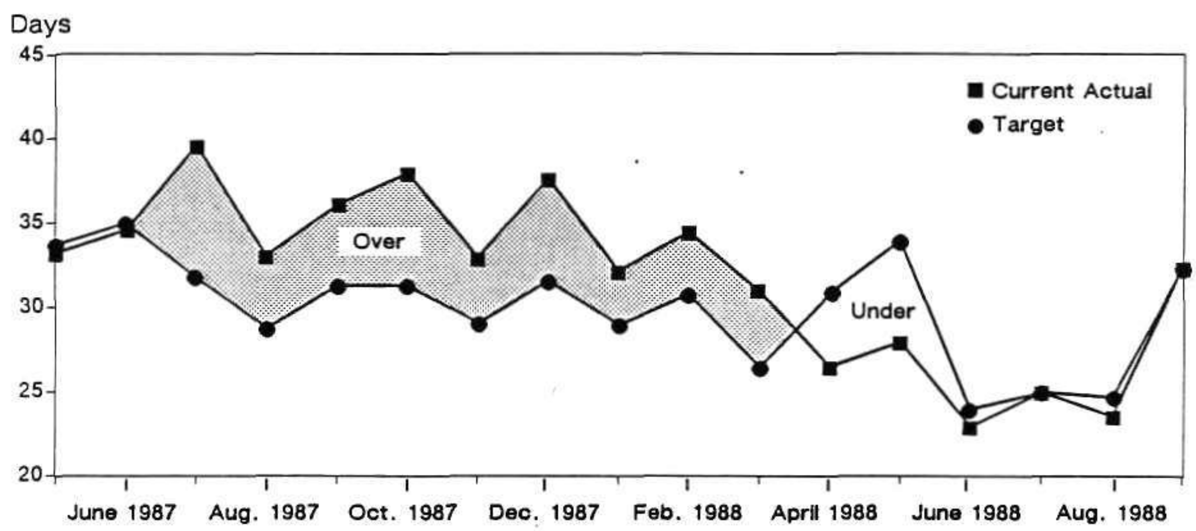
SEPTEMBER PROCUREMENT SURVEY: INVENTORY CONTROL TAKES PRIORITY AS SALES SLOW DOWN

The main concern of the respondents to our current procurement survey is controlling semiconductor inventories within targeted levels as overall sales growth begins to plateau. While sales are expected to continue growing, they are not expected to grow at previous levels. In their efforts to control inventories, both overall and computer OEM respondents have raised their inventory targets to 32.5 days from August's 28-day average target. Memories continue to be a concern, but now SRAMs have become the primary headache producer, with DRAMs taking a close second position. Figure 1 illustrates how actual and targeted inventories continue to remain balanced, albeit at a higher level.

Figure 1

Current Actual versus Target Semiconductor Inventory Levels
(All OEMs)



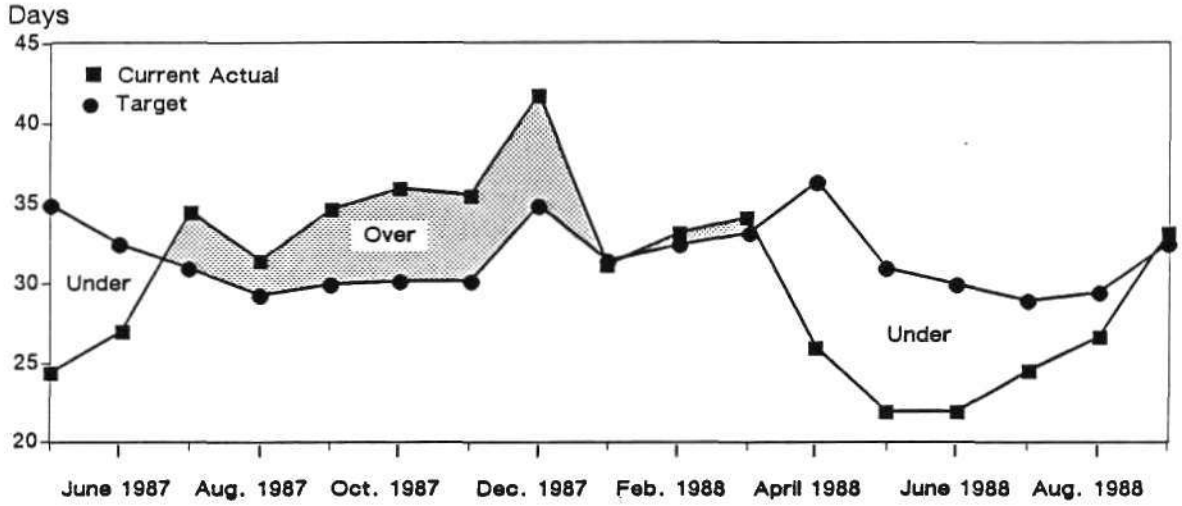
Source: Dataquest
September 1988

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

Computer OEM actual inventories again have exceeded targeted levels (33.4 days actual versus 32.6 days targeted) for the first time in nine months, as shown in Figure 2. Tighter quality controls (in ppm) continued as inventories rose.

Figure 2

Current Actual versus Target Semiconductor Inventory Levels (Computer OEMs)



Source: Dataquest September 1988

Prices have remained relatively stable, but lead times have decreased, on the average, by two weeks, as semiconductor supplies continue to increase. Orders to distributors have edged slightly upward by 1 to 2 percent as a result of efforts to cut inventory costs. While the majority of computer OEMs use surface-mount packages, availability of these parts no longer appears to be an immediate problem, except for some high-speed memory products.

DATAQUEST ANALYSIS

The acid test of the "user-supplier alliance" philosophy is now beginning as system end use shows signs of leveling off and accurate component forecasting becomes mandatory in controlling inventory levels. Vendors of semiconductors will benefit by accurate forecasts (up or down) from their customers by knowing how to allocate capital and human resources, which, in turn, will provide a steadier supply base of components.

Mark Giudici

Dataquest
a company of The Dun & Bradstreet Corporation

Research Newsletter

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1988–34
0001463

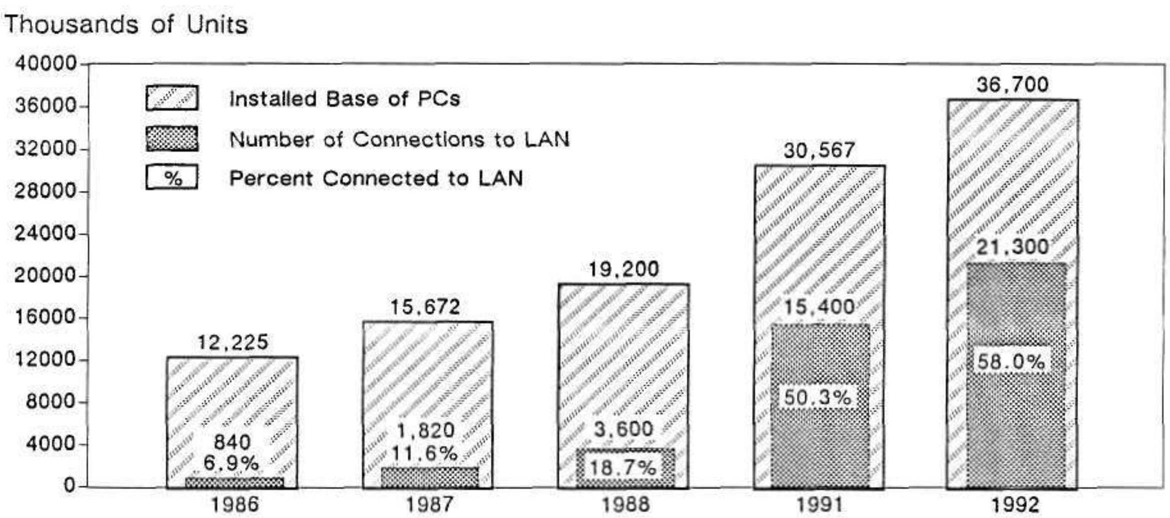
TOKEN-RING PROTOCOL RAPIDLY IS BECOMING POPULAR IN LOCAL AREA NETWORKS

Token-Ring protocol connections are expected to jump from 5 percent of the 1986 shipments of local area network nodes to 40 percent of these shipments in 1992. The driving force behind this increase is the need to improve productivity by allowing business and office personal computers to share information and peripherals, access data bases and mainframes, and exchange data with each other.

The expected growth in PC LAN connectivity is presented in Figure 1. Dataquest expects 18.7 percent of the 19.2-million-unit U.S. installed base of business and office PCs to be connected to a local area network in 1988. Dataquest predicts that this installed base of business and office PCs will increase at a four-year CAGR of 17.6 percent, to 36.7 million units in 1992. During the same period, Dataquest expects an installed base of 3.6 million LAN connections in the United States in 1988 to grow at a four-year CAGR of 56.0 percent, to 21.3 million units in 1992. The PC connection ratio will thus more than triple from 18.7 percent in 1988 to 58.0 percent in 1992.

Figure 1

Estimated Percentage of Personal Computers Installed Base Connected to a LAN (U.S. Business Environment)



Source: Dataquest September 1988

The Ethernet LAN protocol (pioneered by Digital Equipment, Intel, and Xerox) is expected to maintain its current 50 to 60 percent share of connection shipments from 1986 to 1992. The Token-Ring LAN protocol (pioneered by IBM and Texas Instruments) is expected to grow from a 5 percent share of the 1986 connection shipments to a 40 percent share of the 1992 connection shipments. The major use for Token-Ring is in PC LANs, which connect personal computers to a network. The uses for Ethernet, on the other hand, include both PC LANs and facility LANs, which connect mainframes, minicomputers, CAD/CAE workstations, terminals, and network management devices to a network.

Ethernet and Token-Ring form two of the segments for LAN protocols. All of the remaining LAN protocols can be covered by a third segmentation group. Examples of these proprietary, broadband, or other non-Ethernet and non-Token-Ring LANs include AppleTalk (Apple), Starlan (AT&T), and WangNet (Wang). This third "all others" segment is projected to grow at a CAGR of 7.4 percent between 1986 and 1992. However, the double-digit CAGR growths of Ethernet (22.0 percent) and Token-Ring (51.9 percent) during this same period will cause the "all others" share to drop from 40 percent of the connections shipped in 1986 to 10 percent in 1992.

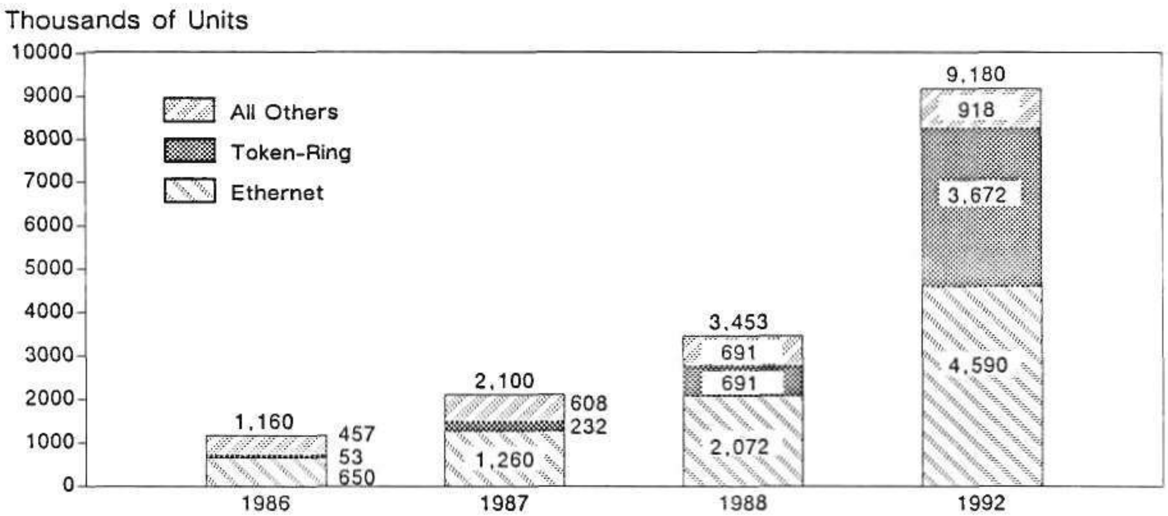
Dataquest's forecast of the shipments of Ethernet, Token-Ring, and "all others" LAN connections for the U.S. market is presented in Figure 2. The installed base of LAN connections and shipments by equipment supplier and protocol for the U.S. market in 1986 and 1987 are presented in Table 1.

(The data in this document were supplied by Dataquest's Telecommunications Industry Service, which provides full and complete coverage of local area network equipment and markets.)

Roger Steciak
Brad Baldwin

Figure 2

U.S. Market Share Forecast for All Ethernet and Token-Ring Connection Shipments



Source: Dataquest
September 1988

Table 1

Installed Base and Shipments of LAN Connections
by Equipment Supplier and Protocol
(Thousands of Units)

	1986			1987		
	Installed Base	Connection Shipments	Shipment Share	Installed Base	Connection Shipments	Shipment Share
Ethernet						
Digital Equipment	397K	232K	35.7%	832K	435K	34.5%
3COM/Bridge	324K	168K	25.9%	606K	282K	22.4%
Ungermann-Bass	225K	125K	19.2%	390K	165K	13.1%
Micom-Interlan	42K	8K	1.2%	122K	80K	6.3%
Novell	0	0	0	80K	80K	6.3%
Others	222K	117K	18.0%	440K	218K	17.3%
Total	1,210K	650K		2,470K	1,260K	
Token-Ring						
IBM	30K	30K	56.6%	202K	172K	74.1%
Proteon	11K	11K	20.0%	31K	20K	8.6%
3COM	7K	7K	12.8%	25K	18K	7.8%
Nestar	3K	3K	5.7%	9K	6K	2.6%
Ungermann-Bass	0	0	0	5K	5K	2.2%
Others	2K	2K	4.1%	13K	11K	4.7%
Total	53K	53K		285K	232K	

Source: Dataquest
September 1988

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FUTURE PC SHIPMENTS: A FORECAST BY MICROPROCESSOR TYPE

SUMMARY

Future developments in microprocessors will have a profound effect on the personal computer industry. This newsletter examines Dataquest's forecast of PC shipments by microprocessor type from 1987 through 1992 and the assumptions on which this forecast is based.

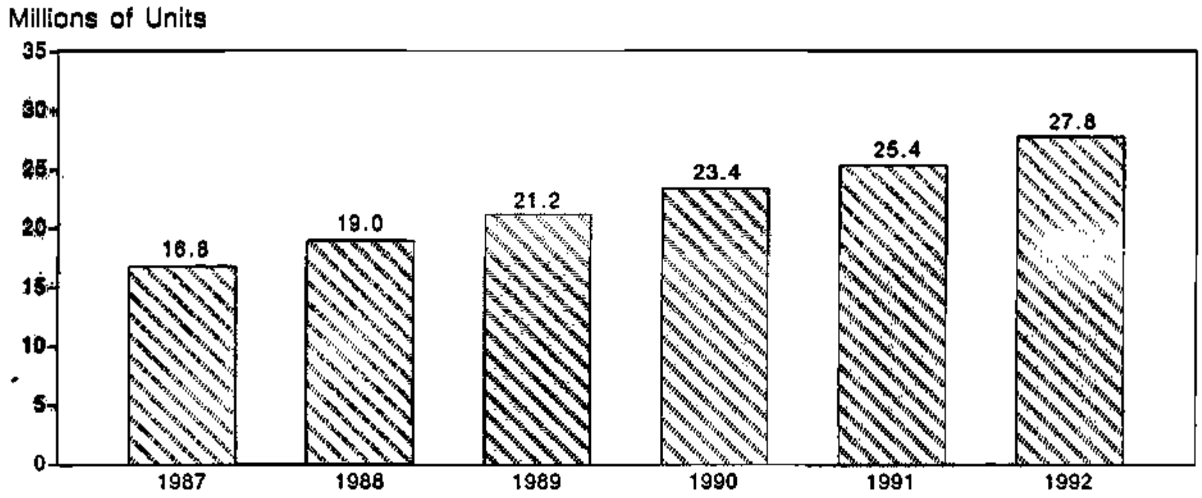
HISTORY AND FORECAST

At the end of 1987, more than 23.2 million Intel 8088-, 8086-, 80286-, and 80386-based machines had been shipped to the home, business, education, and government markets worldwide. By contrast, Dataquest estimates the worldwide installed base of Motorola 680xx-based systems to be 3.0 million units for the same time period.

Dataquest's worldwide five-year PC shipment forecast is shown in Figure 1. We expect worldwide unit shipments to grow from 19.0 million units in 1988 to 27.8 million in 1992.

Figure 1

Worldwide PC Shipment History and Forecast (1987–1992)



Source: Dataquest
August 1988

OUTLOOK FOR PC SHIPMENTS BY MICROPROCESSOR TYPE

Table 1 presents Dataquest's aggregate worldwide forecast, segmented by microprocessor type. The following paragraphs discuss the assumptions we made in formulating this forecast.

Table 1

Worldwide PC Shipment Forecast by Processor Type (Units in Millions)

Processor	1987	1988	1989	1990	1991	1992
8088	2.6	2.0	1.9	1.3	0.9	0.4
8086	3.3	4.1	3.0	2.4	1.9	1.5
80286	4.3	5.7	6.5	7.6	8.3	9.0
80386 All	0.3	0.9	4.4	6.1	7.7	9.8
80386SX	-	0.2	2.8	3.9	5.0	6.3
80386	0.3	0.7	1.6	2.2	2.7	3.5
80486	-	-	-	0.2	0.4	0.8
680XX	1.5	1.7	2.3	2.8	3.4	4.0
Other	4.8	4.6	3.1	3.0	2.8	2.3
Total	16.8	19.0	21.2	23.4	25.4	27.8

Source: Dataquest
August 1988

8088–Based Systems

Dataquest estimates that worldwide shipments of 8088-based systems will decline dramatically from 1988 to 1992, as a result of manufacturers switching from the 8088 to the 8086 microprocessor. For 1988, we estimate the cost of the 8088 chip to average $4.44 and the cost of the 8086 chip to average $5.38, in purchase volumes of 25,000 units per year. The small difference in the price between the two chips and IBM's use of the 8086 chip will provide the incentive for manufacturers to change chips. We believe that the majority of 8088-based systems shipped between 1988 and 1992 will be sold to the home, small business, and education markets.

8086–Based Systems

Worldwide shipments of systems based on the 8086 chip will decline steadily, from 4.1 million units in 1988 to 1.5 million units in 1992. This decline will occur even as manufacturers switch to the 8086 chip from the 8088, and it will result from end users moving up to higher-performance 80286-based systems. During 1989, we expect 8086-based systems to be forced to the less than $500 price category as 80286-based machines invade the $1,000 to $1,500 price range. Most of the 8086-based systems will be IBM Model 25 and 30 clones. These systems will be used as PCs by small business, education, and home users, and as network nodes by larger businesses.

80286–Based Systems

Dataquest expects the worldwide market for 80286-based systems to remain strong through 1992. Worldwide system sales will increase from 5.7 million units in 1988 to 9.0 million units in 1992. We estimate that the average price of the 80286 chip will drop from the $40.00 range in 1988 to $15.00 by the end of 1991, assuming purchase quantities of 25,000 units per year. We expect 80286-based systems to be the entry-level systems for the majority of business users. The demand for 80286-based systems will be driven by users who need OS/2 capabilities and the related software applications that will be developed for use with OS/2. We estimate the price for 80286 systems to drop to the $1,000 level by early 1990.

80386–Based Systems

Dataquest forecasts a dramatic increase in overall 80386 shipments during the 1988 to 1992 time frame. Worldwide shipments will grow from 900,000 units to 9.8 million units in 1992. During this period, we expect the average price of 80386 chips purchased in quantities of 25,000 to drop from $248.00 to $99.00 by 1991. We further anticipate that both IBM and Compaq will fuel this growth by utilizing 80386 processors in their entire product lines by the end of 1989.

Dataquest expects the majority of shipments of 80386-based systems to use the new Intel 386SX chip, and we estimate that worldwide shipments of 386SX-based systems will grow from 200,000 units in 1988 to 6.3 million units in 1992. We believe that initial pricing will begin at $164.00 for purchases of 25,000 units annually. Intel is forecasting a 10 percent reduction in price per quarter. This would result in a price of $37.50 by the end of 1991.

80486–Based Systems

We expect 80486–based systems to appear by late 1990. Dataquest believes that the introduction of the 80486 will put downward price pressure on the 80386– and 80286–based machines. This price pressure will mark the end of the 8088– and 8086–based systems.

680xx–Based Systems

We project that worldwide shipments of systems utilizing the Motorola 68000 line of processors will grow from 1.7 million units in 1988 to more than 4.0 million units by the end of 1992. The growth will come from products manufactured by Apple, Commodore, and Atari. We expect Apple Macintosh 680xx–based systems to grow at nearly a 30 percent annual rate through 1992. Dataquest estimates the current price of the 68000 chip to average $4.81 in 1988, with an expected drop to $4.35 by 1991. The 68020 chip is expected to have an average price of $88.00 in 1988 and $36.60 in 1991.

Systems Based on Other Processors

The segment of systems based on other processors will, in our opinion, continue to decline as Intel and Motorola dominate the PC marketplace. We expect that RISC processors will appear in small numbers during the 1991 and 1992 time frame.

DATAQUEST ANALYSIS

Dataquest believes that the PC market will continue to be dominated by the Intel family of microprocessors throughout the 1988 to 1992 time frame. Systems based on the 80286 microprocessor will be the entry–level machines for business users. The demand for 80286–based systems will be fueled by end–user demand for OS/2 and OS/2–related applications. The declining price of 80286–based systems will force a reduction in the shipments of 8088– and 8086–based systems, and the introduction of the long–awaited Intel 386SX chip will spur the explosion in 80386–based shipments in 1989. We believe that this explosion in shipments will enable 80386–based systems to surpass the number of shipments of 80286–based systems in 1992.

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David Norman
Bill Lempesis

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Research *Newsletter*

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SEMICONDUCTOR PRICE SURVEY: SUPPLIES AND PRICES TIGHT, BUT RELIEF IS ON THE WAY

SUMMARY

Semiconductor pricing in the second quarter of 1988 remained relatively stable compared with the first-quarter price hikes for memory devices. Besides memory prices calming down, the standard-logic and microprocessor prices have continued their supply-demand balanced trends in the face of steady system growth. Availability of DRAMs and some SRAMs is still a concern for procurement managers, but the increased supplies of 1Mb DRAMs and their ripple influences on ancillary devices will improve overall pricing starting in the latter part of the fourth quarter of this year. This newsletter will cover highlights of Dataquest's latest price survey and forecast.

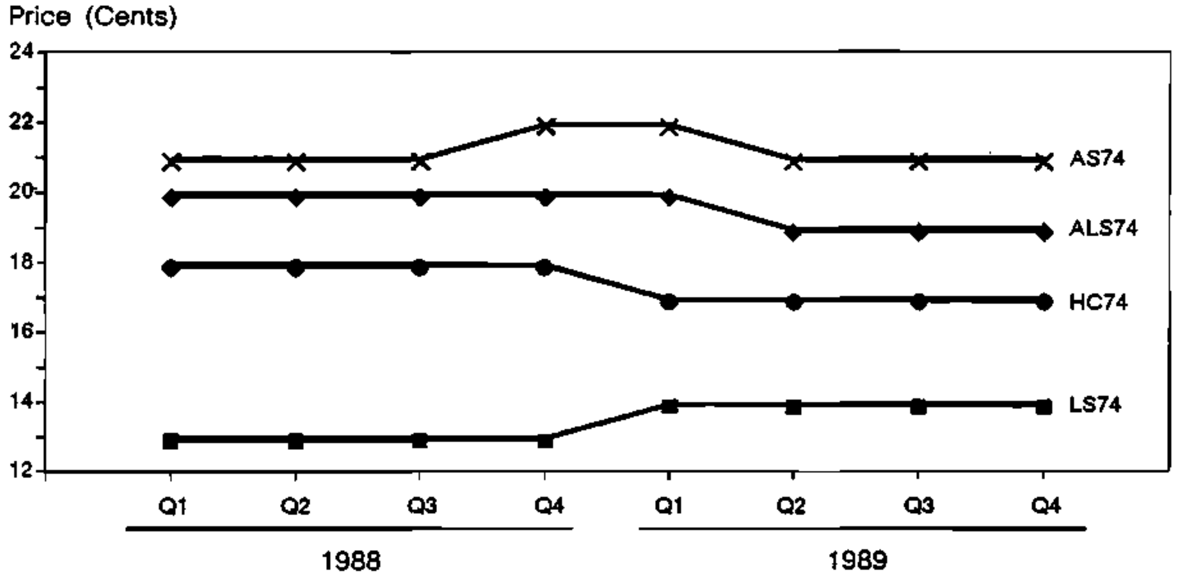
STANDARD LOGIC TRENDS

A balanced market typifies the standard-logic arena, as prices have remained very stable over the last three months (see Figure 1). Prices will firm over the next six months because demand is expected to increase as DRAM availability improves, freeing up latent orders dependent on memory. Lead times have risen slightly by 1 to 2 weeks and now range between 8 to 12 weeks, reflecting this balanced market.

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

Figure 1

Standard Logic Price Trends



Source: Dataquest
August 1988

MICROPROCESSOR TRENDS

Microprocessor prices have also evened out as supply for both high- and low-end processors has stabilized against demand. Demand for high-speed (12+ MHz) 16-bit and 32-bit processors remains strong, keeping prices firm and flat on through the end of the year. New 32-bit microprocessor offerings from Intel (80386SX) and Motorola (68030) are expected to follow gradual declining price curves in the current sole-source, 32-bit environment.

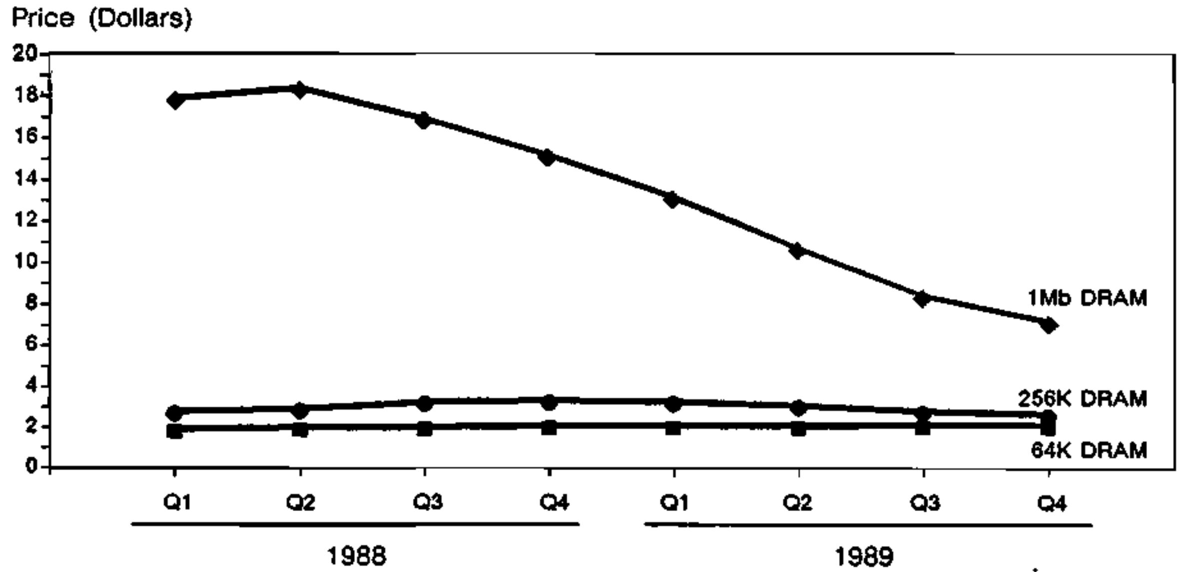
MEMORY TRENDS

Memory availability continues to be in the news, and the beginning of increased supplies of 1Mb DRAMs now slowly coming to the market will have many ramifications on dependent devices. The 1Mb DRAM prices are expected to gradually decline as production ramps up, while 256K DRAM prices will continue to increase and stabilize through the fourth quarter 1988 to the first quarter 1989 time frame, as supplies are cut back 5 percent per quarter through 1989. The expected softening in the electronics market beginning in the second quarter of 1989 will occur just as the majority of the 1Mb vendors reach peak production. The combination of aggressive market share pricing, based on cost reductions with a moderation of demand, will accelerate price declines for the 1Mb part, as shown in Figure 2. For those IC vendors still supplying the rather stable 256K device prices, a shift in capacity to take advantage of decent profit margins will be short-lived until supply meets up with demand and causes 256K pricing to decline also.

SRAM pricing will follow the DRAM trend by about three to six months as this product line again becomes an attractive margin producer. However, in the face of slack demand, prices for these parts will decline also. EPROM pricing has been rather stable and will continue to be so (especially in the lower densities) on through the end of this year as demand for systems remains steady.

Figure 2

DRAM Price Trends



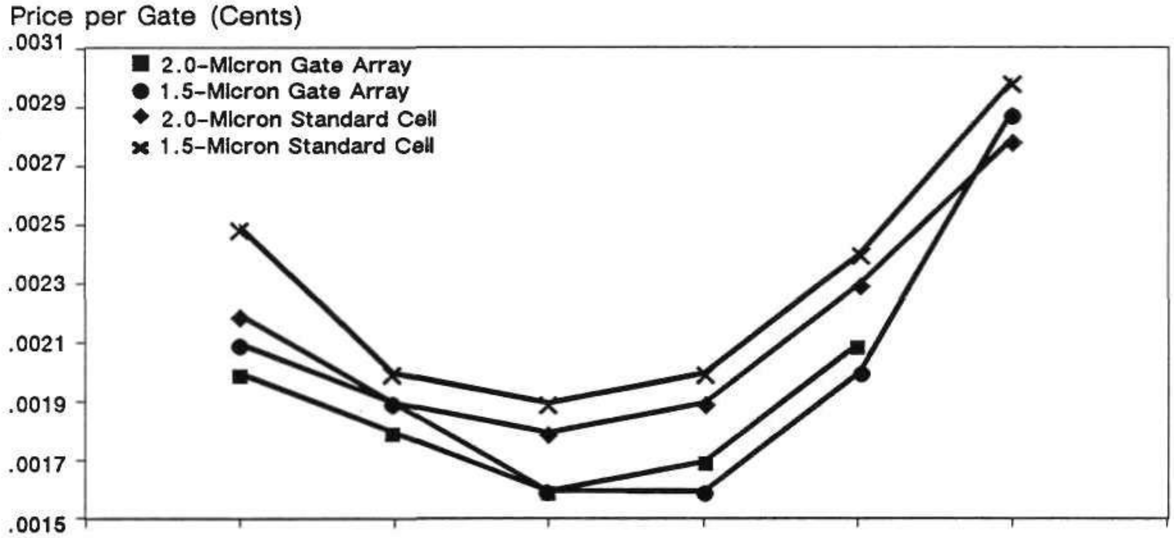
Source: Dataquest
August 1988

ASIC TRENDS

Standard cell prices have declined since our last survey, largely due to competition from high-density gate arrays. NRE charges remain higher for these parts due to the inherent higher costs involved with full mask sets and CAD time. Gate array prices stabilized, with vendors now focusing on throughput and customer service, as seen in Figure 3. ECL gate array pricing is becoming a two-tier structure with small-geometry, ultrahigh performance technologies competing with larger (3.0-micron) geometry, very-high-performance parts. The more expensive small-geometry devices currently take a 50+ percent price premium over current price trends. We expect to see continued price competition in the standard-cell and ECL gate array markets as channelless gate arrays continue to fight for the same sockets as standard cells and more vendors enter the ECL gate array arena.

Figure 3

1988 ASIC Price Trends



Source: Dataquest
August 1988

DATAQUEST RECOMMENDATIONS

The correction of the past unbalanced supply-demand equation in DRAMs will spill over into other IC areas. In the face of current steady demand, the increased supply of memory will reduce the price of these parts and cause a firming of prices for other devices where there is a market balance (some standard logic and microprocessor parts). When electronics system demand moderates in the second quarter of 1989, overall semiconductor pricing will gradually decline. Close communication between semiconductor buyers and vendors will prevent over-inventory and/or over-capacity situations while allowing both parties to flow with the economic tide rather than fight it.

Mark Giudici

Dataquest
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Research *Bulletin*

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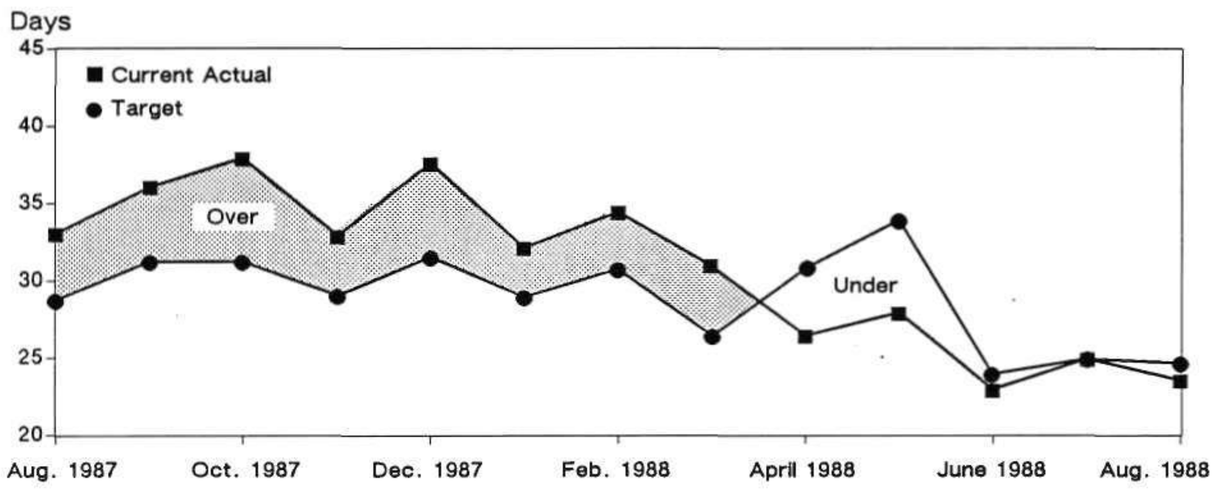
AUGUST PROCUREMENT SURVEY: ORDER RATES FLAT, INVENTORIES MIXED

Respondents to our procurement survey expect August semiconductor orders to remain static, compared with the levels set for July. Sales of electronic systems are forecast to be higher or remain the same during this time frame. The lower overall targeted and actual inventory levels seen in June have continued into July, as shown in Figure 1. The current levels of 24 days targeted inventory and 23 days actual inventory reflect the continued strain that DRAM availability has had on the availability of other semiconductors. While the memory shortage still exists, it appears to have peaked for the majority of users, as procurement practices and inventory levels have adjusted to the situation.

Figure 1

Current Actual versus Target Semiconductor Inventory Levels
(All OEMs)



Source: Dataquest
August 1988

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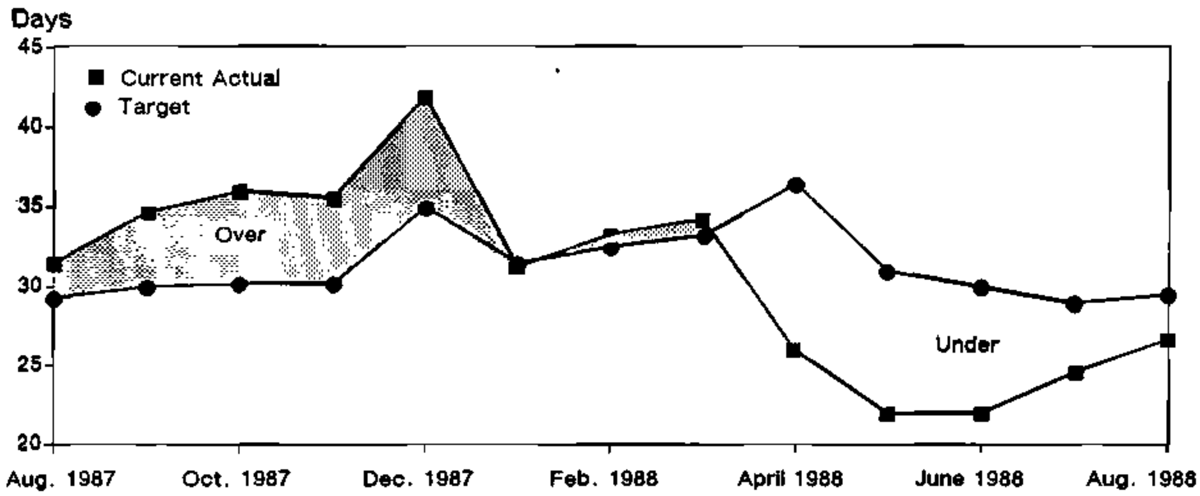
Computer OEM actual inventory levels of semiconductors have risen to slightly more than 26 days, while target levels have remained unchanged at 29 days (see Figure 2). As inventories have increased, more stringent incoming quality assurance levels (in ppm) have been imposed upon vendors.

Figure 2

Current Actual versus Target Semiconductor Inventory Levels (Computer OEMs)



Source: Dataquest
August 1988

Prices and lead times have continued to remain stable, while there is some indication that lead times will decline as product bottlenecks ease. Distribution orders also remain unchanged since our last report, which also reflects the relative easing of product availability. Surface-mount parts continue to be difficult to obtain, especially in the high-speed memory area. Besides DRAM and slow SRAM shortages, some discrete devices are also hard to obtain. The current difficulty in obtaining discretes may become exacerbated once memory supplies improve.

Mark Giudici

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QUARTERLY ELECTRONICS INDUSTRY UPDATE: FROM END–USE EQUIPMENT TO SEMICONDUCTOR CAPITAL SPENDING

SUMMARY

Probably one of the most frequent questions we are asked at Dataquest is "What is driving the semiconductor recovery, and how long will it last?" We have published several newsletters and other material that address various aspects of this question, which our clients have received. The purpose of this newsletter is to compile information that has already been published and present, in one newsletter, a very concise summary of the electronics industry as we see it for the next five years. Our intent is to provide a reference document to be used for high–level forecasts.

The newsletter presents top–level forecasts of the electronic equipment industry, the semiconductor production required to meet the electronic equipment demand, and the capital spending required by the semiconductor manufacturers to meet semiconductor demand.

ELECTRONIC EQUIPMENT

The electronics industry has gained clout as a major driving force behind the worldwide economy. Few are aware that in 1988 $770 billion worth of electronic equipment will be produced, creating direct demand for a $49 billion semiconductor market.

The electronics industry, made up of six major markets, will grow more than 12 percent this year. Figure 1 reflects the major factors behind that growth—the data processing and consumer markets. In the United States, Japan, and the Far Eastern countries, these two markets comprise the bulk of electronic equipment production. Major growth areas within these markets are personal computers, workstations, terminals, televisions, VCRs, and compact disk players. All of these areas have two points in common: high pervasiveness, meaning high semiconductor content, and high volume. All of the previously mentioned products are tied to individual use; that makes for a very large total available market.

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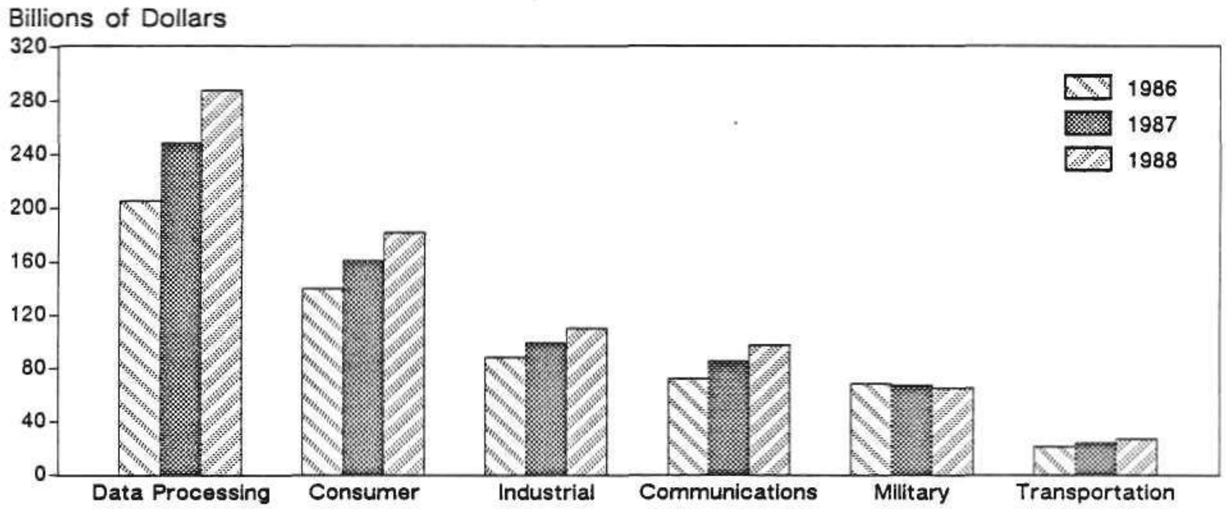
Figure 1

Worldwide Electronic Equipment Market by Electronics Segment



Source: Dataquest
August 1988

Table 1 shows Dataquest's estimates for worldwide electronic equipment market. Solid state technology now affects all of us; our appliances, entertainment, transportation, telephones, and productivity tools rely on semiconductors. The commoditization of electronics and the semiconductor industry may ultimately create a more stable marketplace. Market demand is broad based, and marketing and manufacturing strategies are assessed across an international marketplace. Closer ties between users and vendors create implications for more stable growth. We believe that there will be less dramatic swings in the semiconductor industry, which will be largely due to a changing worldwide electronics industry.

Table 1

Worldwide Electronic Equipment Semiconductor Production and Capital Spending (Billions of Dollars)

	1986	1987	1988	1989	1990	1991	1992	CAGR 1986-1992
Electronic Equipment Market	$595.0	$685.0	$769.0	$819.0	$843.0	$968.0	$997.0	9.0%
Semiconductor Production	32.8	39.9	49.1	54.1	54.2	62.8	75.9	15.0%
Capital Spending	5.3	6.0	8.3	9.0	9.1	11.8	15.4	19.5%

Source: Dataquest
August 1988

SEMICONDUCTOR PRODUCTION

Electronic equipment demand drives semiconductor production. Figure 2 shows the semiconductor consumption by electronic equipment segment. Here we see that the data processing and consumer electronics markets alone will consume almost $30 billion worth of chips in 1988; this represents more than 60 percent of all the chips produced in 1988. Table 1 shows Dataquest's latest estimates of worldwide semiconductor production by all producers, including captive and merchant.

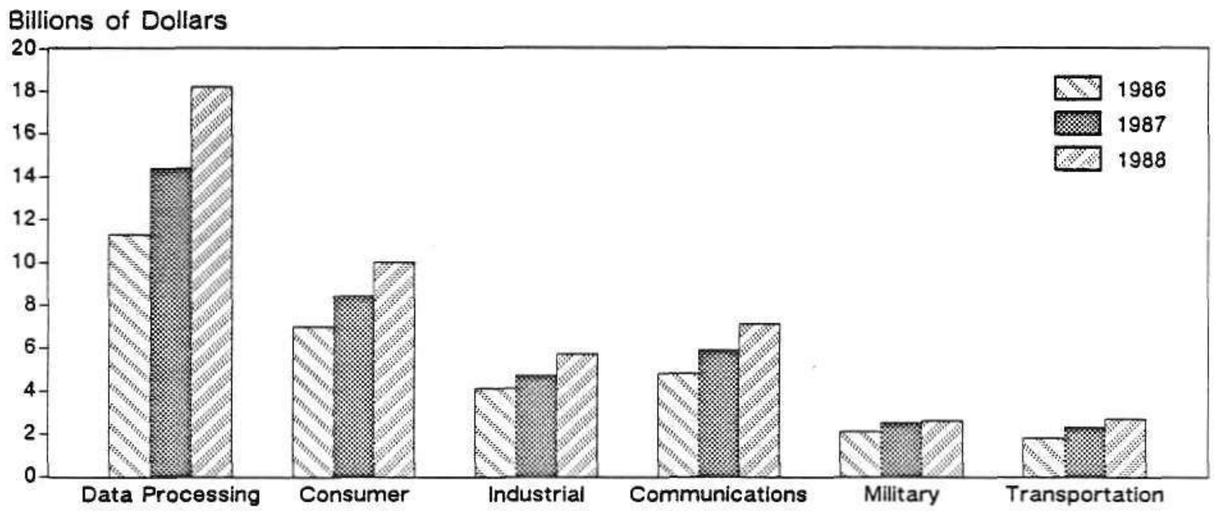
Semiconductor production in 1988 will increase by 23 percent over 1987 levels, which were up 22 percent over 1986 levels. The bookings momentum and the shortages in leading-edge semiconductor products suggest that strength in shipments should continue through the first half of 1989. Growth in 1989 should be 10 percent, followed by a flat 1990.

In spite of memory chip shortages, the short-term outlook is very strong because of the increasing demand for high-end microprocessors and ASIC devices that are consumed in the production of data processing equipment. Overall capacity utilization is estimated to be 82 percent by the end of 1988, up from 78 percent in 1987. Capacity is tight for the leading-edge products, with capacity utilization in excess of 90 percent for the finer-line geometries in the 1.5-micron range.

As new plants are brought on stream, capacity utilization for high-integration devices should ease a bit later this year. High-end microprocessors should soon cease to be supply limited, but microprocessor demand in 1988 is constrained by memory shortages. Although we expect DRAM demand to exceed supply in 1988, we expect supply to catch up in 1989 as a result of increased capacity and improved yields for 1Mb DRAMs, putting downward pressure on prices.

Figure 2

Worldwide Semiconductor Consumption by Electronics Segment

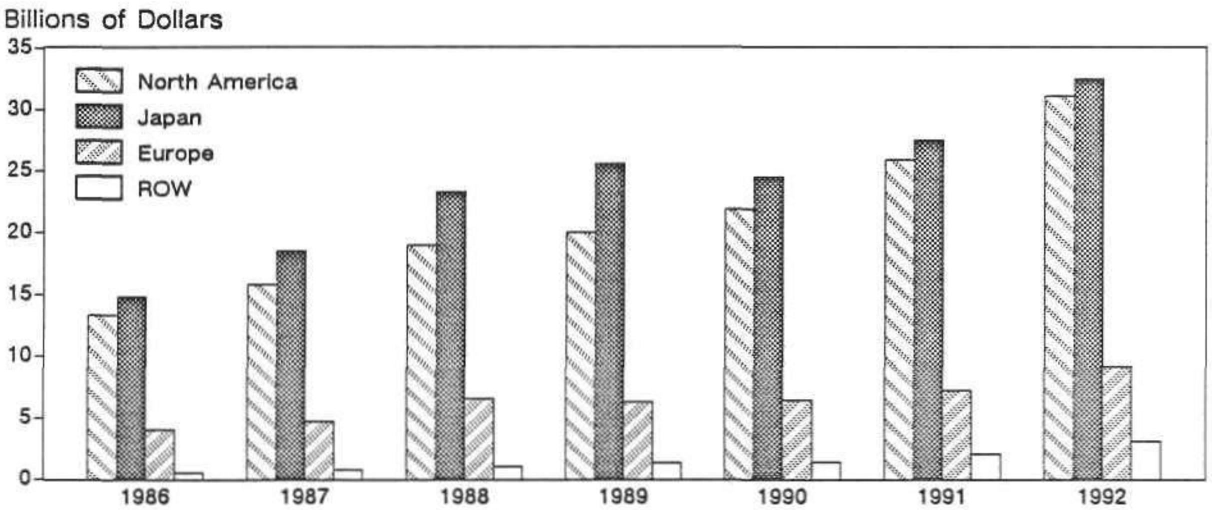


Source: Dataquest
August 1988

Figure 3 shows the regional production of semiconductors, which includes production by all companies in the region, regardless of country location of headquarters. Table 2 shows the shift in regional production from 1984 through 1992. Here we see that for North America, in spite of the increase of Japanese and European fabs in the United States, its share of worldwide semiconductor production will only be about 41 percent by 1992.

Figure 3

Worldwide Semiconductor Production by Region



Source: Dataquest
August 1988

Table 2

Worldwide Semiconductor Production by Region

	1984	1992
North America	49.8%	40.9%
Japan	38.3	42.8
Europe/ROW	11.9	16.3
Total	100.0%	100.0%

Source: Dataquest
August 1988

CAPITAL SPENDING

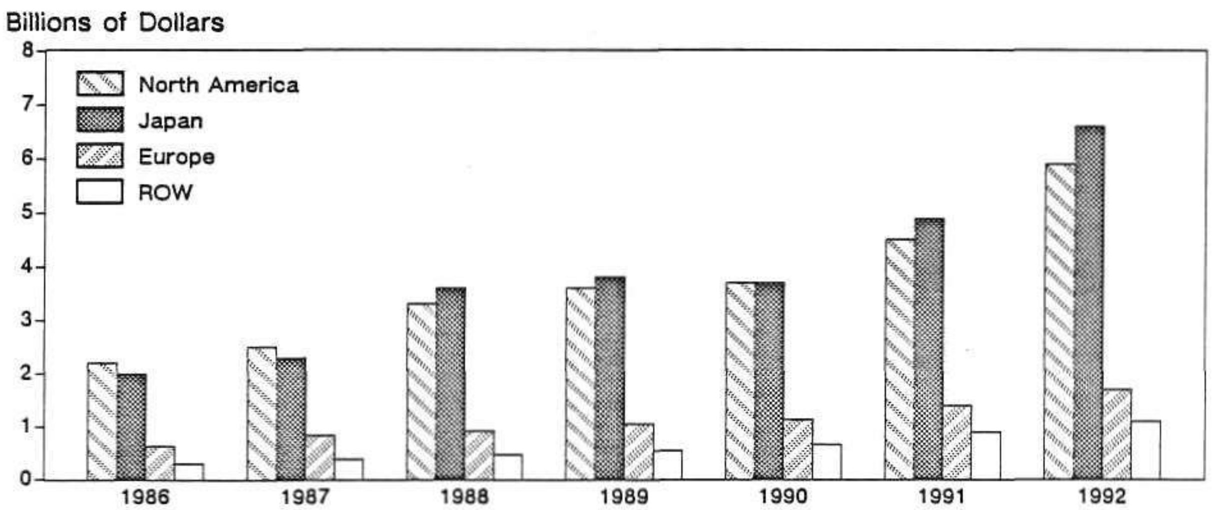
Table 1 also shows the capital spending that must be made by the world's semiconductor producers in order to meet the projected semiconductor demand. Capital spending will be driven by the need for increased capacity and upgrades, especially for leading-edge devices. Capital spending will also be fueled by competitive pressures as many manufacturers locate front-end facilities offshore to be close to their markets and to protect themselves from the double nemesis of trade friction and currency fluctuations.

Capital spending, like the electronics end markets that it eventually serves, will grow at a much more steady rate than in the past. Semiconductor manufacturers, although spending for more capacity, will remain cautious; they prefer to increase equipment availability and to increase yields before adding capacity. Consequently, although Dataquest does not anticipate the skyrocketing growth that occurred in 1984, we also do not anticipate the devastating descents that occurred in the 1985 to 1986 time frame. The peaks may not be as high, but the ride will be smoother and more sustainable.

Figure 4 shows the capital outlays by region that must be made to support the semiconductor output of those regions. Again, these projections represent spending by all companies in the region, regardless of the company nationality. We expect spending by all companies in Japan (including U.S. merchants and IBM) to increase at a CAGR of 24 percent. The reason for this high growth in Japan is the fairly low starting base, especially in terms of yen. Spending in yen by Japanese companies, U.S. companies, and IBM in Japan actually fell 65 percent from 1984 to 1987—from ¥924 billion in 1984 to ¥325 billion in 1987.

Figure 4

Worldwide Capital Spending by Region



Source: Dataquest August 1988

We also expect spending by all companies in the Asia-Pacific region to grow at a CAGR of 24 percent. This growth rate will be driven by Asia-Pacific companies' commitment to become world-class manufacturers and by new fab construction by European and North American companies.

Spending in North America will grow at a healthy 19 percent CAGR, and will be almost $6 billion in 1992. This spending will be fueled by new fabs and upgrades for leading-edge devices, especially DRAMs and microprocessors. Dataquest also anticipates a strong surge of spending by Japanese companies in the United States, as several Japanese companies either have already initiated new fab construction or are soon planning to begin.

Europe will experience the slowest growth rate—only 15 percent. The relatively slow rate in Europe is due to the recent completion of major expansions by Philips and Siemens and to the rationalization of existing facilities by SGS-Thomson. Captives will play a major role in Europe: AT&T will complete its new fab in Spain in 1989, and IBM will begin production on the largest 200mm fab in the world at Singlefingen, West Germany, also in 1989.

Capital spending, like the electronics industry it serves, will be more stable than it has been in the past. It will also be more international—and more competitive. Equipment vendors will have to serve markets that are culturally different from their home offices and compete with new competitors on their home turf. Capital spending may grow at a more stable rate than in the past, but competition will be as fierce as ever.

DATAQUEST CONCLUSIONS

The forecast presented here for the electronics industry—from end-use markets through capital spending—shows a consistent picture of healthy and sustainable growth rates. Furthermore, worldwide markets, increased dialog, just-in-time inventory control, and more realistic capacity planning are beginning to pay off for the electronics industry. The good growth rates, combined with a more mature business point of view, signify that the electronics industry is emerging from the vertigo of youth and should rationally grow to a $1 trillion level by 1992. That is, indeed, good news.

Anthea Stratigos
Joseph Borgia
George Burns
Joe Grenier

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Research *Bulletin*

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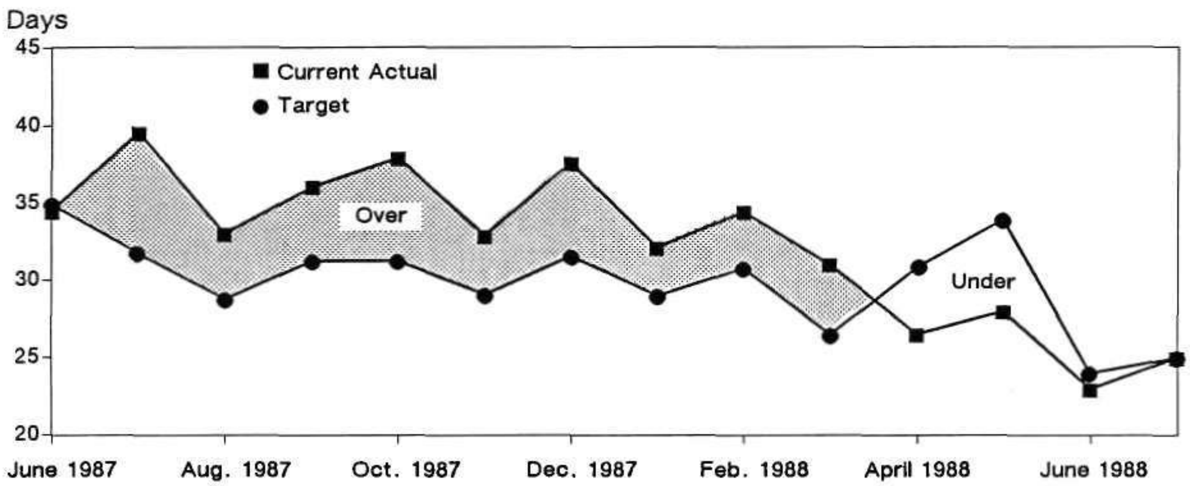
JULY PROCUREMENT SURVEY: ORDER RATES AND INVENTORIES LEVEL OFF

Respondents to this month's survey expect to see both semiconductor billings and orders remain at, or below, last month's levels. This leveling of semiconductor orders is in response to the mixed levels of electronic system sales—some of our respondents expect higher sales while others expect lower sales this month. Both targeted and actual semiconductor inventory levels have leveled out at around 10 turns per year, as seen in Figure 1. Many of our respondents noted that although memory supplies (DRAM and SRAM in particular) are still in tight supply, some parts are more easily available than in the recent past. Long-term contracts continue to provide adequate supplies of key components.

Figure 1

Current Actual versus Target Inventory Levels (All OEMs)



Source: Dataquest July 1988

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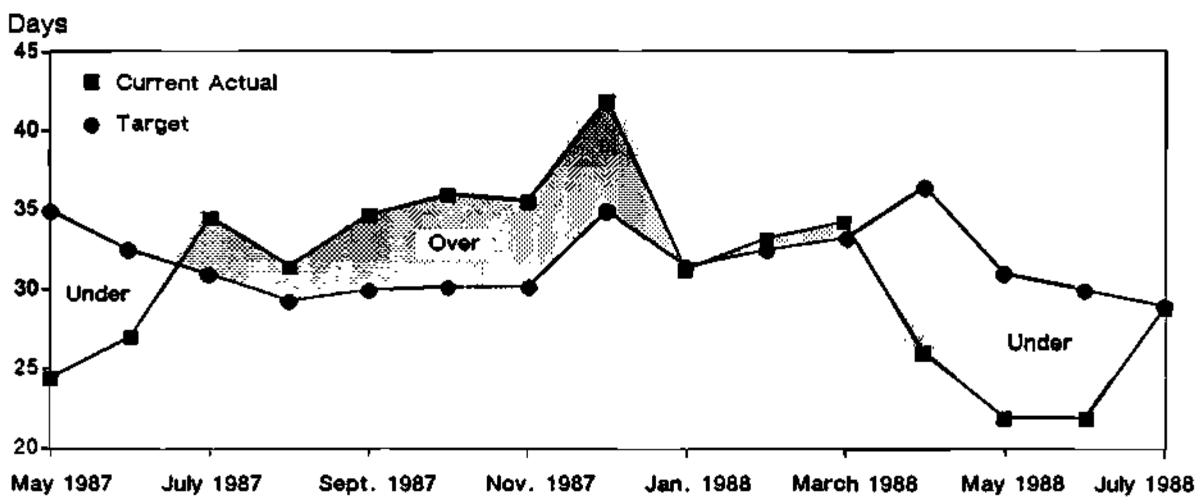
Computer OEM actual semiconductor inventory levels have remained steady at 29 days while the actual level has risen up to meet it. The DRAM/SRAM shortage is now a given in procurement plans, and purchases of DRAM-dependent ICs have been adjusted downward to accommodate this situation.

Figure 2

Current Actual versus Target Inventory Levels (Computer OEMs)



Source: Dataquest July 1988

Pricing has remained the same and in some cases has risen, while overall lead times have remained steady or declined from June's survey. Distribution orders have declined slightly, primarily in response to the perceived easing of supply for some IC parts. For over half of the respondents who use surface-mount parts, availability of surface-mount ICs is a serious problem, especially in the memory area. We expect this situation to continue until the DRAM shortage begins to ease in the fourth quarter of 1988 through first quarter of 1989 timeframe.

Mark Giudici

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Research *Newsletter*

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HOW WILL TOKEN–RING NETWORKS IMPACT THE 3270 DISPLAY TERMINAL MARKET?

SUMMARY

Dataquest user surveys and market projections show that the market for 3270 display terminals is expected to expand moderately until well into the 1990s. One of the limiting factors in that expansion is the increased use of mainframe-communicating personal computers to support many of the new office applications that require host interactivity. The use of a PC in the dual roles of desktop processor and terminal emulator usually eliminates the potential market for a traditional 3270 display terminal at that location.

The recent increase of local area network (LAN) installations in corporate MIS environments, particularly Token–Ring LANs, signals that networked PCs are likely to have an even more pronounced impact on the market for traditional 3270 display terminals. Many Token–Ring LANs are or will be concentrated in the same Fortune 1000–size companies that represent the largest user base of IBM/PCM mainframes and 3270–type networks. We expect, therefore, that a proliferation of Token–Ring LANs will have a much more significant impact on the market for 3270 (and compatible) devices than will Ethernet and other standard or proprietary LAN installations.

Present and projected increases in Token–Ring LAN installations are attributed to the fact that IBM has clearly established Token–Ring as its strategic local networking scheme for the foreseeable future. Additionally, the IEEE's adoption of the same technology as one of its LAN standards provides further assurance of the availability of Token–Ring products and support. In the face of previous uncertainties regarding IBM's strategic direction and long–range LAN support plans, major corporations were hesitant to commit to a particular technology on which to base their own intracompany LAN implementations. Those uncertainties are now largely cleared, and many of those large companies are embarking on ambitious LAN implementation programs.

This newsletter presents an overview of the market for local area networks as it is quantified and projected by Dataquest. We also describe those characteristics of IBM's Token–Ring Network system that will lead to its increased acceptance in major corporate MIS networks; and thus, its increased impact on the market for 3270 display terminals. We conclude the newsletter with our analysis of how the proliferation of those Token–Ring LANs is likely to affect the market for traditional 3270 devices.

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LOCAL AREA NETWORKS; A MARKET OVERVIEW

The desire to interconnect standalone personal computer products into work group clusters was originally fostered by the need to provide equipment economies and intra-group sharing of common data files. However, as had been the case with standalone PCs earlier, many of the work group LANs generated subsequent demands to have convenient access to data files and applications that reside in corporate mainframe complexes.

In Fortune 1000-size corporations, where IBM SNA and 3270 environments are concentrated, the marketplace has been hesitant to adopt full-scale connectivity of those LANs into the mainframe environment. That early reluctance was caused at least partially by the lack of a clear-cut strategic direction by IBM in the connection of desktop processors—and clusters of them—to mainframe hosts. Confusion as to IBM's longer-range plans for its PC Cluster and PC Network product lines added to the confusion of potential LAN users, even for some time after IBM announced its Token-Ring Network system. Other factors that contributed to the slow buildup of LAN installations in large corporate markets included:

- The absence of LAN system/equipment standards to assure prospective network implementers that their investments would be viable for a reasonable period of time
- A shortage of multiuser/multitasking application software for PC LANs
- Concerns regarding the control and safeguarding of corporate data resources
- A lack of effective network management software for networked PCs
- Relatively high initial and lifetime costs per user

Over the past two years, however, most of these initial deterrents to the implementation of LANs have been gradually alleviated—first by the independent LAN software and equipment product developers and eventually by IBM. The adoption of industry standards through the IEEE 802 Local Computer Network standards committees provided an added feeling of comfort and investment protection for prospective LAN users.

Two LAN technologies are presently competing for market domination in corporate computing complexes—Ethernet and Token-Ring. Both are based on IEEE standards and are, therefore, nonproprietary. The basic technological differences are centered on Ethernet's carrier-sensed multiple access with collision detection (CSMA/CD) physical link versus the token-passing access method for devices attached to a Token-Ring network. Debates continue as to which provides better operation under various loading conditions and other performance-related factors. Based on list prices of LAN components, Ethernet technology appears to have a price advantage over Token-Ring equipment. This newsletter will not attempt to resolve or even to fully explain the cost and performance issues—we mention them here simply to point out that there are, in fact, price/performance differences.

Ethernet networks currently dominate the U.S. market for PC LANs in terms of both 1987 installed base and unit shipment levels. Table 1 shows Dataquest's estimates of product unit shipments for Ethernet, Token-Ring, and "other" PC LAN connections. The "other" category consists of proprietary or standard LAN products such as AppleTalk, Arcnet, Omninet, and Starlan systems.

Table 1

U.S. PC LAN Connections
(Thousands of Units)

	Actual 1987	Forecast 1988	1990	1992	CAGR 1988-1992
Ethernet Shipments	230	410	990	1,708	42.9%
Market Share	34.3%	35.0%	36.0%	36.5%	-
Token-Ring Shipments	211	433	1,155	2,036	47.3%
Market Share	31.5%	37.0%	42.0%	43.5%	-
Other Shipments	229	328	605	936	30.0%
Market Share	34.2%	28.0%	22.0%	20.0%	-
Total Shipments	670	1,171	2,750	4,680	41.4%

Source: Dataquest
July 1988

Ethernet systems entered the marketplace much earlier than Token-Ring products, and the Ethernet technology was very actively promoted as a de facto standard (by Digital Equipment, Hewlett-Packard, Xerox, and a host of independent manufacturers) long before the IEEE took formal adoption action. The availability of cost-effective, field-proven Ethernet products supplied by multiple vendors over a longer time period has established Ethernet LANs as the present market share leader.

Due to the large installed base of IBM and compatible PCs, IBM's obvious desire is to make Token-Ring the accepted standard for interconnecting most of its products. IBM has developed or catalyzed the development of most Token-Ring products. They are marketed as the primary IBM-authorized LAN system. Dataquest expects that IBM will continue to develop and release Token-Ring connections for all of its strategic products; eventually encompassing all workstations, departmental processors, and mainframes in peer-to-peer relationships.

Ethernet also supports the networking of IBM and compatible PCs. Many independent vendors have developed LANs and LAN-compatible products based on this IEEE standard. Ethernet's popularity stems from its ability to support a wide range of devices, applications, and interconnection media types—including connections to host computers, terminals, PCs, bridges, and gateways. Ethernet also supports two kinds of coaxial cable, twisted-pair wiring, and fiber-optic cable as interconnection media.

As was shown in Table 1, however, Dataquest believes that Token-Ring products are rapidly overcoming the lead built up by the Ethernet technology. We expect that U.S. shipments of Token-Ring connections will clearly surpass those of Ethernet connections in the 1990-1991 period. The rapid growth rate for Token-Ring products is attributed to the fact that IBM has unmistakenly designated that technology as its strategic LAN system. Perhaps the major factor behind the rapid upsurge of Token-Ring product shipments is the fact that major corporations, where IBM/PCM host mainframes dominate the DP complex, can now proceed with PC LAN implementations with strong assurance that their installations will be fully supported by future IBM releases.

IBM TOKEN-RING NETWORK CHARACTERISTICS

As IBM's designated strategic general-purpose LAN, the Token-Ring Network was designed primarily for host-based network applications. It offers users an alternative to SNA for department- and corporate-level networking, providing access to SNA Distribution Services (SNADS) and Distributed Office Support System (DISOSS) services on a peer basis. The Token-Ring Network will eventually interconnect the full range of IBM's information products—mainframes, small systems, PCs, terminals, and communications processors. Token-Ring support has been announced for the 3174 Subsystem Control Unit, the PC and PS/2 families, and the System/36 and 9370 processors. 3174 Control Unit Token-Ring support provides access to System/370 processors for up to four separate Token-Ring Networks.

Token-Ring is a star/ring topology network that uses digital baseband signaling over any of several various media—including shielded twisted-pair, unshielded twisted-pair, and fiber-optic cabling. Access protocol is the IEEE 802.5 Token-Passing Ring deterministic technique. Transmission media for the ring are defined within the IBM Cabling System that was originally announced in 1984. The Token-Ring Network topology is considered hybrid because it is a star-wired ring. The physical connection of ring stations (such as PCs) to wiring concentrators called Multistation Access Units (IBM Model 8228) creates a physical star, but the network behaves logically as a ring. The ring operates at 4 Mbps and uses a Manchester Encoding scheme to support baseband signaling. A single ring can support up to 260 device connections over data-grade media. However, if the devices are interconnected over unshielded telephone twisted-pair cables, a single ring is limited to support of up to 72 devices.

The token-passing ring scheme allows circulation of a single token on each ring. A device with data to transmit must wait until the device senses a free token (one without other ring data attached) before beginning transmission. This method allows certain devices such as bridges (which interconnect rings or other identical networks) and gateways (which connect rings to nonring networks) to gain transmission opportunities ahead of other, lower-priority attached devices.

Previous obstacles to the implementation of local area networks in major corporations included the lack of adherence to fixed standards and the need for effective network management tools for complex LANs. The IBM Token-Ring Network conforms to the IEEE 802.2 standard, providing a common interface at the Logical Link Control layer of the OSI Reference model. Users and/or developers of Token-Ring connectivity applications can generate programs to the IBM NETBIOS (Network Basic Input/Output System) or APPC/PC (Advanced Program-to-Program Communications) application programs interfaces. These are the same APIs used for development of IBM PC Network application programs, assuring a large base of compatible software for Token-Ring installations. IBM and independent LAN software vendors also offer a variety of network management programs for Token-Ring support.

The role of the 3270-type control unit in supporting micro-to-mainframe communications is well established as a result of the rapid proliferation of communicating PCs using add-in terminal emulation products, such as the Digital Communications Associates' (DCA) IRMA, and similar products. Those PC add-in products have evolved to provide LAN gateway capabilities by enabling a networked PC to emulate a 3274 control unit thus supporting multiple concurrent terminal or printer sessions between networked devices and an S/370 or PCM mainframe. Attachmate, DCA, and Novell are among the developers and manufacturers of those products.

Since the introduction of its 3174 control units in mid-1986, there is little doubt that IBM's strategy includes continued Token-Ring connectivity via the controller. Two models (3R and 53R) of the 3174 are specifically equipped for operation as nodes on a Token-Ring network, while all of the other 16 and 32 device models of the 3174 can provide gateway access into the 3270 environment for Token-Ring LANs. Several of IBM's competitors also offer similar Token-Ring connectivity options for their control units; most notably those that supply OEM products developed and manufactured by McData Corporation.

The bottom line is that IBM clearly intends that Token-Ring will become "the" standard local area network for connecting its PCs—together and/or to host processors. The largest users of Token Ring networks are most likely to be the same organizations that are also large users of 3270 display terminals. Given those factors, it seems inevitable that Token-Ring networks will have a major impact on the available market for 3270 display terminals.

DATAQUEST ANALYSIS AND CONCLUSIONS

IBM has clearly designated the Token-Ring LAN as its strategic local network product for linking mainframes, midrange processors, front ends, control units, and PCs. In Dataquest's opinion, that endorsement assures that Token-Ring networks will become the predominant LAN technology employed in major corporate DP/MIS complexes where 3270 networks currently abound. Much of the explosive growth that Dataquest projects for Token-Ring LAN products is premised on the market within Fortune 1000-size corporations.

Productivity and convenience factors dictate that many of these LAN-connected PCs will require some amount of interaction with host systems, necessitating that they be able to appear to the host as a display terminal. To the extent that these host-communicating PCs occupy desktops and perform display terminal functions, they limit the market opportunities for placing standard terminals in those locations. IBM's announced 1988 and 1989 releases of OS/2 Extended Editions are to include an advanced Communications Manager with 3270 emulation and LAN support capabilities. Dataquest believes that these operating system enhancements will further catalyze the installation of networked PS/2 systems in host-interactive applications.

A recent Dataquest user survey shows that selection between a display terminal or a host-connected personal computer (whether connected via a LAN or via other alternatives) depends on the primary application(s) to be supported by that device. Display terminal users are unlikely to substitute personal computers for their terminals; nor will a personal computer user choose to purchase a display terminal, even if it is significantly less expensive. The huge U.S. installed base of 3270-type displays (nearly 4.3 million terminals) has been built up to support applications that will, in our opinion, continue to be run on IBM/PCM host computers for the foreseeable future. Therefore, we believe that replacement of the terminals within that installed base will be largely immune to the likelihood of being supplanted by PCs—networked, or standalone.

Dataquest believes that as the 3270 market extends its reach further into the nontraditional sphere of office applications, it will provide increasing numbers of opportunities for display terminals, as well as for PC LANs. Growth for 3270 display terminal products will be aided by continued refinements to those products—particularly those enhancements that support the increasing user requirements for limited local processing as an adjunct to mainframe interaction. Dataquest's forecasts for 3270 display terminals and processing terminals in the 1988–1992 period predict that an increasing percentage of the expansion market for terminal devices will be filled by such processing terminals. We believe that failure of the vendors to provide timely, cost-effective displays with integral processing capabilities will permit further erosion of 3270 display terminal markets by local area networked PCs.

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Dave Norman
Joe Wagner

October–December

The following is the list of newsletters in this section:

(Continued)

October-December

(Continued)

October-December

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Research Newsletter

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EISA—WILL IT BE AN ALTERNATIVE FOR MCA?

SUMMARY

An alternative to IBM's microchannel architecture bus structure (MCA) was announced by a group of PC competitors on September 13, 1988. Support for the enhanced industry standard architecture (EISA) bus has been widely endorsed by PC vendors, hardware manufacturers, and software vendors.

This announcement has caused a strong reaction in the marketplace, with uncertainty as to which architecture to support. Businesses need to plan for the future, and the issue of whether to purchase MCA systems now or wait for EISA systems to become available is an important one. Dataquest believes that there will be some clear winners and losers with the EISA announcement and that the end result will be two "standards" playing to a confused customer base.

BACKGROUND

EISA was started by several PC manufacturers, led by Compaq, that did not want to pay the royalties that IBM demanded for using its microchannel architecture. They have argued that IBM developed MCA as a strategy to increase its market share and to limit the number of manufacturers of PCs by increasing the barriers of entry to low-cost manufacturers. IBM has denied this, stating that the MCA bus was developed due to its technical superiority and its ability to meet future computing demands.

At present, there is no product that uses the features of the MCA or EISA bus. The need is there, however, as speakers at Dataquest's PCIS conference dramatically proved. The immediate requirement is for high-speed graphics, optical storage, scanners, distributed processing, LANs, and data base management to control the masses of paper that businesses must process in a single day.

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The present ISA, or AT bus, is not capable of solving this requirement. As Bill Lowe, president of IBM Entry Systems Division, stated, the introduction of the EISA bus simply proves that a new bus structure is essential.

Technically, MCA and EISA can both support the same applications. Although proponents of each group claim advantages for their own design, the real question is: Which bus structure will win or will they coexist?

EISA

EISA Delivery Time

At this writing, the EISA bus is in its evolutionary phase. A preliminary technical synopsis has been developed with the goals stated and the outline developed. Each member of the consortium is now listing its input and needs. At some point in the future—say in six to nine months, according to the firm hired by the consortium to administer the details—the finished specification will be published. Work must still be done to generate the silicon, build prototypes, test and benchmark the system, obtain agency approvals, and so on.

Once PCs are introduced with the EISA bus, third-party manufacturers of add-in product will have a forum into which to sell their products. The board manufacturers' urgency to supply EISA boards will be limited to the size of this market. As EISA systems increase in the marketplace, third-party manufacturers will then allocate resources to service those systems. This delay in shipping EISA third-party boards can only boost MCA creditability.

EISA's success will depend greatly upon the perceived need of when an extended bus is required. The sooner the MCA bus can demonstrate that it can satisfy new demands, the fewer buyers will wait for the EISA bus to become available. Companies are balancing today's applications with tomorrow's advances and making risk decisions as to which bus structure to follow. If a company buys a PC without the extended bus today and an application that requires the new bus becomes available before the life of the newly purchased PC is over, then it has lost. On the other hand, why make higher expenditures for PCs if they will not provide a higher payback?

The average life of a PC is five years. Typically, older products are passed down to areas with no PCs, are discarded due to failure, or are sold to employees. A system purchased today, therefore, will perform the same tasks for its life. Dataquest believes that, perhaps as early as Comdex, high-speed graphics cards, communications boards, and improved disk and I/O management products will be introduced. These products will use the MCA bus because it is the only extended bus architecture at present. This will immediately place the proponents of EISA in a catch-up mode.

EISA Backward Compatibility

According to its advocates, EISA's main advantage is its backward compatibility for the customer. Customers have large investments in LAN cards, communication boards, and peripheral products that can be moved to newly purchased systems.

Dataquest does not agree that this issue is strong enough to dissuade businesses from purchasing a different bus architecture, for the following reasons:

- Because older systems are passed down intact to areas that were previously devoid of PCs, businesses do not have surplus boards available.

- The new systems probably contain standard features that were options on older systems.

- The third-party board manufacturers have added new features and functions to their products, which makes upgrading attractive.

These factors were amply demonstrated when the PC AT system was introduced. Imagine placing a 10MB, 85ms hard disk drive running on an 8-bit controller into the AT, or doing CAD/CAM with a CGA monitor driven by the original color card in an effort to save money.

Although backward compatibility is feasible with EISA, Dataquest believes that in a business environment, the bus layout will not significantly alter sales—provided support products, third-party boards, and peripherals are competitively priced and readily available. The total system price and the support product availability will ultimately determine which product will sell.

EISA Second Sources

Many companies selecting PCs prefer to have multiple sources for the same product. The number of PC manufacturers supporting the EISA Bus makes the EISA PC attractive for this reason. Dataquest believes that this is an especially critical area to watch—to ensure that the EISA bus is identical from one PC to another.

The potential exists for one manufacturer to "improve" on features to leverage market share, as in the case of expanded memory. A prominent group of companies developed an approach to use memory in protected mode to "stretch" real mode memory so that larger spreadsheets could be manipulated. Instead of staying with this scheme, another company developed a similar but different scheme with different features. Now, both EMS and EEMS memory management techniques exist.

MCA

MCA Delivery Time

IBM has been shipping MCA bus PCs since April 1987. Dataquest estimates that 1.5 million MCA-based systems will be installed by the end of 1988. Thus, companies that expect to have new applications for their PCs do not have to wait for a PC with the MCA bus to be developed.

Dataquest believes that third-party manufacturers of application hardware initially will concentrate their resources on MCA-based PCs, simply because of the large marketplace into which they can sell product. Strong development of products using the MCA bus will place the EISA bus in a catch-up mode.

MCA Backward Compatibility

MCA's disadvantage is that is is not compatible with the nearly 33 million MS-DOS PCs shipped since 1983. However, Dataquest does not view this as a strong justification for not purchasing the MCA PC for the reasons stated earlier. Those reasons are: the requirement to use existing PCs intact, the desire to upgrade to the new features and functions offered by third-party boards, and the fact that certain features are now standard on new PCs.

MCA Second Sources

Several companies have announced plans to ship MCA PCs or have announced that they are already shipping them. These companies, which are members of the EISA consortium, have stated that, one way or another, they will satisfy the customer. The argument that there is only one vendor for MCA has therefore been eliminated.

Apple's success is another illustration that shows the fallacy of the argument that companies are reluctant to purchase products from a sole source. Although it has a completely noncompatible bus and operating system and is the only company producing the product, Apple holds the number two spot behind IBM with an estimated 12.2 percent of the 1988 U.S. market.

MARKET PARTICIPANTS

To examine the success or failure of EISA or MCA, the participants must also be examined.

IBM

Dataquest believes that IBM holds the winning hand in this card game. It is in a good position to influence the outcome of the EISA/MCA challenge and can sway the business community to embrace MCA. Our analysis is based on the following factors:

- EISA may not be available from PC manufacturers for 12 to 24 months. This gives IBM time to introduce products that can take advantage of MCA, and to establish a user base. The sooner useful MCA applications hit the market, the greater the market share MCA will capture.

- Although it has stated that the royalty structure will remain in place, IBM always has the option of changing its mind, if it becomes beneficial.

- Companies that have a universal cross-licensing agreement in place with IBM may not be required to pay the same royalty fees as companies that do not. This makes it more attractive for those companies to manufacture MCA-based PCs.

- Most importantly, whereas MCA exists now, EISA is, at present, vaporware.

Compaq

Compaq Computer will hold an estimated 4.1 percent worldwide market share of all personal computers shipped in 1988. Compaq is also the leader of the EISA consortium, and we believe that it holds enough market share and following to make EISA a viable product. It was the first company to introduce an 80386 PC and continues to be a leading force in the industry.

Dataquest believes that Compaq will follow through and introduce EISA regardless of how the rest of the PC industry reacts to extended bus architectures.

EISA Consortium

Dataquest believes that the EISA Consortium is very serious. It is well organized and well supported by the members. Nevertheless, it faces an uphill battle against MCA with obstacles that IBM will exploit at every opportunity.

The first obstacle is that the EISA standard is being formed by a group of competitors anxious to increase their own market shares in an extremely competitive market. Even with the common interest of EISA, it is hard to believe that any group of competitors with a common goal will stay together. Any fragmentation in the ranks will be quickly noted by IBM.

A second obstacle is one of economics. Members of the EISA consortium will hedge their bets and will develop, or already have developed, MCA PCs, and will actively market them. This is partially due to the effort they have already put into cloning MCA systems and partially due to the fear of being caught without an extended architecture product if EISA stalls. Tandy, for example, is shipping MCA products now. John Roach, president and CEO of Tandy, stated at Dataquest's PCIS Conference that he would be ready to satisfy his customers whether they wanted MCA or EISA product. Dell has also announced that it has MCA systems.

The Winners and the Losers

The Winners

Dataquest believes that, provided Apple Computer can capitalize on its stable NuBus platform, it will be a clear winner as a result of the chaos caused by multiple PC bus standards. Corporations vacillating between the Apple and the IBM product will purchase Apple because it has a viable 32-bit bus technology without competitive confusion. Another winner will be the third-party board manufacturers that will sell their products to both buses—MCA and EISA. Board vendors view the two standards as expanded opportunities. They see the MCA and EISA markets as a larger total market that offers increased opportunities for selling their products. Certainly, Microsoft will win as it is hardware independent and will sell products to both MCA and EISA-based PCs.

The Losers

The losers will be the public, which ultimately will pay the price for this confusion, and the manufacturers, which must invest limited funds into both standards. Designing two products is costly due to development time, distribution and revision changes, service, and repair.

DATAQUEST CONCLUSIONS

Dataquest thinks that IBM will react strongly to the introduction of EISA in the following ways:

- Introducing applications—possibly at Comdex—that use the unique characteristics of the microchannel architecture

- Encouraging companies with cross-licensing agreements to introduce MCA products quickly and offering assistance to third-party vendors in order to increase the use of MCA

- Squeezing PC-clone vendors by lowering prices to make MCA PCs more attractive

- Seizing every opportunity to discredit the viability of EISA, as members of the EISA group introduce MCA products

However, Dataquest believes that IBM will reduce its licensing fees for MCA technology only as a last resort.

In the near term, we expect sales of MCA-based PCs to increase due to the creditability given to a new bus structure by the PC-clone manufacturers. In our opinion, IBM's influence, EISA's late entry, and fragmentation within the EISA ranks will hinder the acceptance of EISA systems. Compaq's strong influence and determination means that MCA systems and EISA systems will coexist in the market, with MCA products gaining market share as other vendors offer MCA systems.

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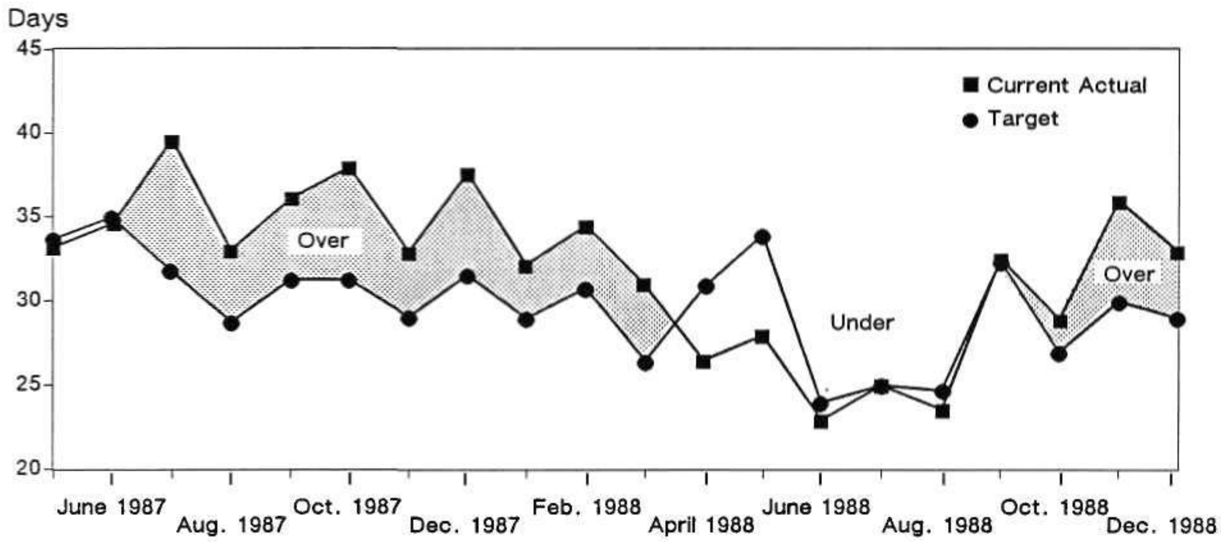
DECEMBER PROCUREMENT SURVEY: INVENTORY CONTROL REFLECTS ORDER RATE STABILITY

This month's survey respondents' actual inventory levels have edged back downward closer to targeted levels. Order rates for semiconductors remain mixed but also are edging downward, reflecting the need to keep actual and targeted inventories in line. System sales continue to fluctuate; the aggregate trend shows short-term high growth with slower growth rates expected next year. Overall, semiconductor billings are expected to be lower, mostly due to holiday downtime. As seen in Figure 1, the overall targeted inventory level has declined by 1.3 days down to 29 days, while the actual level has dropped a substantial 3.3 days down to 32.9 days. Improvements in memory availability and the effects upon other parts are being incorporated into procurement plans, keeping inventory levels in check.

Figure 1

Current Actual versus Target Semiconductor Inventory Levels (All OEMs)



0002165-1

Source: Dataquest
December 1988

Inventory levels for computer OEMs still remain over target but have significantly dropped since last month's survey. This month's difference between targeted and actual levels (4.2 days) is half that of last month, with targeted inventories lowered to 30 days and actual levels down to 34.2 days. The larger adjustment in computer company

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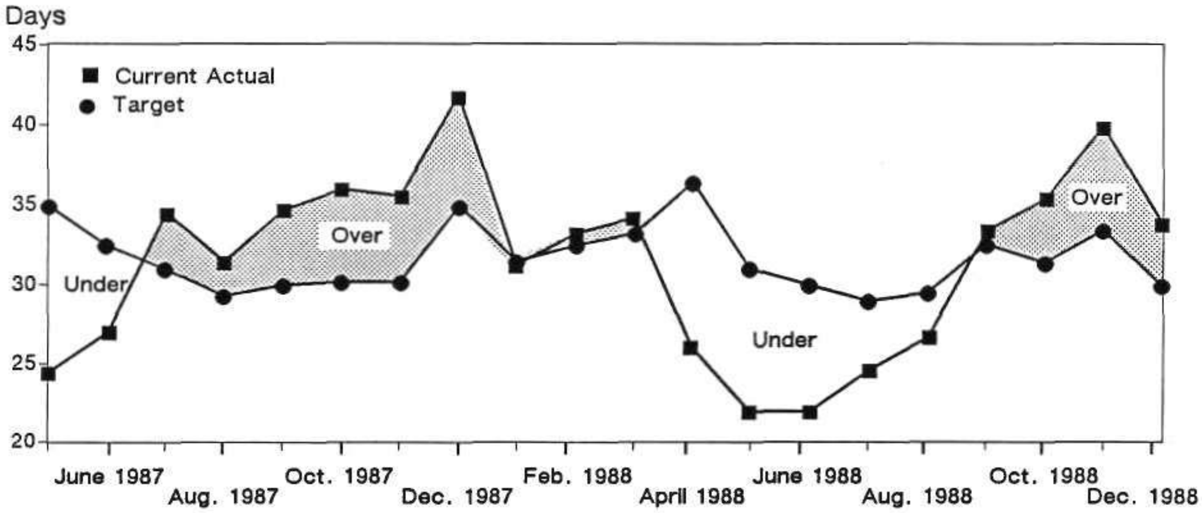
inventories is due to two factors: their relatively higher use of memory that has begun to be more available and the close communications this segment of the industry has exhibited with its semiconductor vendor base.

Figure 2

Current Actual versus Target Semiconductor Inventory Levels (Computer OEMs)



0002165-2

Source: Dataquest December 1988

Semiconductor pricing has stabilized compared with last month's softening. SRAM pricing remains firm and, in some configurations, is rising due to the continued lack of supply. DRAM pricing is softening in the 1Mb density, while remaining steady for the 256K parts. Overall lead times have declined by less than a week and still remain at 11 weeks. Surface-mount package availability continues to be a problem for some users, and the perennial problem of memory availability has not yet disappeared. Memory x4 configurations and sub-100ns speed availability are now of prime concern to many DRAM users.

DATAQUEST ANALYSIS

The inventory pendulum has begun to swing back toward targeted levels in response to lowered booking levels and related softening prices and lead times. The anticipated correction in inventory levels is on course. Dataquest expects this trend to continue through the end of this year, and actual levels should be very near or possibly below target by the end of January 1989. As 1Mb DRAMs continue to become increasingly available in the upcoming months, the momentum that is now beginning to decrease inventory levels will ensure that targets are hit or lowered. The current low inventory levels infer the following:

- Users are loathe to replay the 1984–1985 scenario.
- Good forecast communications are now in place that should smooth out some of the cyclicality of this volatile market.

We expect these trends to be the lasting legacy of the 1984–1985 fiasco and remain with the industry through this and upcoming cycles.

Mark Giudici

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FIRST JOINT DATAQUEST–SIA CONFERENCE HIGHLIGHTS MARKET IMPACT OF TREND TOWARD ELECTRONICS PERVASIVENESS

INTRODUCTION

At the first conference jointly sponsored by Dataquest and the Semiconductor Industry Association (SIA), 12 speakers and 150 industry participants discussed the strategic and high-growth markets for semiconductors. One theme ran through the speaker presentations: the "pervasiveness" of electronics in society as a long-term trend, and the challenges and opportunities for worldwide electronics manufacturers in terms of system technologies and product competitiveness. This newsletter highlights the event.

SEMICONDUCTOR APPLICATION MARKETS

The conference speeches focused on such high-growth markets as personal computers, workstations, graphics terminals, high-definition television (HDTV), computer storage, local area networks, voice processing, and military/aerospace systems. The speakers—many from manufacturing—drew upon deep experience in designing, marketing, and manufacturing electronic equipment in order to share with semiconductor suppliers their insights into meeting the needs of users. For semiconductor suppliers, the conference generated strategic information for winning long-term accounts at start-up companies and at established systems manufacturers.

SPEAKER HIGHLIGHTS

During the morning session, Allan E. Alcorn, Apple fellow, Apple Computer Inc.; Dennis W. Andrews, assistant general manager, IBM Corporation (Advanced Engineering Systems); George M. Scalise, president and CEO, Maxtor Corporation; Robert Cohn, president and CEO, Octel Communications Corporation; and Robert F. Lakin, director of strategy, Tandem Computers, shared insights on practical issues such as successfully supplying silicon products to fast-growth systems companies.

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During the afternoon, Richard J. Elkus, Jr., chairman and CEO, Prometrix Corporation; Gregory L. Sheppard, senior industry analyst, Dataquest's MilAero Technology Service; J. Daniel Robertson, vice president, Manufacturing, 3Com Corporation (Distributed Systems Division); and W. Mike Tyler, director, Dataquest's Graphics and Imaging Service, linked the issues of electronics pervasiveness and strategic silicon procurement to other challenging developments such as U.S. dependence on foreign technology.

Manny A. Fernandez, president and CEO of Dataquest, welcomed the speakers. In his remarks, Mr. Fernandez touched on the pervasive role of the PC in the current DRAM/memory procurement scenario. He stated that the anticipated growth in average PC memory content—from 256K/PC during 1986 to 3Mb/PC by 1990—makes DRAM procurement a continuing challenge for all suppliers and users.

Anthea Stratigos, director of Dataquest's Semiconductor User and Applications Group, set the stage for talks by systems and semiconductor manufacturers. She predicted smoothing of the wide cyclical swings between semiconductor demand and supply because semiconductor users and suppliers are learning to work in closer coordination through strategic partnerships. Inventory controls in place at system companies are also tempering wide or boom-bust cycles.

Ms. Stratigos identified the eight fastest-growing large semiconductor application markets. These markets mean both opportunity and challenge for semiconductor suppliers. As shown in Table 1, listing these eight markets, high-growth opportunities exist for manufacturers of systems that link computers with other systems—which translates into concomitant business for IC vendors. Speakers were unanimous, however, in their opinion that IC sellers would win and preserve long-term accounts only by anticipating and proactively satisfying users' needs.

Table 1

Fastest-Growing Large Markets
Estimated U.S. Revenue
(Billions of Dollars)

Segment	1988	1992	CAGR 1988-1992
Processing Terminals	0.1	1.0	86.7%
Optical Disk Drives	0.4	3.0	61.8%
Electronic Publishing	1.6	6.6	42.2%
3- to 4-In. Disk Drives	3.7	14.2	39.5%
Workstations	1.9	4.8	25.6%
Manufacturing Networks	0.7	1.7	23.9%
LAN Connections	2.4	5.4	22.4%
Cellular Radio	3.6	7.9	21.9%

Source: Dataquest
December 1988

As shown in Table 2, users' number one procurement issue during 1988 concerned product supply, whereas the major 1987 issue centered on pricing. The differentiation in priority signals the users' concern with competitive manufacturing cost versus the 1988 issue of securing components. Semiconductor suppliers need to track user issues like this one carefully in order to anticipate and meet users' changing needs. For example, a question from the audience regarding the apparent decline in user concern with semiconductor quality really translates into this message from users to suppliers: "The quality of semiconductor products is now fine, but don't dare let quality decline."

Table 2

Users' Major Issues

1987	1988
Pricing	Availability/lead times/shortages
Availability/lead times	Pricing
Quality/reliability	On-time delivery
On-time delivery	Cost control
FMVs/trade agreement	Memories
Cost control	Quality/reliability
JIT/inventory control	Reducing vendor base
Surface mount	New products/obsolescence
New products/obsolescence	JIT/inventory control
ASICs	Fluctuating yen/currency exchange
Offshore manufacturing and procurement	

Source: Dataquest
December 1988

Allan Alcorn of Apple Computer Inc., Robert Cohn of Octel Communications Corporation, and J. Daniel Robertson of 3Com made the same point to prospective suppliers of these rapid-growth companies. First, do not try for the big order/big design win on the first try. Learn your buyer's culture—the company's end-market pressures, procurement needs, strategies—and win the orders over time. Apple Computer, for example, uses a "strategic silicon" strategy whereby the company's design engineers, purchasing team, manufacturing staff, and marketing organization seek silicon products and technologies that offer multiproduct functionality and systems growth potential. Apple includes ASICs, microprocessors, and video DACs/RAMDACs as examples of strategic silicon.

Dennis W. Andrews of IBM Corporation pinpoints his concern with electronics pervasiveness in this way: The personal computers already developed and under development at IBM should be viewed as all-pervasive micro business systems—for example, as a mainframe on the desk and not as a simple PC. In terms of systems technology, Mr. Andrews sees the long-term pervasiveness equation as: "More MIPS + More Memory + More Bandwidth = Enhanced Human Interface."

Robert F. Lakin, Tandem Computers' strategic director, envisions the trend toward electronics pervasiveness in terms of enterprise-wide transaction processing. His vision is a single plug that connects all individual PC/workstation users into an enterprise-wide electronic network of PCs, mainframes, and voice/video communications. This vision of North American participation in the trend to electronics pervasiveness faces several challenges. From the systems technology side, the need for interface standards and parallel architectures becomes critical to the development of enterprise-wide electronic systems. In terms of organizational structure, there will be corporate budgetary battles, for example, between centralized corporate headquarters and decentralized individual users of systems.

As the leader of a Silicon Valley start-up company that has nurtured and grown an electronic systems technology, Robert Cohn of Octel Communications reinforced the central message from users to suppliers—that semiconductor suppliers must know their users' business, especially fast-growth systems houses, in order to know and anticipate users' special needs. Succinctly put, Octel needs high-performance devices to meet the needs of Octel's Fortune 500 customer base. Consequently, Octel demands high-quality parts and dependable supply/pricing practices from suppliers. Furthermore, Octel wants <u>both</u> the marketing team and the supply base team to work closely with outside suppliers to coordinate systems activity and semiconductor procurement.

Wading through the visions of electronics pervasiveness, Mr. Cohn sees closer user-supplier relationships as the key long-term trend in procurement strategy. Exemplifying through the 1987 procurement challenge associated with 256K DRAM, he reports that limited availability of the device restricted Octel's 1988 system sales somewhat. His point is that closer user-vendor arrangements can minimize, if not completely avoid, the kind of demand/supply mismatch that translates into lost sales for fast-track systems manufacturers.

The afternoon session began with a less optimistic—in fact, gloomy—view of the ability of North American systems houses to gain from the trend toward systems pervasiveness. Drawing upon his prior experience with Ampex, Richard J. Elkus, Jr., chairman and CEO of Prometrix Corporation, analyzed the benefits gained by the Japanese electronics industry through the purchase of VCR technology by Sony from Ampex during the early 1970s. The Japanese electronics industry made advances in semiconductor manufacturing, industrial electronics, and other media through VCR technology and earned huge revenue and profits from consumer electronics sales in the process. Looking ahead, Mr. Elkus foresees a fierce challenge for North American systems manufacturers should the United States fail to develop high-density TV (HDTV) system technology.

At worst, Mr. Elkus sees North American systems manufacturers, particularly those in the industrial and communications markets, as being dependent on Japanese or European electronics companies for HDTV technology. Technology dependence here translates into second-rate industrial strength at best and outright exclusion at worst. A corollary is that control of systems technology can spill over to semiconductor manufacturing, robotics, and other unforeseen areas.

Mr. Elkus effectively used the joint Dataquest-SIA conference as a forum for calling to North American users and suppliers of semiconductors to work with one another now and over the long term to confront the serious challenge of U.S. dependence on foreign technology.

Moving to the military arena, Gregory Sheppard of Dataquest foresees continuing challenge in the military/aerospace segment. The selection of George Bush in the 1988 presidential election means a 2 percent to 4 percent increase in real military spending versus Dukakis' proposal. Regardless of budgets, electronics will become an increasingly pervasive element of the content of military systems.

J. Daniel Robertson of 3Com looked ahead to the pervasive electronics systems of the year 2000. He contrasted the distributed computers of the mid-1990s with the networked (personal) computers of today. New ISDN chips and intelligent interfaces among other devices will be demanded by systems manufacturers such as Apple, IBM, and Tandem as they seek to interconnect systems. Coming from manufacturing, Mr. Robertson stressed that practical procurement issues will play a great role in the development of tomorrow's systems.

Despite the threat represented by the move to distributed data processing and HDTV in the 1990s, Mike Tyler of Dataquest brought our attention to the relentless zeal with which the worldwide electronics industry responds to hot opportunities like the current demand for workstations and graphics terminals. The overall message of Mr. Tyler's presentation is that this opportunity in workstations was not clearly foreseen 20 years ago. Furthermore, in unbridled Silicon Valley spirit, North American systems manufacturers and semiconductor suppliers are likely to capture a healthy chunk of other "unforeseen" opportunities in the pervasive electronics industry of the 1990s and the next century.

DATAQUEST RECOMMENDATION

The speaker comments can be summarized in a Dataquest recommendation. For semiconductor suppliers aiming to form long-term relations with fast-growth systems houses, the recommendation is as follows:

- Know your users' needs, business, and culture.
- Forget first day/big sales wins.
- Quality is the quiet king.
- Closer user-supplier relations mean:
  - Staying together through early sets of challenges and problems
  - Collaborating—and <u>not</u> competing—on product specifications and technology evolution

Ron Bohn

Dataquest

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Research Newsletter

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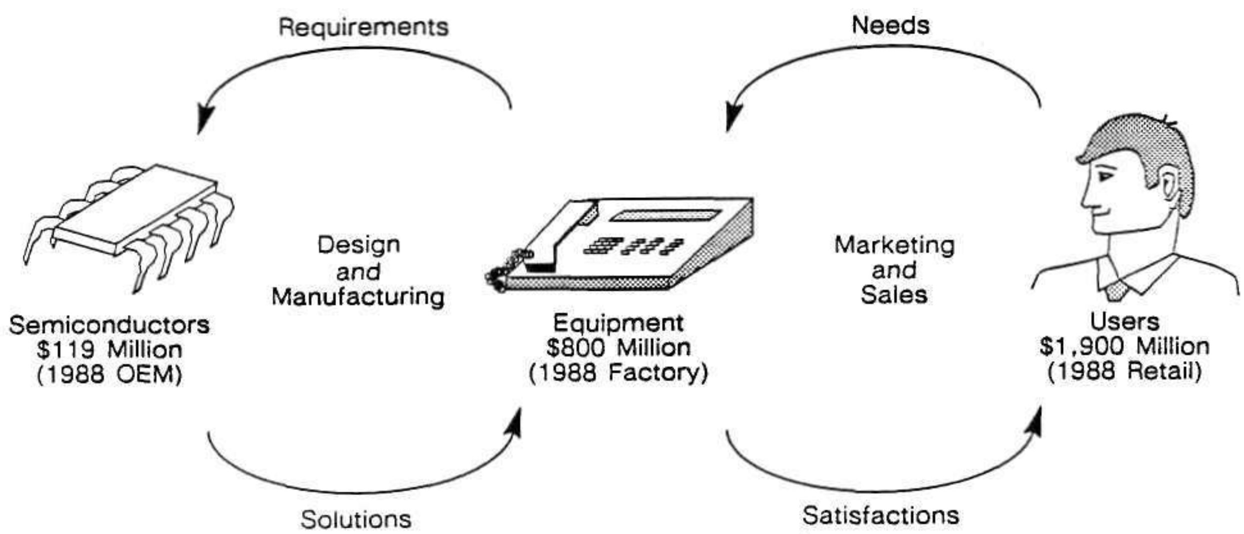
FAX MACHINES: TERMINALS TODAY, TOOLS TOMORROW

SUMMARY

A revolution in personal communications is occurring today because consumer demands and technology capabilities are now impacting each other. Figure 1 illustrates the favorable environment needed to create the type of progress that is currently happening. Equipment designers and semiconductor suppliers are presented with challenging opportunities whenever consumer needs or component technologies change or advance. This newsletter focuses on the specifics for fax machines from the standpoint of these concurrent and interrelated market and product evolutions.

Figure 1

Linking Market and Product Evolution



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Source: Dataquest
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Dataquest believes that continuing evolutionary advancements in semiconductors will make a revolution in fax machines possible. End-user needs drive equipment designs, and equipment requirements drive semiconductor components. However, advances in semiconductors make better equipment designs possible, and the end users receive more value for the purchase price of the equipment. We conclude that the result will be the widespread acceptance of fax by the business community within the next few years, and that fax then will be as essential to running a business as the telephone is today.

Dataquest estimates that in the United States, fax machine prices will continue to decline at a compound annual percentage rate (CAGR) of negative 10 percent; unit shipments will continue to increase at a CAGR in the 20 to 40 percent range; penetration of the business market, which is approximately 20 percent in 1988, will increase to about 70 percent in 1992; and a home market for fax will emerge in the early 1990s. We also predict that over the next decade, the capability for remote hard copy replication will become a standard feature on the deluxe models of some computer and communications equipment, such as laptop computers, laserbeam printers, cellular telephones, and personal computers.

THE MARKETING SIDE OF FAX MACHINES

Dataquest's estimate of fax machine sales in the United States is presented in Table 1. Between 1983 and 1987, Dataquest estimates that unit sales increased at a CAGR of 41 percent, while the average retail price declined at a CAGR of negative 11 percent. For 1988 through 1992, Dataquest estimates that unit sales will increase at a CAGR of 21 percent, while the average retail price will continue to decline at a similar CAGR of negative 12 percent. Semiconductor content is calculated using an average input/output ratio of 6.2 percent of retail sales.

Table 1

Estimated Sales of Fax Machines in the United States

Year	Unit Shipment (Thousands)	Average Price	Retail Sales (Millions)	Semiconductor Consumption (Millions)
1981	56	$4,747	$ 267	$ 17
1982	64	$4,429	$ 283	$ 18
1983	75	$4,195	$ 316	$ 20
1984	89	$3,827	$ 341	$ 21
1985	157	$3,170	$ 497	$ 31
1986	188	$2,682	$ 504	$ 31
1987	425	$2,352	$ 999	$ 62
1988	864	$2,227	$1,924	$119
1989	1,288	$1,921	$2,474	$153
1990	1,740	$1,627	$2,832	$176
1991	2,092	$1,327	$2,839	$176
1992	2,282	$1,146	$2,615	$162

Source: Dataquest
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User Base Expansion Is Under Way

Dataquest predicts that as the retail price of fax machines continues to decline, they will begin to be located at the department level in larger companies. (We believe that most fax machines today are located in centralized fax rooms.) We also predict that in the United States, the installed base of fax machines will increase from 1.5 million units in 1988 (or 19 percent of the 7.7 million business establishments) to 5.7 million units in 1992.

As additional evidence of the growing popularity of fax machines, Dataquest notes that there have been recent developments in the channels used to market fax machines to smaller businesses and also in the communications networks used to transmit fax. For example, in 1988, the Tandy Corporation announced that it would sell its $1,299 TandyFax 1000 fax machine through its 7,000 Tandy and Radio Shack retail outlets. Also in 1988, MCI Communications Corporation announced a new service called MCI FAX for the transmission of domestic and international facsimile messages.

THE MANUFACTURING SIDE OF FAX MACHINES

Dataquest's estimate of the semiconductor content of economy and midrange fax machines is presented in Table 2. Virtually all fax machines today are made in Japan and meet the Group III standard of the CCITT, which means they use digital transmission techniques based on modems and require approximately 20 to 30 seconds to transmit a page of information. Fax machines based on the Group IV standard currently being defined will use the ISDN network and will require about 2 to 5 seconds to transmit a page of information.

Fax machines based on the Group I or Group II standards are being retired from the installed base, and Dataquest estimates that they will no longer be in use after 1990. Group I and Group II machines use analog transmission techniques and require 120 to 360 seconds (2 to 6 minutes) to transmit a page of information.

Table 2

Estimated Semiconductor Content of Group III Fax Machines

Semiconductor Components	Economy Machines	Midrange Machines
Integrated Circuits		
Memory		
SRAM	1 (64K)	1 (256K)
EPROM	1 (256K)	1 (512K)
Microcomponents		
Microprocessor	1	1
Microcontroller	0	2
Microperipheral	1 (modem)	2 (modem, watch)
Logic		
Standard Logic	10	20
Gate Array	2	2
Linear	10	10
Discrete	51	57
Optoelectronic		
CCD	1	1
LED Array	1	1
Total Semiconductors	¥15,550 $124	¥18,850 $151
Facsimile Equipment	¥87,000	¥143,300
Factory Cost	$696	$1,146
Retail Price	$1,670	$2,750
Input/Output Ratio (factory)	17.9%	13.2%
(retail)	7.4%	5.5%

Note: ¥125 = $1.00

Source: Dataquest
December 1988

Component Prices Continue to Decline

The negative 11 percent CAGR reduction in fax machine prices is made possible in part by the reduction in numbers and prices of the components used to make the fax machine. For example, the fax modem component was a complete card in 1983, with an estimated OEM-volume price of approximately $300, and it was supplied only by Rockwell. In 1988, Dataquest estimates that this same circuit function is implemented as either one or two semiconductor components with an OEM-volume price in the $80 to $100 range, and that more than six component manufacturers have entered the market. (The fax modem suppliers include Hitachi, Hycom/Sharp, Matsushita, Oki, Rockwell, Toshiba, and Yamaha. Dataquest believes that SGS-Thomson also will be offering a fax modem component soon.) In 1989, Dataquest estimates that the OEM-volume price of the fax modem component will be reduced to the $40 to $50 range, as these component manufacturers attempt to grow their sales by competing for design-ins and bookings.

Component Functionality Continues to Increase

Another trend in fax machines is the use of components that can be programmed with software to perform a number of different operations. For example, the NeXT Computer system will use a digital signal processor (DSP) component made by Motorola that can be configured with software to be either a fax modem, a high-speed data modem, a speech synthesizer, or a CD-quality sound generator. Dataquest believes that OEM-volume pricing for such a component will be less than $40 in 1989, and if a user needs all of these features in an item of equipment that already has a microprocessor, the equivalent cost of the fax modem would be just a fraction of the cost of the DSP component itself.

There also may be fax component opportunities for suppliers of application-specific integrated circuits (ASICs). Dataquest believes that additional standard logic, linear, and discrete components might be integrated into ASICs to reduce the manufacturing cost and product size. Even though most fax machines sold today anywhere in the world are made in Japan, Dataquest notes that the Japanese manufacturers have been accelerating overseas production since 1986 to compensate for the high yen and the fear of trade barriers, such as tariffs and import restrictions. Local content regulations also have been proposed in some market areas, and if enacted, these rules would encourage the use of components supplied by companies located within the same market areas.

Component Technology Continues to Advance

As users are becoming experienced with fax, new feature-related needs are emerging that will affect the components required inside a machine. Dataquest believes that there are potential markets for fax machines with capabilities for color, store-and-forward, plain paper, error correction, multiple copies, shades-of-gray, and broadcast distribution. These deluxe model features will become more practical and more common as technology advancements continue to reduce their implementation costs to the point where users can afford them.

For example, the reliability and resolution of the scanning operation could be improved by changing from charged-coupled device (CCD) to contact image sensor (CIS) technology. However, Dataquest believes that the cost of the CIS technology will have to be reduced before it becomes a widely accepted substitute for the CCD technology currently used in most machines. Also, the current typical transmission time of 20 seconds per page for Group III machines using the Modified Huffman coding technique could be reduced by 55 percent to about 9 seconds per page using the Modified Modified Read (MMR) coding technique. Memory and microprocessor components are needed to run the software programs used to implement these coding techniques, and Dataquest estimates that the prices on these components will continue to decline in general at CAGRs in the negative 5 to negative 15 percent range over the next four years.

DATAQUEST CONCLUSIONS

The market for fax machines is growing rapidly, the number of suppliers of fax-related components is increasing, and the base of users of fax machines is segmenting. These trends in the fax industry indicate opportunities for entrepreneurs to find new groups of users for new kinds of fax-related equipment.

Fax Machine Sales Expected to Continue

Dataquest estimates that the maximum potential installed base for fax machines at companies in the United States is 7.5 million units. Although there are an estimated 7.7 million business establishments in the United States in 1988, 77 percent of these are the 5.9 million companies that have fewer than 10 employees. While a Fortune 500 company may own several hundred fax machines, some of the smaller companies may decide that the services of a neighborhood fax center are sufficient to meet their needs.

Dataquest also believes that there will be a home market for fax machines and the fax-related equipment that will emerge in the early 1990s. Our estimate for the potential installed base for fax equipment in the home is 7.5 million units. Some of these home users would be telecommuters who work at home several days each month, and a fax machine would supplement the office-compatible personal computer systems they already use at home for their work. Other home users would be people who moonlight in home businesses. Dataquest notes that statistics on moonlighters and home businesses are difficult to obtain, because participants in these activities are often reluctant to reveal their involvement. However, there are approximately 68 million white-collar workers and 91 million households in the United States in 1988, and we believe that the 7.5 million potential installed base of fax machines in the home to be a conservative projection.

Additional Opportunities in Niche Markets

Dataquest believes that the application markets for fax components are beginning to diversify. Today, most fax components are used in standalone fax machines, and Dataquest expects that this application will be the major market for fax components over the next five years. There are, however, other application markets currently in the niche stage that could expand as additional users discover the potential benefits of these fax-related products.

For example, fax cards for personal computers are available on the market now at prices ranging from $400 to $1,200, depending on the features included. Dataquest estimates that the 1987 PC fax card sales of 11,000 units in the United States will increase to 349,000 units in 1992, for a CAGR of 101 percent. Dataquest also believes that fax modem ports will be offered as features on deluxe models of laptop and portable computers, cellular telephones, and laserbeam printers. Coin-operated fax machines also are beginning to appear at some locations frequented by business people (such as airports), and Dataquest believes that this trend will continue as fax becomes an essential part of everyday business.

Long-Term Implications of Present-Day Developments

As communications networks continue to evolve throughout the 1990s, Dataquest expects that more image storage and transmission will take place electronically. Companies directly or indirectly involved in the telecommunications market must become aware of the impact of the present fax phenomenon upon their business. Fax machine manufacturers' purchasing managers for example, will want to have good relationships established with marketing managers at fax component manufacturers to ensure a dependable supply of parts.

Dataquest believes that separate pieces of equipment, such as personal computers, copiers, and fax machines, will begin to merge during the 1990s into an all-electronic communications network. Peripherals such as scanners and printers will be attached to this network as the link to the world of hard copy. The likelihood of this happening sooner rather than later depends on how fast the business community adopts fax as a necessity. That acceptance depends, to a large extent, on technology continuing to find ways to reduce the manufacturing cost of a fax machine today.

(Some of the data in this research newsletter were supplied by Dataquest's Japanese Semiconductor Application Markets service and Telecommunications Industry Service.)

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Research *Newsletter*

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THE MACINTOSH RIGID DISK SUBSYSTEM MARKET ERUPTS

SUMMARY

The subsystem question of the year turned out to be, "Why are so many companies jumping into the Macintosh hard disk market?" The supplier list has grown on a monthly basis, with entrants including companies like the mighty Control Data and the masterful marketer of MS–DOS storage products, CMS Enhancements.

Recent Dataquest research indicates that Apple Computer's pricing and product policies are responsible for its diminished share of the Macintosh storage market. Third–party vendors are reaping the benefits of Apple's errors to the tune of an estimated $350 million in 1988.

BACKGROUND

Over the past two years, all indicators seemed to point to the conclusion that the Macintosh storage subsystem market is small and unique, fragmented so badly that most participants have little chance of making a success of it. Three things seemed apparent:

- Apple is thought to have been shipping a hard drive with at least 75 percent of all Macintosh computers.
- The Macintosh storage market is too small, compared with that of MS–DOS.
- Macintosh buyers that do not buy a hard drive within 90 days of their computer purchase never will buy one.

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Some deeper research turned up some facts that proved these three assumptions to be completely false.

The Macintosh hard disk subsystem market is, indeed, one that can easily support several good suppliers. The add-in and add-on disk market for Macintosh storage will approach the $350 million mark in 1988, a number that is likely to grow to $900 million in 1990. Several factors make this possible.

Apple has failed to dominate as a supplier of hard disk drives to its Macintosh buyers. While the shipments of Apple-installed drives peaked at 75 percent of Macintosh shipments and averaged 50 percent in 1987, this number has plunged to less than 20 percent in 1988. The reason appears to be rooted in Apple's high pricing structures and limited-storage-capacity product options.

With Apple's market share decreasing, dealers have found a great opportunity to install their own 3.5-inch drives, configured to the buyers' requests. For example, a dealer can buy a 20-Mbyte, 3.5-inch, SCSI disk drive from a distributor for $250 or less, resell it at $500, and still undercut the latest Apple price by $100. Dealer upgrades have been a very large, profitable business in the MS-DOS world and are now becoming a way of life for Mac dealers. Buyers also benefit from being able to pick a storage product from a wide selection of capacities and performance characteristics.

New software releases are forcing floppy-only Macintosh users into belated decisions to buy a hard disk. They can no longer tolerate the limited capacity of 3.5-inch diskettes.

CURRENT STATUS OF MARKET

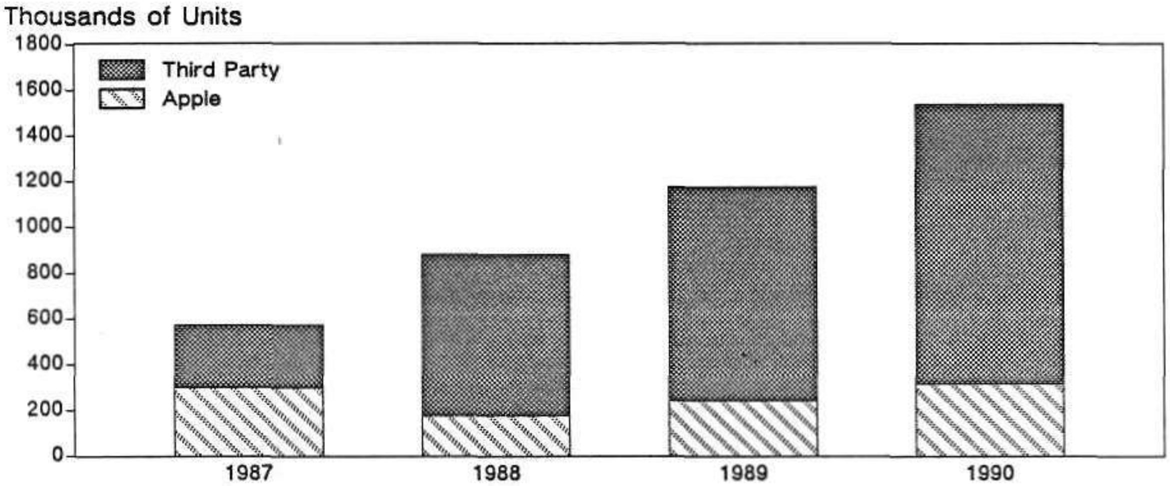
The Macintosh phenomenon is different from the MS-DOS world in many ways. For instance, the amount of software actually used by the Mac owners is two to three times that of MS-DOS users, and data file sizes are enormous. HyperCard has single-handedly done more for hard disk capacity requirements than any single piece of software in history. Mac users are actually required to have a hard disk drive in order to be productive. Insiders at Apple Computer disclosed that 95 percent of all SE owners have a hard drive, as do 99 percent of the Mac II owners, reflecting Apple's push into the business market and away from the home.

Capacity requirements for rigid disks on Macintoshes tend to be higher than those for MS-DOS machines. The SE owners average more than 40 Mbytes per drive; the Mac II drives have capacities in excess of 60 Mbytes. Network file servers for Macs average more than 300 Mbytes per server.

The Macintosh family's success is widely understood. Storage subsystem vendors gambled on Apple's failure to capture the storage revenue, and the time-of-sale upgrade market blossomed. Out of the total 880,000 Mac SEs and IIs that will be purchased with a hard drive in 1988, Apple will provide only 180,000 (see Figure 1). The remainder of the 700,000 drives sold will be supplied by the more than 40 companies now selling into this market.

Figure 1

Macintosh Rigid Disk Drives by Supplier



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Source: Dataquest
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WHO ARE THE PARTICIPANTS?

Winners in the MS-DOS subsystem wars will not necessarily be the beneficiaries of the spoils in this market. CMS Enhancements may be the exception to the rule. CMS became Seagate's largest "Super-VAR," selling hundreds of thousands of disk drive kits (including controllers) to small distributors for time-of-sale upgrades to IBM-compatible computers. CMS appears to be about to repeat its successes in the Macintosh market. Strong buying power and solid experience in the retail market are the CMS winning traits. Dataquest estimates that CMS will sell close to $80 million of hard disk subsystems to distributors and dealers in calendar 1988.

On the other end of the spectrum of suppliers is a very new venture into this market. MicroNet put together a business plan in late April 1988. In September, it shipped $500,000 worth of rigid disk drives into the Mac market. Offering very high-performance, high-quality disk drive products, MicroNet found the phone ringing day and night with international requests from dealers and distributors. Selling 33 percent of its products in the European market is a mark few new companies have attained that quickly.

Jasmine is the mature mail-order direct seller into the Mac market. A self-funded operation that continues to attract the best of the disgruntled employees from other Mac-oriented companies, Jasmine holds the third place position in the market.

An interesting rags–to–riches–to–rags story surrounds SuperMac. Still holding the top brand–name recognition distinction in the retail market, SuperMac has gone through both an acquisition and a deacquisition in a short period of time. Unfortunate times while under the mantle of Scientific MicroSystems have left SuperMac a shell of its former high–energy, high–tech self. Good understanding of the Mac user needs and a stronger financial position is likely to return this company to its original status.

Ranking the top storage subsystem vendors is a fairly easy job. Rodime Systems, a division of the disk drive company, has made up for its parent's loss of the Apple Computer OEM contract by becoming the largest after–market supplier of hard disks for the Macintosh. CMS is a close second, and Jasmine's mail order operation ranks it third. These three companies represent two–thirds of the total worldwide market.

Macintosh users are a group that demands high performance, fast access, and high technology. Storage companies like Quantum and Control Data have done well to focus on these needs. Apple Computer itself knows the value of superior mass storage products. Looking into the future for this market requires the suppliers to provide leading–edge devices at moderate prices.

DATAQUEST CONCLUSIONS

It is unlikely that Apple will take this revenue loss for too many more years. When processor margins diminish, watch the storage prices fall into line.

Our survey of the Macintosh hard disk market in late 1988 has been illuminating. Times have changed in favor of the third–party suppliers. This new industry should be advised that its success depends upon:

- High–quality, high–performance products
- Fair pricing
- Brand–name recognition (advertising dollars)
- Apple Computer's slow reaction to third–party successes

The months to come are more than likely to show strong growth in sales of hard disks to Macintosh buyers. This buyer's market will continue until Apple Computer decides to reclaim its rightful revenue.

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Research *Newsletter*

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AT&T: SEMICONDUCTORS, SYSTEMS, AND SERVICES (PART 2)

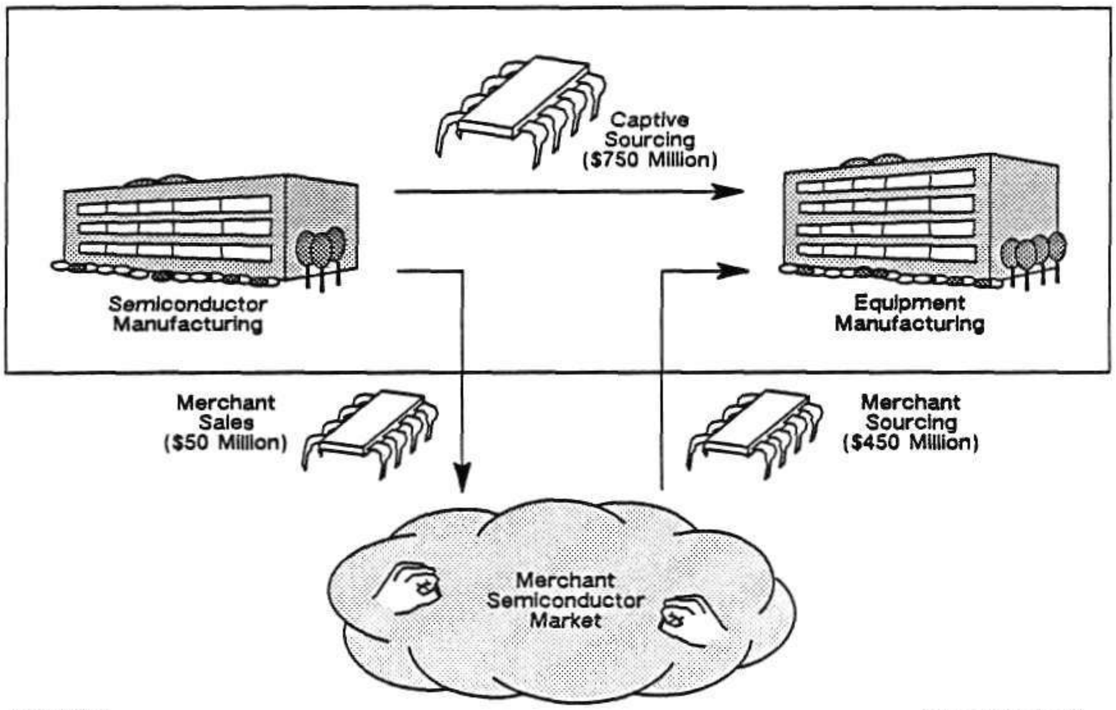
INTRODUCTION

AT&T is a vertically integrated company in transition from a regulated utility to a market-driven supplier of goods and services. This newsletter focuses on AT&T's $1,200 million consumption and $800 million production of semiconductors as it relates to its transition strategy.

AT&T is a manufacturer, seller, and purchaser of semiconductors as shown in Figure 1. We believe that the company will continue to expose its captive semiconductor operations to greater merchant competition as part of its overall strategy to survive in nonregulated businesses. In this newsletter, Dataquest examines AT&T's use of semiconductors along with the role of AT&T's captive semiconductor operation.

Figure 1

Semiconductor Consumption and Production at AT&T



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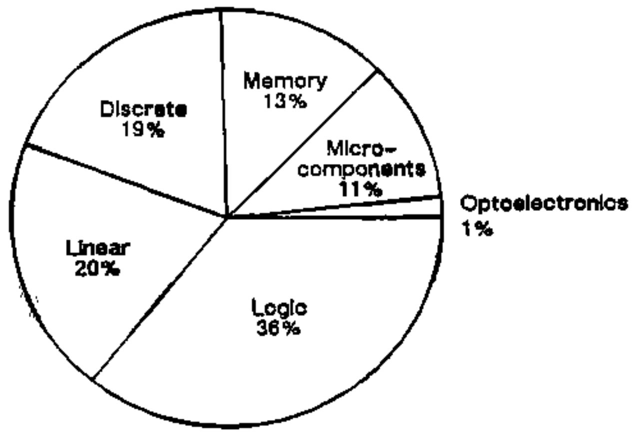
SEMICONDUCTOR USE

Dataquest's estimate of AT&T's 1987 semiconductor consumption by device type is presented in Figure 2. Communications-specific semiconductors such as codecs and combos are classified as linear devices. Logic devices include both application-specific integrated circuits (ASICs) and standard logic. AT&T has developed advanced ASIC CAD tools and uses its extensive knowledge of both networks and equipment to design customized devices for its communications products.

Figure 2

AT&T's Estimated 1987 Semiconductor Consumption by Device Type



Semiconductor Consumption = $1,224 Million

0002080-2

Source: Dataquest December 1988

Dataquest's estimate of AT&T's 1987 semiconductor consumption by end equipment (with our estimate of AT&T's U.S. market share for this equipment) is presented in Table 1. The company has its strongest presence in the public network equipment market. In the customer premises equipment market, Dataquest estimates that AT&T's consumption of semiconductors for use in telephone equipment and facsimile machines, for example, is very small because AT&T purchases most of its consumer telephones and facsimile machines from manufacturers in the Far East.

Dataquest's estimates of AT&T's semiconductor consumption and production by captive versus merchant sources are presented in Table 2. The percentage of semiconductors supplied to the company by its own component operations began to decline when AT&T dropped out of the DRAM manufacturing business. This trend reflects the company's process of adapting to a nonregulated business environment by dealing more with the outside merchant market. (AT&T's estimated captive versus merchant semiconductor sales will be discussed later in this newsletter.)

Table 1

AT&T's Estimated 1987 Semiconductor Consumption by End Equipment (Millions of Dollars)

Equipment Type	Equipment Revenue	U.S. Market Share	Semiconductor Content
Public Network	$3,759	50%	$688
Central Office Switches	1,395	49%	251
Trunk Carrier	494	45%	74
Multiplexers	350	37%	53
Subscriber Carrier	312	57%	47
Microwave Radios	104	22%	16
Satellite Earth Stations	15	5%	2
Others	1,089	N/A	245
Customer Premises	$2,580	25%	$450
Private Branch Exchanges	705	21%	120
Key Telephone Systems	637	28%	96
Telephones	320	15%	5
Modems	210	22%	32
Local Area Networks	45	2%	7
Data Service Units	30	48%	5
Facsimile Machines	27	3%	0
Automatic Call Distributors	16	13%	2
Voice Messaging Systems	15	5%	2
Modem-Based Network Control	13	20%	2
Integrated Voice/Data Workstations	5	8%	1
Video Teleconferencing	2	2%	0
Others	555	N/A	178
Data Processing	$ 575	3%	$ 63
Personal Computers	460	3%	46
Minicomputers	115	2%	17
Military	$ 560	N/A	$ 23

N/A = Not Applicable

Table 2

AT&T's Estimated Semiconductor Consumption and Production by Captive and Merchant Operations

Semiconductors	1985 $M	1985 %	1986 $M	1986 %	1987 $M	1987 %	CAGR 1985-1987
Total Consumption	$1,405		$1,188		$1,224		(7%)
Captive Source	1,095	78%	968	81%	757	62%	(17%)
Merchant Source	310	22%	220	19%	467	38%	23%
Total Production	$1,100		$ 983		$ 802		(15%)
Captive Use	1,095	99%	968	98%	757	94%	(17%)
Merchant Sales	5	1%	15	2%	45	6%	200%

Source: Dataquest
December 1988

All merchant-sourced semiconductors needed for manufacturing are purchased through AT&T's Integrated Circuit Procurement Center (ICPC) in Allentown, Pennsylvania. This centralized purchasing facility acts as a liaison between the company's several factory locations in the United States and the several semiconductor suppliers serving AT&T. The company and its suppliers enter into a partnership arrangement. The AT&T selection committee is composed of the following four members:

- Integrated Circuits Procurement Center
- Engineering for Purchased Integrated Circuits (EPIC)
- AT&T Bell Labs IC Reliability and Qualification Group
- Quality Management Services Organization (Springfield, New Jersey)

Selection criteria used by AT&T for establishing partnerships with a supplier include the candidate's pricing, product quality and reliability, manufacturing capacity, responsiveness on requests for quotations, and commitment of the management and staff to serving AT&T. Major trends at AT&T include the shift to surface-mount packaging, the growing use of ASICs, a narrowing of its supplier base, and the goal of implementing a just-in-time manufacturing system.

AT&T is also a major proponent of Integrated Services Digital Network (ISDN) and will be needing components for its ISDN equipment. The company's components group is planning to manufacture ISDN semiconductors both for AT&T's own internal use and for other customers. For this reason, Dataquest believes that a merchant supplier of ISDN semiconductors will face stiff competiton when trying to obtain design-ins at AT&T.

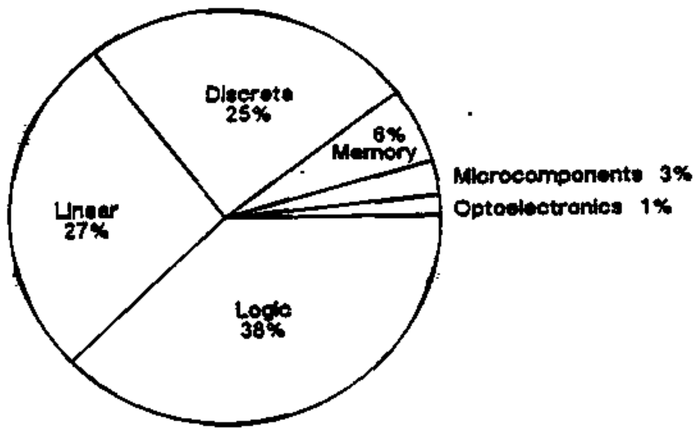
COMPONENT OPERATIONS

Dataquest's estimate of AT&T's 1987 semiconductor production by device type is presented in Figure 3. AT&T's estimated $802 million semiconductor output makes the company one of the 15 largest semiconductor manufacturers in the world. AT&T has focused its design efforts on ASICs, DSP, linear, communications, and high-voltage semiconductors. In the early 1980s, AT&T was one of the first semiconductor manufacturers to introduce a 256K DRAM product to the merchant market; it also introduced the 1Mb DRAM in the mid-1980s. In 1986, AT&T dropped its DRAM product line when these items could be purchased from the merchant market at a lower cost than they could be manufactured internally. AT&T is still a leader in SRAM technology and will supply its 64K specifications and tooling data to Sematech. All of AT&T's SRAM production, however, is consumed by its own equipment manufacturing.

Dataquest's estimate of AT&T's semiconductor production by captive versus merchant sales was presented in Table 2. Virtually all of the company's semiconductor production was consumed internally in 1987. Merchant sales have been growing at a CAGR of 200 percent, however, and AT&T has a goal by 1993 of deriving 50 percent of its semiconductor revenue from the merchant market. (Dataquest predicts that the company's 1988 merchant semiconductor sales will be in the $100 million range.)

Figure 3

AT&T's Estimated 1987 Semiconductor Production by Device Type



Semiconductor Production = $802 Million

0002080-3

Source: Dataquest
December 1988

Western Digital and AT&T have entered into a strategic alliance that includes extensive technology transfer; design support; and fab, assembly, and test of semiconductors. We estimate that Western will purchase approximately $55 million of custom CMOS ICs from AT&T in 1988 using AT&T's standard cell technology, and we believe that this business will expand to the $80 million range in 1989. We also believe that AT&T has a goal of establishing partnership arrangements with a total of 25 to 50 OEM companies as the preferred way of doing business in the merchant market.

AT&T recently reorganized its $2 billion component operation into five decentralized strategic business units. These units include MOS, lightwave, high performance (e.g., linear and digital bipolar, high voltage, and GaAs), power (e.g., transformers, power supplies, batteries, and magnetics), and interconnects. Dataquest believes that this organization change signals AT&T's commitment to being successful in the merchant market because the organization structure parallels the decentralized P&L approach already used by many component suppliers in this market.

Dataquest's estimate of AT&T's semiconductor fabrication capabilities is presented in Table 3. The company's broad mix of technologies and capabilities includes analog and digital, bipolar and MOS, commercial and military, and silicon and gallium arsenide. Both integrated circuits and photonics (i.e., fiber optics) are the semiconductor-related strategic research areas at AT&T Bell Labs. (Superconductivity is also a strategic research area at AT&T Bell Labs. However, just how superconductivity technology might apply to semiconductor components is not yet clear. As it did with the transfer-resistor—now shortened to the word "transistor"—in the 1940s, the company has a tradition of funding basic research with the hope that it might have a practical use.) Dataquest believes that AT&T will be installing submicron digital CMOS fab equipment in its factories before the end of 1988. Besides its own internally developed component technology, the company is willing to obtain technology from the outside as it is now doing with Sun Microsystems on the SPARC 32-bit microprocessor.

Table 3

AT&T's Semiconductor Fabrication Capabilities

Process	Location	Wafer Size	Capacity (Starts/Month)	Products
MOS	Allentown, PA	5-in.	16,000	Microperipherals, ASIC, DSP, communications (Mil. Std.)
	Allentown, PA	4-in.	10,000	ASICs, logic, communications,
	Orlando, FL	5-in.	28,000	SRAMs, cell-based ICs, microperipherals
	Spain	6-in.	Start-up	ASICs
Bipolar	Allentown, PA	4-in.	10,000	Logic
	Kansas City, MO	4-in.	10,000	Diodes, small-signal transistor
	Reading, PA	4-in.	2,000	Interface, telecom
	Reading, PA	5-in.	2,000	Op amps, converters
GaAs	Reading, PA	3-in.	1,000	Logic, memory, linear (Mil. Std.)

Source: Dataquest
December 1988

DATAQUEST CONCLUSIONS

Dataquest believes that, as part of its strategy to survive in nonregulated business areas, AT&T is encouraging its equipment manufacturing groups to obtain their components from the best available source. By doing so, AT&T will make its equipment more competitive in the marketplace. Its competitors, for example, will always strive for lower costs, higher performance, more features, and better quality as a way to differentiate their products from AT&T's products and from those of one another. Because these equipment-level characteristics are strongly influenced by the components used, we believe that AT&T's policy is a good one.

For the merchant manufacturers supplying (or wanting to supply) semiconductors to AT&T, this policy represents a business opportunity. Although the captive semiconductor operation may have been in a better position to supply components to AT&T's equipment factories prior to 1984, we believe that all semiconductor suppliers—both captive and merchant—now will be judged on their competitive merits when doing business with AT&T.

For the captive semiconductor operation at AT&T, however, this policy represents a business challenge. No longer is there a guaranteed market inside the company for its semiconductors. In addition, AT&T has begun to offer its semiconductor products to the merchant market. Hence, the company's semiconductor group now feels competition from both inside and outside AT&T.

Dataquest believes that AT&T must still learn how to compete in a nonregulated market. Just a few years ago, for example, the company was a leading supplier of 256K and 1Mb DRAMs to the merchant market. It had made an investment in the technology and had earned its leadership position. Yet AT&T quickly surrendered the market to the merchant suppliers just as soon as they could deliver higher volumes at lower cost. The company has demonstrated that it knows how to make breakthrough discoveries. We believe that AT&T must now learn how to do "street fighting" in a competitive market.

Dataquest has observed several recent developments at AT&T suggesting that the company is headed in the right direction, and we believe that it will expedite the formation of a culture driven by customer needs within AT&T. The company also has shown a willingness to make modifications and adjustments to a previously made decision when necessary. Dataquest sees AT&T's willingness to learn and to make midcourse corrections when necessary as major strengths.

Although AT&T has not yet made any major inroads into the merchant semiconductor market, we believe that the company will do so within the next five years. The company's ASIC design tools are state of the art, and its strategy of forming partnerships with several major OEMs will reduce some of the risk it sees in the semiconductor market. In the short term, these partnering arrangements may provide the company with enough of a breathing spell to get its objectives, strategies, and tactics in alignment. The merchant semiconductor market is not a static one, however. AT&T will likely find the merchant market of five years from now to be much different from the market of today because its merchant competitors also will be adapting their objectives, strategies, and tactics to the changing marketplace over the next five years.

Although most merchant semiconductor manufacturers do not consider AT&T a serious threat today, they might want to watch AT&T closely over the next five years to avoid being lulled into a false sense of security. With AT&T Bell Labs continuing to provide leading-edge technologies and the willingness of AT&T management to learn step by step how to succeed in a nonregulated rough-and-tumble marketplace, Dataquest believes that AT&T will emerge in the 1990s as a formidable semiconductor competitor.

Roger Steciak

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Research Newsletter

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SEMICONDUCTOR PRICE SURVEY: COMMODITY PRICES EASE WHILE KEY MEMORIES REMAIN FIRM

SUMMARY

Prices of commodity semiconductors (standard logic, mature microprocessor, and nonvolatile memories) began to decline as capacity increases of the past year finally caught up with demand levels. Supplies of 1Mb DRAMs continue to increase, and we are beginning to see slow decreases in prices as pent-up demand begins to be met. Other key memory products (256K DRAMs and slow SRAMs) remain in short supply and will continue to have firm, if not rising prices through the first quarter of next year. This newsletter will cover highlights of Dataquest's latest price survey and forecast.

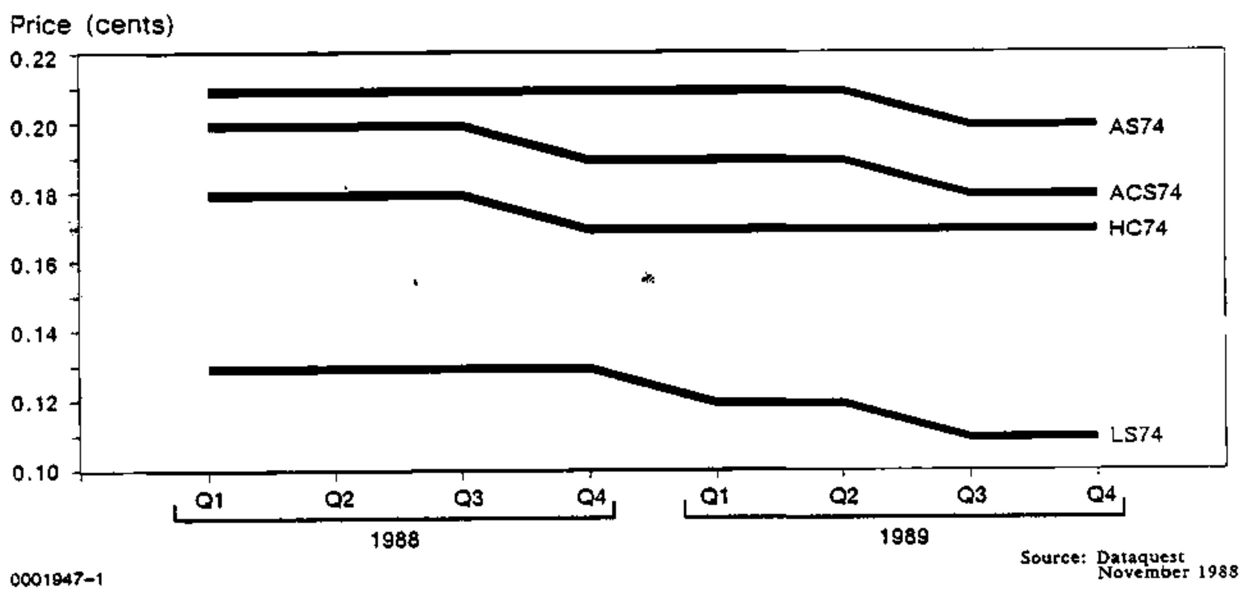
STANDARD LOGIC TRENDS

The supply–demand balance that was in evidence in our last survey has now become one of imbalance as production levels have outpaced overall demand. The traditional summer bookings slowdown experienced this year did not result in a corresponding correction in capacity. Standard logic prices (especially in the more mature families) have declined since summer and are expected to continue declining through the first quarter of next year, even though demand will remain steady due to the increased availability of the DRAM product (see Figure 1). Lead times have been cut in half and are now four to six weeks.

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

Figure 1

Standard Logic Price Trends



MICROPROCESSOR TRENDS

Microprocessor price trends show a softening in the slower 8- and 16-bit devices as the personal computer markets begin to show signs of a leveling of growth. The demand for high-end, 32-bit devices is becoming moderate, but prices remain firm and in line with the projected 5-percent-per-quarter price declines. The acceptance of the Intel 80386SX, Motorola 68020, and 80286-16 have caused some price erosion in the 10- and 12-MHz 80286 market, as these new products vie for market share. Lead times now range from 6 to 8 weeks.

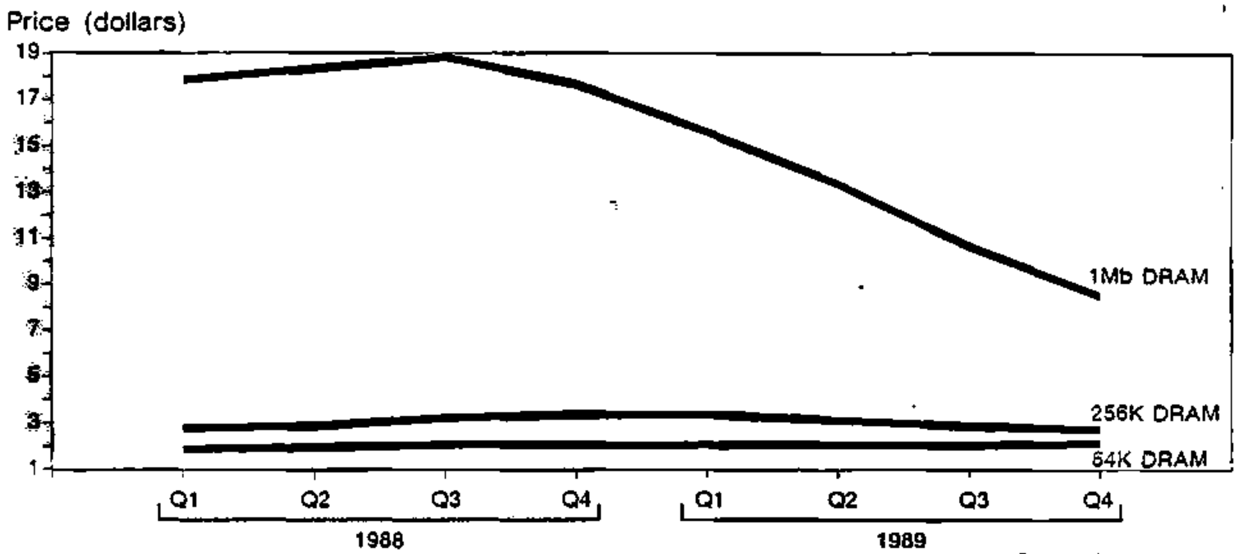
MEMORY TRENDS

Memory price trends fall into the following two camps: nonvolatile (EPROM, EEPROM, PROM et al.) and volatile (DRAM and SRAM). Nonvolatile memory prices have remained consistent, as a balance between supply and demand for these prices continues. Lead times for EPROMs and EEPROMs vary from between six and eight weeks and are expected to remain there.

The volatile memory market remains constrained because DRAMs have shown no easing in price for the 256K density (see Figure 2). The only decline seen has been in the 1Mb area; prices are beginning their long-anticipated decline due to production ramp-ups. We expect the 1Mb DRAM price erosion to continue and begin to accelerate in the second quarter of 1989, once supply catches up with pent-up demand. Prices for the 256K devices are expected to plateau by the end of the first quarter of next year and then will gradually ease as the overall electronics market demand softens. SRAM pricing is expected to follow the DRAM price trend by about three to six months. Slow, low-density (16K and 64K) SRAM vendors continue to make rumblings of an exodus from this market even though prices continue to climb. Until Korean and second-tier Japanese SRAM suppliers begin to fill this supply vacuum, prices will continue to rise. Lead times for the volatile memories range from 16 to 26 weeks (allocation).

Figure 2

DRAM Price Trends



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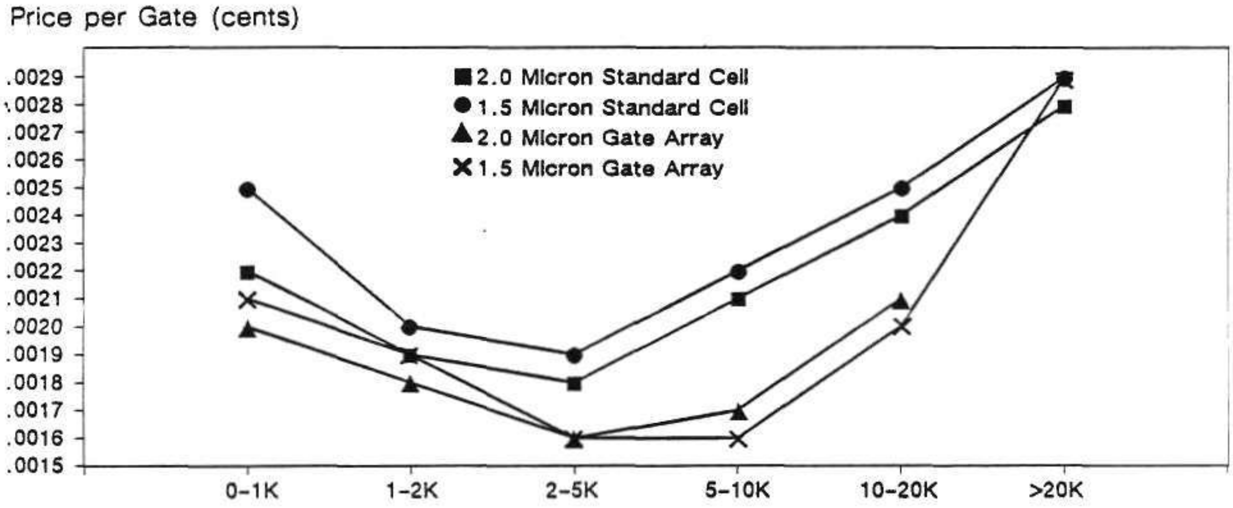
Source: Dataquest November 1988

ASIC TRENDS

Prices for both gate arrays and standard cells, as seen in Figure 3, have remained relatively unchanged since our last review. The differential between gate prices in the 1.5- and 2-micron range have narrowed, with the 1.5-micron technology now being at parity with the middensity (2K to 10K gates) range. Standard cell pricing still has the 2-micron process edging the 1.5-micron cells, while nonrecurring engineering (NRE) charges are almost the same. ECL gate array prices continue to exhibit high and low ranges reflecting the high- and ultrahigh-performance technologies now in the market. The more expensive small-geometry parts continue to take a 50-plus percent price premium over current price trends. We expect to see continued price competition in both gate array price per gate and NRE, as geometries are reduced and more Japanese vendors enter the market.

Figure 3

1988 ASIC Price Trends



0001947-3

Source: Dataquest
November 1988

DATAQUEST RECOMMENDATIONS

The increase in 1Mb DRAM supplies now beginning to be seen in the market will have a direct impact on prices for these and similar process memories. Pricing for the other IC families will also be tempered, as pent-up system demand eases. Contracts involving 1Mb DRAMs should, where possible, include clauses allowing for quarterly price reviews (+ and -). Prices for 256K DRAMs should be locked in at current levels for at least six months until the 1Mb supply balance and the electronics market slowdown begin to siphon off demand. System and component forecast accuracy, which is always important, is especially crucial during changes in the business cycle and when supply dynamics are in flux. In order for semiconductor users to retain the gains made through closer vendor communications, accurate forecasts are more important now than ever.

Mark Giudici

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Research *Bulletin*

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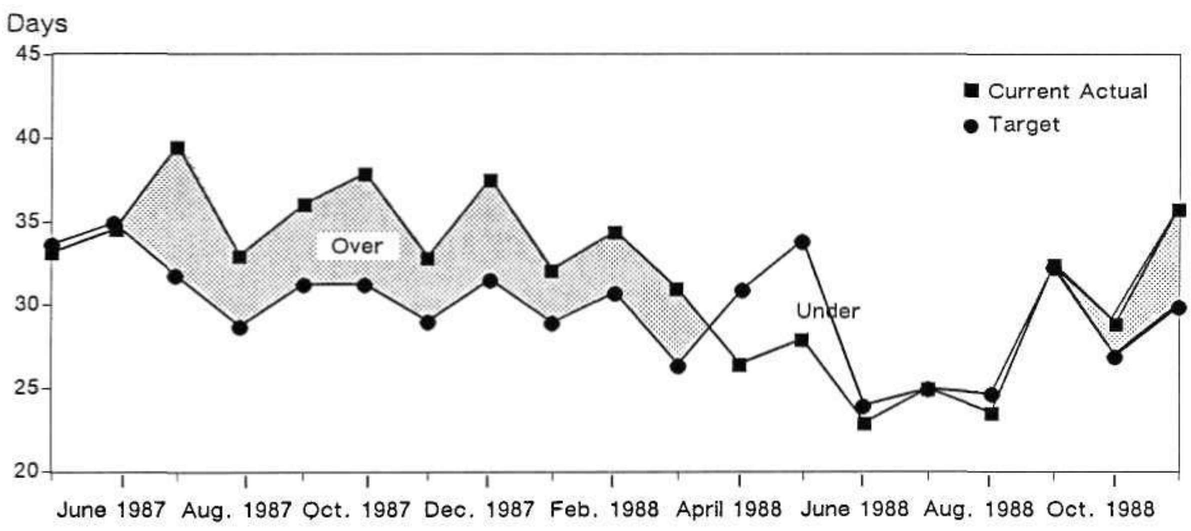
NOVEMBER PROCUREMENT SURVEY: INVENTORY TARGETS REMAIN ELUSIVE WHILE ORDER RATES STABILIZE

For the respondents to this month's survey, actual inventory levels continue to rise above targeted levels. Buyers have kept semiconductor orders at the same or slightly lower levels than last month in efforts to control these inventory costs. System sales have been mixed, with an even mix of respondents seeing slight increases and declines in their billings. As seen in Figure 1, the overall targeted inventory level has risen to 30 days, but the actual level of 36 days still remains above the new average target. This higher inventory target reflects how the momentum of past component shortages and recent availability improvements have combined to cause an overcorrection in actual inventory levels.

Figure 1

Current Actual versus Target Semiconductor Inventory Levels
(All OEMs)



0001882-1

Source: Dataquest
November 1988

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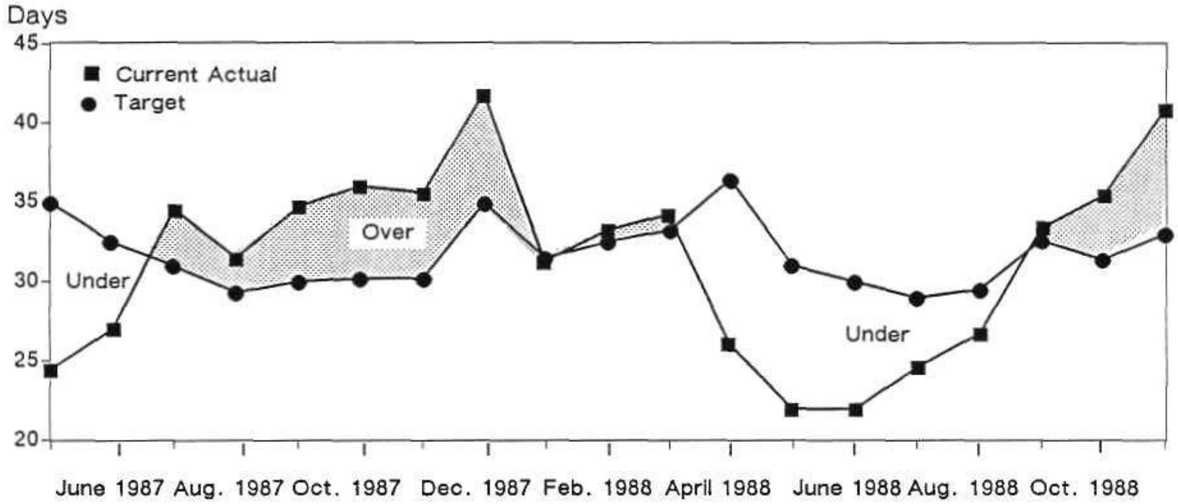
Inventories of computer OEMs remain over targeted levels, as seen in Figure 2, but the overage has stabilized with targets now set at 33 days and actual levels averaging 41 days. The adjustment period in inventories is expected to continue through the end of this year as a result of the aforementioned momentum of pent-up component demand.

Figure 2

Current Actual versus Target Semiconductor Inventory Levels
(Computer OEMs)



0001882-2

Source: Dataquest
November 1988

Pricing of semiconductors has softened in commodity standard logic and in some microprocessor devices. DRAM and SRAM prices remain high, but there is continued easing in 1Mb DRAM availability and prices. Overall lead times have remained the same at 11 weeks. Some renewed problems have occurred with surface-mount package availability, especially in the high-pin-count ASIC packages. Memory availability continues to be a problem; however, some ASIC supplies and deliveries now have become a procurement issue also because of shortages of high-pin-count ceramic surface-mount packages. This package situation should ease as more users shift to low-cost plastic alternatives.

DATAQUEST ANALYSIS

The continuation of inventory control measures now being exercised is initially reflected in the softening of commodity semiconductor prices and lead times and a resulting lowering of the semiconductor book-to-bill ratio experienced over the past two months. As 1Mb DRAMs continue to increase in supply, other related products (SRAMs, Video RAMs) will improve in availability also. Accurate forecasts of these key components will ensure that inventory levels of both semiconductor manufacturers and users do not drastically remain out of balance. As mentioned in our last bulletin, we expect this inventory correction to continue on through the end of this year.

Mark Giudici

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DATAQUEST LOOKS INSIDE IBM'S MODEL 30-286

SUMMARY

On September 13, 1988, IBM introduced a new addition to its PS/2 family—the Model 30-286. After analyzing the Model 30-286, Dataquest has made the following observations:

- The Model 30-286 will allow IBM to regain some of the market share lost to AT-compatible manufacturers in the business market.
- The Model 30-286 will extend the life of the PC AT architecture and delay the acceptance of microchannel.
- A Model 25-286 will be introduced in the near future.
- IBM's use of a PC chip set in the Model 30-286 will accelerate the use of PC chip sets by other PC manufacturers.

This newsletter discusses the positioning and the IC content of the Model 30-286 in further detail.

PS/2 MODEL 30-286

Product Specifications and Positioning

Has IBM reincarnated the original IBM PC AT? The Model 30 is not the original AT reincarnated but an enhanced version. Table 1 compares the specifications of the Model 30-286 and the IBM PC AT. The most notable changes are the 3.5-inch floppy disk drive, the inclusion of graphics capabilities on the motherboard, a 10-MHz processor instead of an 8-MHz processor, three expansion slots instead of seven, and a price of $2,595 instead of $4,595.

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Table 1

IBM PS/2 Model 30-286 versus the Original IBM PC AT (Feature Comparison)

Feature	Model 30-286	IBM PC AT (Model 339)
Processor	80286 (10 MHz)	80286 (8 MHz)
Bus Architecture	16-bit AT	16-bit AT
Memory	512KB	640KB
Graphics	VGA	N/A
Floppy Disk Drive	3.5-inch	5.25-inch
Hard Disk Drive	20MB	30MB
Expansion Slots	3	7
Price	$2,595	$4,595

N/A = Not Applicable

Source: Dataquest
November 1988

The question often asked is: Does the introduction of an 80286-based AT-architecture PC by IBM mean that IBM is moving away from the new microchannel bus? IBM's introduction of an AT certainly does not mean that the company will not continue to support the microchannel architecture in the future. However, the introduction of a new AT bus machine does create some confusion in the marketplace and probably will push the acceptance of microchannel-based machines even further into the future.

The 30-286 fills a hole in IBM's product line that the 8086-based Model 30 did not fill well—the low-end mainstream business PC user segment. Because IBM's 8086-based Model 30 is not competitive on a price/performance basis with the clone products, this market is being satisfied by the AT clone manufacturers. The new Model 30 is similar to current AT compatibles in that it has the AT bus, an Intel 80286 microprocessor, a 20MB hard disk drive, and VGA graphics capabilities. The new Model 30 differs from the standard AT compatible today in that it has only 512KB of main memory versus 640KB (expandable to 4MB), and a 3.5-inch floppy disk drive versus a 5.25-inch floppy disk drive. These differences should not hinder the acceptance of the Model 30-286 in the current marketplace. When the memory shortage has passed, IBM may increase the base memory configuration, and many vendors are offering customers the option of a 3.5-inch floppy disk drive.

The model 30-286 is much more price-competitive than the original Model 30. It costs just $300 more than the original Model 30 and has higher-resolution graphics and a higher-performance processor (80286 versus 8086). Dataquest believes that this price/performance improvement will allow IBM to gain back some of the market share lost to the AT clone manufacturers.

IC Content Analysis

The motherboard of the Model 30-286 is all surface-mount technology and highly integrated. The surprise was to see IBM using VLSI Technologies' PC chip set instead of the IBM proprietary gate array design that was used in earlier PS/2 family models. A number of reasons may have prompted IBM to move from a proprietary solution to the off-the-shelf VLSI Technologies chip set:

- VLSI's solution may be less expensive.
- The design time using the VLSI chip set may be faster than a proprietary solution.
- IBM may not have wanted to commit more fab capacity for the manufacturing of proprietary chips.

Whatever the reasoning for using chip sets, IBM's decision to do so has turned VLSI Technologies into a major participant in the PC chip set market. Dataquest believes that IBM's decision to use a standard chip set solution will lower the barrier to entry for chip sets to be designed into other PC manufacturers' products. Table 2 presents Dataquest's IC content analysis for the Model 30-286.

Table 2

IBM PS/2 Model 30-286 IC Analysis

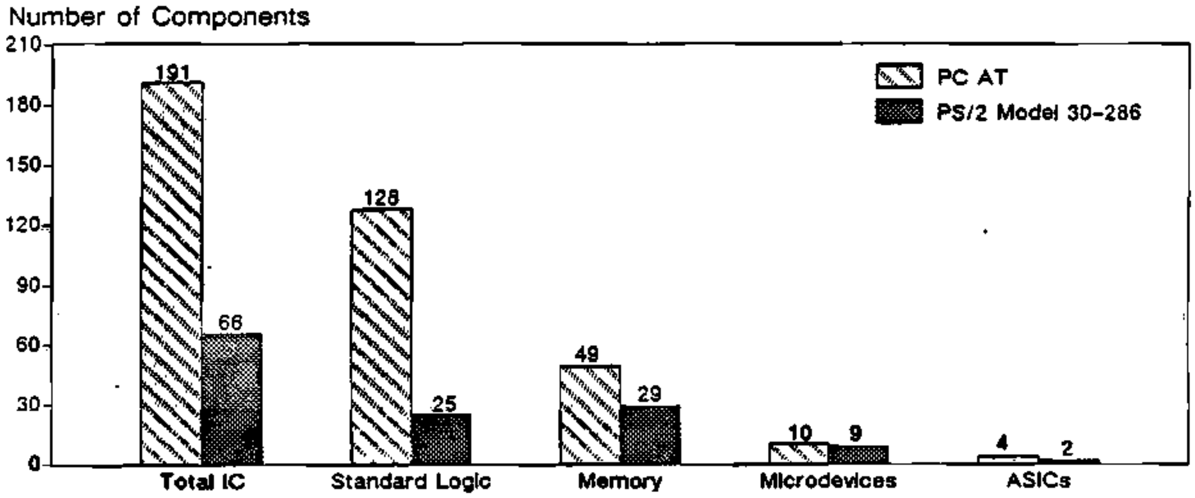
Description	Quantity	Cost	Major Suppliers
SSI/MSI Standard Logic	25	$ 5.43	National, Signetics, TI
Memory Devices			
256K DRAMs	18		TI
64K DRAMs	8		NEC
256K EPROM	2		Intel
SRAM	1		Inmos
Total Memory	29	$129.80	
ASICs			
Proprietary Custom VLSI	2	$ 21.00	IBM/SMOS
Microdevices			
80286 (10 MHz)	1		Intel
PC Chip Set	5		VLSI Technology
Floppy Controller	1		NEC
Clock/Calendar	1		Dallas Semiconductor
Peripheral Interface (8742)	1		Intel
Total Microdevice	9	$106.65	
Total IC	65	$262.88	

Source: Dataquest
November 1988

Figure 1 shows a comparison of the IC content of the original IBM PC AT with that of the Model 30-286. The IBM PC AT used a total of 191 components at a cost of $304.54 for the motherboard and separate display board. The PS/2 Model 30-286 uses 66 ICs at a total cost of $262.88. That is a 65 percent reduction in IC count and a 14 percent reduction in IC cost. The performance gain of the Model 30-286 in clock speed is 25 percent. The Model 30-286 also provides more than a 4X improvement in display resolution. The point is that advances in semiconductor technology have allowed IBM to manufacture their low-end PC with fewer components and higher performance at a lower cost than their high-end PC of less than three years ago.

Figure 1

IBM PS/2 Model 30-286 versus IBM PC AT
(IC Content Comparison)



0001887-1

Source: Dataquest
November 1988

DATAQUEST ANALYSIS

Earlier this year, IBM stated that all of its PCs would be based on the Intel 80386, 80386SX, or higher-performance processors by the end of 1989. The move to upgrade the Model 30 from an 8086 to a 80286 processor appears to be in line with this strategy of moving the PS/2 family to higher-performance processors. Dataquest believes that the introduction of the Model 30-286 at its current price point rings the death knell for the 8086-based Model 30. This introduction also foreshadows a similar upgrade for the Model 25. In fact, when looking at the Model 30-286, we noticed that the board layout is very similar to the current Model 25 motherboard. IBM may use the same motherboard for both systems.

The Model 30-286 moves the Model 30 from a machine based on dated technology to a segment of the market that Dataquest expects to grow over the next four years. We forecast 80286-based machines to grow at a 12 percent compound annual growth rate (CAGR) over the next four years, while 8086-based machines are expected to decline at a 22 percent rate for the same time period.

Dataquest believes that the use of an off-the-shelf chip set in the Model 30-286 is a fantastic coup for VLSI Technologies. It is also a good sign for other chip set vendors, indicating that chip sets will continue to replace proprietary ASIC and "discrete" standard logic solutions, especially in low-end systems.

Dave Norman

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Research *Newsletter*

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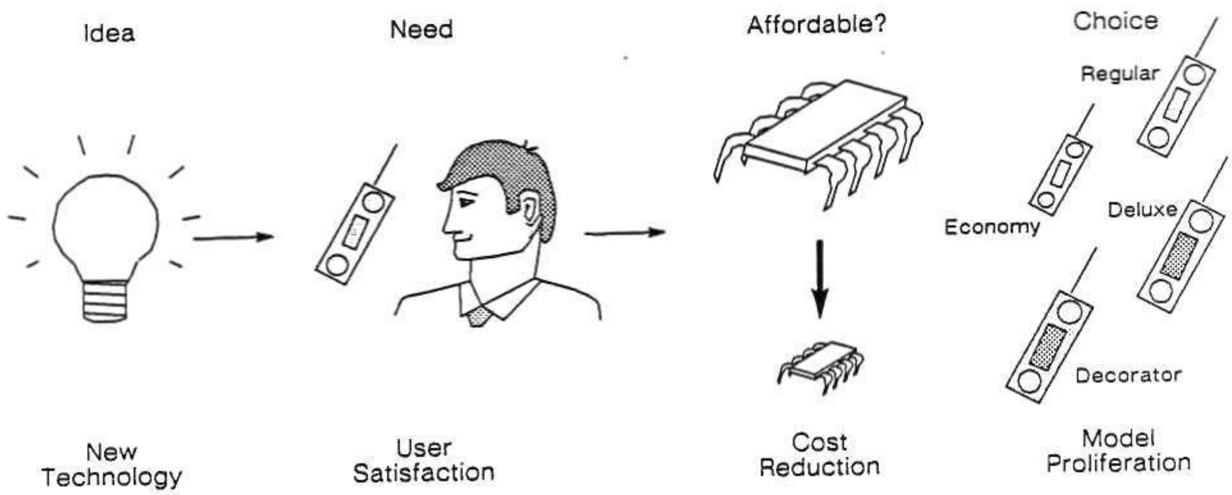
PERSONAL COMMUNICATIONS: FANTASY, FAD, OR PHENOMENON?

Pocket telephones, pager watches, laptop fax machines, and wireless modems are the personal communications products expected to be the next strategic opportunities in electronics. This newsletter focuses on the emergence of successful new consumer products out of the laboratory and onto the shopping list as illustrated in Figure 1.

Figure 1

Establishing New Consumer Products



0002915

Source: Dataquest
November 1988

Dataquest believes that the necessary forces of consumer awareness and need, technology-driven cost reduction, and a favorable regulatory climate are all converging today to create a revolution in personal communications in the 1990s.

Electronic calculators, digital watches, personal computers, and VCRs are the hot retail items of today. The consumer has a need for what they do and technology has made them possible and affordable. These products have already merged into the mainstream of everyday life and serve as examples for the potential of personal communications.

Car telephones and fax machines are communications-related retail items presently experiencing falling prices and ramping volumes. (Car telephone prices dropped 77 percent between 1983 and 1988 and annual shipments have increased by a factor of 100. Fax machine prices dropped 80 percent between 1983 and 1988 and annual shipments have increased by more than 300 percent.) Although the main purchasers of these products today are businesspeople, Dataquest predicts that consumers will soon be finding ways to put them to good use as technology continues to find ways to make them more and more affordable.

CONSUMER PRODUCT DYNAMICS

Any new product must satisfy a real and personal need as perceived by the consumer. Otherwise, the new product is nothing more than an interesting toy or novelty item. In the area of personal communications, Dataquest believes that consumers want to use the telephone more conveniently, no matter where they happen to be or what they happen to be doing at a particular moment.

The new product must be cost reduced so that it can be profitably manufactured at the low prices that consumers demand. At the retail store, for example, high-technology gadgets compete with clothing and sporting goods, and consumers will spend their money on those items that they perceive will give them the greatest value and satisfaction. Here is where semiconductor technology has always driven down costs by achieving scale economies. For personal communications goods to be successfully mass marketed, Dataquest believes that consumers will expect to pay between $5 and $50 for smaller items and between $50 and $500 for larger ones.

Success in the mass market also requires products to be available in a variety of models. Dataquest estimates that only about 16 percent of the population can be classed as innovators and early adopters who are willing to purchase new products when prices are still high and the selection is limited. Falling prices and the availability of several versions (e.g., from economy to deluxe and decorator models) are required to encourage the "two-thirds majority" of the population to buy. We estimate that the remaining 16 percent of the population are the laggards who will eventually adopt a new innovation, but only after the product has been on the market for a very long time and prices have become very low.

Dataquest believes that car telephones and fax machines are being purchased by today's innovators and early adopters and will be seriously considered by the "two-thirds majority" only when prices fall below the $500 level expected in the early 1990s. Semiconductor technology will continue to drive down the costs of these products in the meantime. As the "two-thirds majority" begins to purchase these products, Dataquest expects new uses to be found for them (e.g., clubs distributing monthly newsletters to their members via fax, civilians reporting traffic accidents to emergency response services via car telephones, etc.).

PERSONAL COMMUNICATIONS NEEDS

Telephones were first introduced in the 1870s and now have become firmly established with the public. About a decade ago, wireless versions of the telephone intended for the mass market began to appear. In 1987, for example, Dataquest estimates that more than 95 percent of the 90 million households in the United States had telephone service, with cordless telephones achieving a 7 percent penetration of the installed base of 194 million residential telephones. (The cordless telephone frequencies were first allocated by the FCC in 1977.) Also in 1987, Dataquest estimates that less than 1 percent of the 180 million automobiles in the United States had cellular-based car telephones. (The first cellular construction permit was authorized by the FCC in 1983.)

A pager is another type of wireless communications device. Instead of having the capability for two-way conversation, however, pagers merely alert or message users that someone wants to contact them. The pager user must then locate a telephone to proceed with the conversation. In 1987, Dataquest estimates that 3 percent of the 244 million people in the United States had pagers. Additional communications-related products and services now on the market include answering machines and voice mail systems.

As part of the coming revolution in personal communications, Dataquest believes that the features and benefits offered by these different kinds of communications equipment will be merged into a single hand-held unit. The communications elements to be integrated are summarized in Table 1. The resulting pocket telephone will alert the consumer of an incoming call, store a brief message if no one answers or there is a busy signal, allow two-way conversations for both incoming and outgoing calls, and permit both local and wide area movements during the call. Thus consumers will have the freedom and convenience to make and receive telephone calls at or away from their homes, offices, or automobiles.

Not all of these elements would have to be present in all communications products. A wristwatch with a built-in pager function (i.e., just the alerting and messaging elements) could be used by parents to summon their children home at dinnertime. (A wristwatch pager currently is being put on the market and is being purchased by businesspeople with a need for being paged over a relatively wide area. These pagers are designed for the nationwide paging networks expected to be in place in the United States by the early 1990s.)

Table 1

Integration of Communications Elements

Element	Present Discrete Implementations
Alerting	Telephone ringing, beeping, or voice pagers
Messaging	Answering machines, message pagers, voice mail (for storage and timeshifting)
Two-Way Conversation	Telephones
Local Area Roaming	Cordless telephones
Wide Area Roaming	Cellular mobile radios (metropolitan-wide areas), national cellular/paging networks (continent-wide areas when installed)

Source: Dataquest
November 1988

Dataquest also expects wireless technology to be applied in many kinds of products that would have greater value and convenience to the user simply by "cutting the cord." Examples include:

- Laptop fax machines
- Wireless modems
- Cordless mice
- Wireless PBXs
- Wireless LANs

Dataquest notes that consumers are already familiar with noncommunications wireless technology such as garage door openers (which use radio waves) and remote control units for TV sets and VCRs (which use infrared light).

THE PERSONAL COMMUNICATIONS REVOLUTION

The forces presently converging that will either make or prevent the personal communications revolution from happening are listed in Table 2. Dataquest believes that all of these factors are necessary, and any one not occurring will bring all progress to a halt. For example, the consumer must perceive the need for the service, the key technologies must be developed to build the system, government regulations must be favorable, semiconductor technology must make the hand-held units possible and affordable, and the network infrastructure must be put in place for the communications service to be offered.

Table 2

Converging Forces for the Personal Communications Revolution

Factor	Description
Consumer Benefits	Telephoning convenience Freedom to roam while communicating
Key Technologies	Radio frequency engineering High-efficiency modulation Voice compression Simulcast paging systems Digital communications Packet communications Voice store and forward
Regulatory Standards	Europe: PARS mobile radio Pan-European cellular system Japan: Cellular system standard (NTT) U.S.: Cellular mobile radio (CMR) Cellular technology testing Simulcast paging (FM/SCA)
Semiconductor Components	Low-voltage and low-power CMOS Very large-scale integration Surface mounting Silicon motherboarding
Network Infrastructure	Cellular networks, microcells Europe: 1991 service start-up plan Japan: Cellular network expansion U.S.: Metropolitan CMR network

Source: Dataquest
November 1988

United States

The United States is encouraging cellular network operators to introduce new technologies and test new services. The reason for this policy is the need to use the radio spectrum more efficiently. The cellular systems in New York, Chicago, Los Angeles, and Washington/Baltimore, for example, are heavily subscribed and are in danger of reaching maximum capacity in the relatively near future (e.g., Los Angeles in 1991). New technologies for efficient spectrum use and new services for cellular paging are being proposed. Dataquest believes that this regulatory flexibility will let the marketplace choose both the services it needs and the best technologies for the application.

Europe

The European Commission has issued a directive requiring that the technical specifications of all telecommunications terminals be made public, and that starting in September 1989, anyone may sell terminals that have been approved. The reason for this policy is the concern for competition within the European Economic Community. The pan-European cellular plan has been approved, and commercial service is expected to begin in late 1991. This service will be Europe wide and will include encrypted speech and data, electronic mail, message paging, and data communications up to 9.6 kilobits per second. The European system is implemented with digital technology and has significantly increased capacity over present systems based on analog technology.

Japan

Japan began its cellular activity in 1979 with the installation of systems in four cities, and expansion has been under way since then. In addition, a person-to-person wireless communication system operating at 900 MHz has become very popular. Other Pacific Rim countries installing cellular networks and new paging systems include Australia and Taiwan.

Future Plans

Dataquest believes that the technologies, systems, and services for personal communications will migrate along the path presented in Table 3. The late 1980s have witnessed the steady increase in sales of cordless and car telephones and the installation of metropolitan-wide cellular networks. In the early 1990s, Dataquest believes that these networks will become continent-wide. Dataquest also believes that there will be a change from analog-based systems to the use of digital techniques to improve capacity and flexibility. By the late 1990s, Dataquest believes that the pocket telephone and other personal communications products will emerge as throwaway consumer items available in discount stores everywhere.

Table 3

The Projected Migration Path for Personal Communications

Time Frame	Events
1985-1990	Metropolitan-wide cellular/paging networks Analog-based RF products (cordless and car telephones) Prices driven down by scale economies Purchasers and users are businesspeople
1990-1995	Continent-wide cellular/paging networks Digital-based RF products (cordless and car telephones) RF channel and hand-held unit technologies improved Increased purchases and usage by consumers
1995-2000	International cellular/paging networks Pocket telephones become throwaway consumer items Pagers become standard in watches and smart cards Wireless services comprise 30 percent of industry revenue

Source: Dataquest
November 1988

DATAQUEST CONCLUSIONS

Personal communications products are consumer-driven products. Dataquest expects pocket telephones, pager watches, laptop fax machines, and wireless modems to experience the same growth dynamics in the 1990s that electronic calculators, digital watches, personal computers, and VCRs experienced in the 1970s and 1980s. We believe that consumers will want the conveniences and freedoms offered by pocket telephones and other personal communications products based on wireless technology, and that these wants will turn into needs once consumers have tried the products and deemed them essential.

Dataquest believes that all the forces necessary to make the revolution in personal communications happen are present today. For example, the advanced technologies needed to implement a practical personal communications system exist in the laboratory. However, these must still be developed into products that meet the needs of the consumers and the regulatory requirements of the system. All of the technologies, components, products, networks, systems, regulations, and services needed must move forward together to make personal communications a reality.

We also believe that many of the technologies for personal communications have applications in other fields and will therefore be developed whether the personal communications revolution happens or not. For example, signal processing to improve the quality of sound in audio systems has potential applications wherever there are microphones, speakers, earphones, or headsets. Cordless appliances and tools (such as vacuum cleaners and electric drills) and battery-operated toys will continue to drive advancements in energy storage technology. Dataquest predicts that wireless technology (such as radio frequency engineering, high-efficiency modulation, miniaturized construction, and "battery life preservation" semiconductors) will have potential applications wherever the communication signals presently used in a system are below a frequency of 150kHz and a consumer or user would like to "get rid of that cord."

Dataquest recommends that the electronics industry watch the developments in personal communications because wireless technology has the potential to become the audio frequency "wire and cable" of tomorrow.

Roger Steciak

Dataquest
a company of The Dun & Bradstreet Corporation

Research Newsletter

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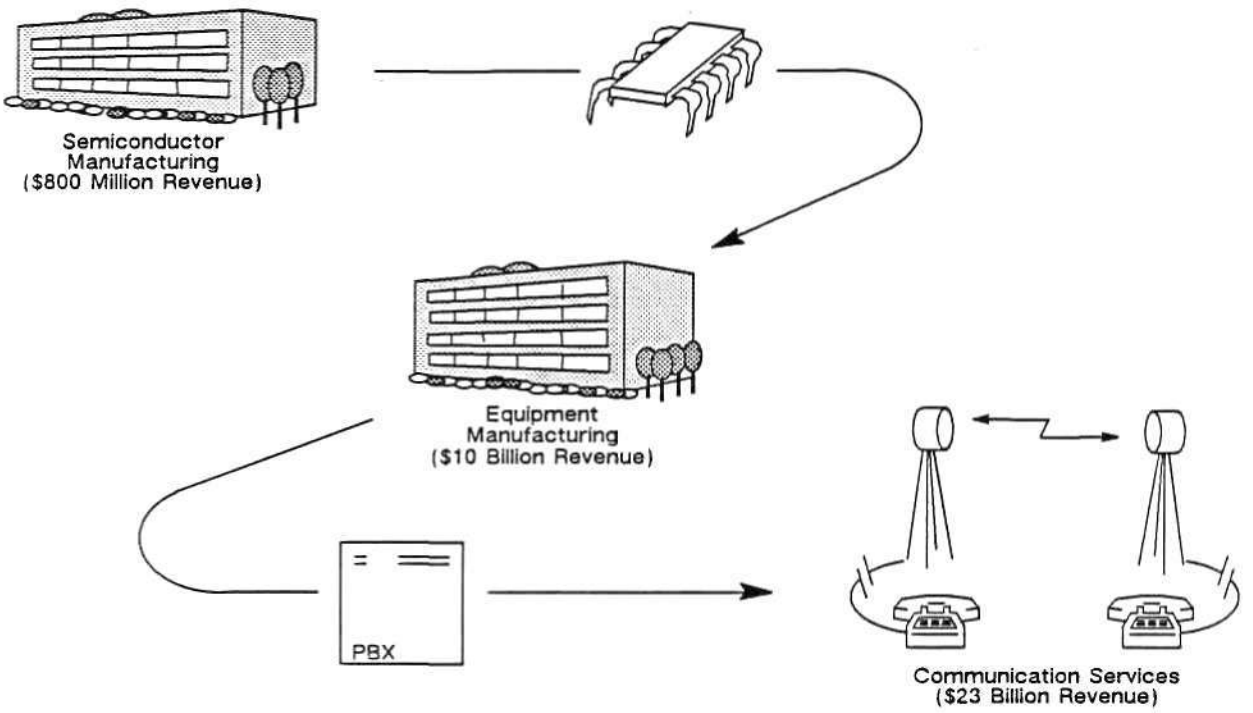
AT&T: SEMICONDUCTORS, SYSTEMS, AND SERVICES (PART 1)

SUMMARY

AT&T is a $34 billion vertically integrated "sand-to-service" company, as shown in Figure 1. AT&T is also a company in transition from a regulated utility to a market-driven supplier of goods and services, and both its equipment and component operations are being affected by this changeover.

Figure 1

Vertical Integration at AT&T



0001908-1

Source: Dataquest
November 1988

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The company lost 54 percent of its revenue and 76 percent of its assets overnight in 1984, when it had to divest itself of its local telephone business as part of an out-of-court settlement to an antitrust lawsuit. This 1984 settlement also replaced a 1956 out-of-court settlement to an earlier antitrust lawsuit that had prohibited AT&T from competing in the merchant markets for equipment and components. Since 1984, AT&T has been restructuring its organization and making whatever other adjustments are necessary to be able to compete in nonregulated business areas.

The downsized and unshackled AT&T remains on the "Fortune 10" list, but its manufacturing operations alone would have always qualified for the "Fortune 30" list. Dataquest has examined AT&T as a vertically integrated manufacturer of both semiconductors and systems to determine where the company is headed now that it has this new freedom to compete. We conclude that, although the company still has some adjustments to make, it is learning quickly and is destined to become a "lean-and-mean giant" in the 1990s, capable of competing in any areas it chooses.

Part 1 of this newsletter focuses on AT&T's $10 billion equipment manufacturing business as it relates to its transition strategy. Part 2, to be published at a later date, will focus on AT&T's $1,200 million consumption and $800 million production of semiconductor components as they relate to its transition strategy.

MANUFACTURING OPERATIONS

AT&T derives $10 billion per year from the sale of products, representing 30 percent of the company's revenue. AT&T's product lines consist of equipment for the communications, data processing, and military markets. In addition, AT&T has its own components group to supply communications-related materials and devices to its equipment manufacturing operations and to the merchant market. AT&T also has the Bell Labs organization to conduct basic and applied research into technology areas that are strategic for the company. Of the company's $2.4 billion research budget, 90 percent is applied toward the development of revenue-generating products and services; the remaining 10 percent of the budget is applied toward fundamental research in fields that show promise for revenue-generating applications in the future, ranging from basic physics to software. It is these capabilities for research, design, and manufacturing that AT&T is adjusting in order to survive and prosper in nonregulated businesses.

AT&T's performance results for the years 1985 through 1987 are presented in Table 1. Overall, revenue has remained relatively flat at $34 billion and head count has been reduced slightly to a level of 300,000 employees. However, income has increased during this time period as a result of the company's ongoing efforts to adjust. In 1986, for example, the company recognized the need to establish a reserve of $2.5 billion (pretax dollars) to cover the cost of restructuring over the next several years. To date, four equipment manufacturing plants have been closed, two more facilities are scheduled for closing, and Dataquest believes that other production lines will be consolidated in the future to lower the company's manufacturing costs.

Table 1

AT&T's Performance Results

	1985	1986	1987	1985-1987 CAGR
Revenue ($M)	$34,417	$34,087	$33,598	(1.2%)
Income ($M)	$ 1,557	$ 139	$ 2,044	13.5%
Employees	338,000	317,000	303,000	(5.3%)
Merchant Product Sales ($M)	$11,235	$10,178	$10,206	(4.7%)
Merchant Products/Revenue	33%	30%	30%	

Source: AT&T Annual Report
Dataquest
November 1988

AT&T has traditionally been a company based almost entirely in the United States. One aspect of its new strategy is to establish a stronger international presence, and AT&T now is engaged in joint ventures with companies in Europe, Japan, and Southeast Asia to smooth its entry into these markets. The company also has begun to locate some of its production activities offshore using either company-owned facilities or contract assemblers to lower its manufacturing costs.

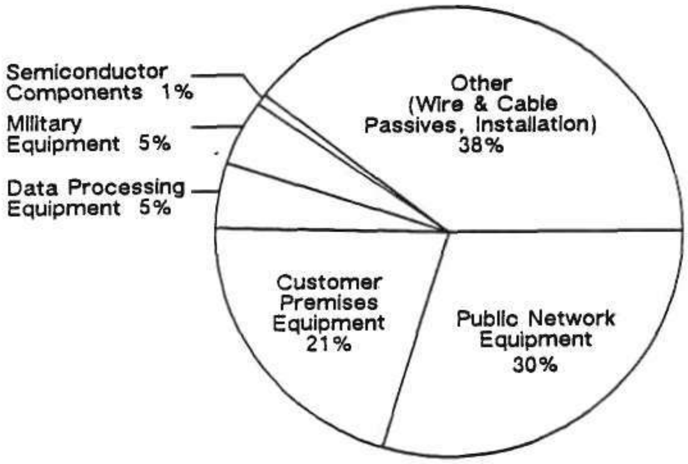
EQUIPMENT SALES

The relative sizes of AT&T's manufacturing businesses (including captive sales) are shown in Figure 2. The majority of electronics-based revenue is derived from the sale of public network equipment. Dataquest estimates that AT&T has 50 percent of the U.S. market; the customer base for this equipment includes AT&T Communications, the seven regional Bell operating companies (i.e., the local telephone service companies spun off from AT&T in 1984), and the approximately 1,400 independent telephone companies operating in the United States.

Dataquest also estimates that the company's sales of customer premises equipment represent 25 percent of the U.S. market and that the company's sales of personal and minicomputers represent 3 and 2 percent of the U.S. market, respectively. (The 1956 ban on AT&T supplying computers to the merchant market was lifted in 1984 as part of the antitrust settlement.) The United States Air Force awarded AT&T a $1 billion contract in 1988 for the delivery of computer equipment and software for both military and civilian installations worldwide. Besides the potential for up to $5 billion of revenue to the company over the next five years, we believe that this contract award will have spillover effects by helping to improve AT&T's reputation and position in the merchant computer market. In addition, AT&T's military business makes it one of the 20 largest defense contractors to the U.S. government.

Figure 2

AT&T's Manufacturing Businesses (Including Captive Equipment Sales)



1987 Product Sales = $12,400 Million

0001908-2

Source: Dataquest November 1988

Dataquest believes that AT&T manufactures $2 billion of components each year. Approximately $800 million of this production is semiconductors, and the remainder is other products such as wire and cable, passive components, batteries, electronic power supplies, and transformers. About $300 million of this $2 billion production is sold to the merchant market, and the remainder is consumed internally. We further believe that AT&T's $45 million of semiconductor component sales in the merchant market in 1987 provided it with less than 1 percent of its manufacturing-derived revenue.

AT&T's 1987 overseas manufacturing activities are listed in Table 2. The company desires to increase the amount of revenue it derives from sources outside the United States from the present 9 percent to an eventual 25 percent. Besides manufacturing, AT&T has joint marketing arrangements in other countries. In Japan, for example, AT&T Ricoh markets key business telephone systems, Toshiba distributes AT&T's private branch exchange equipment, and Japan ENS Corp. (which is 50 percent owned by AT&T) provides value-added network services. Most of these ventures were started within the past five years. We believe that AT&T has found the competition in these overseas markets to be stiffer than expected and will continue to make adjustments as necessary to keep these businesses growing.

Table 2

AT&T's Manufacturing Activities Overseas

Location	Partner	Products
Denmark	NKT	Fiber-optic cable
Hong Kong	Owned by AT&T	Printed circuit boards
	Radofin	Telephone equipment
	Termbray	Telephone equipment
Italy	Olivetti	AT&T: sell Olivetti microcomputers and office automation equipment in U.S. Olivetti: sell AT&T minicomputers and private branch exchanges in Europe
Japan	Shindengen Electronics (in process)	Power supply modules
Korea	Goldstar	Central office switches, fiber-optic cable
Mexico	Metamores (subsidiary)	Power equipment, transformers, inductors
Netherlands	Philips	Central office switches, network and transmission systems
PRC	Termbray	Telephone equipment
Singapore	AT&T Consumer Products	Telephone equipment
	PCI	Telephone equipment
	Subsidiary	Semiconductor assembly and test
Spain	CTNE	Semiconductors
Taiwan	AT&T Taiwan Telecommunications	Central office switches
Thailand	N/A	Telephone equipment
	Subsidiary	Semiconductor assembly and test

N/A = Not Available

Source: Dataquest
November 1988

AT&T's manufacturing facilities in the United States are listed in Table 3. Two of these facilities are to be closed and others are being downsized either as production lines are being consolidated or as the production itself is being transferred to an overseas location. AT&T has continued to reorganize and shift personnel in an attempt to convert from a "U.S. company with a U.S.-only strategy" to a "U.S.-based company with a global strategy." Not all of AT&T's strategic alliances are with overseas companies. In the United States, for example, AT&T has entered into an agreement with Sun Microsystems that covers both software (e.g., the UNIX operating system) and hardware (e.g., SPARC—Scalable Processor ARChitecture). GTE and AT&T also have formed a joint venture (subject to regulatory approval) to manufacture ISDN-based switching products.

Table 3

AT&T's U.S. Design and Production Locations

Location	Activity	Products
Phoenix, AZ	Production	Cable
Little Rock, AK	Production	Printers, terminals, keyboards
Denver, CO	Production	PBXs, key systems
Orlando, FL	Production	Semiconductors
Norcross, GA	Production	Cable and optical fiber
Montgomery, IL	Production	Datacomm
Naperville, IL	Design	Central office switching equipment, computers
Skokie, IL	(To be closed)	Data terminals, peripherals
Shreveport, LA	Production	Office communications
North Andover, MA	Production	Carrier systems
Kansas City, MO	Production	Relays, discrete and hybrid semiconductors, connectors
Ohmaha, NB	Production	Cable apparatus
Clark, NJ	Production	Undersea cable repeaters
Holmdel, NJ	Design	Transmission systems
Lincroft, NJ	Design	Computer products, datacomm

(Continued)

Table 3 (Continued)

AT&T's U.S. Design and Production Locations

Location	Activity	Products
Middletown, NJ	Design	Workstations, data networks, PBXs
Morristown, NJ	Design	Personal & minicomputers
Neptune, NJ	Design	Datacomm
Parsippany, NJ	Design	Power equipment
Piscataway, NJ	Design	Communication interfaces
W. Long Branch, NJ	Design	Datacomm
Whippany, NJ	Design	Military equipment
Greensboro, NC	Headquarters	Military equipment
Winston-Salem, NC	(To be closed)	Subscriber carrier systems
Columbus, OH	Production	Voice & data switching systems
Oklahoma City, OK	Production	Switching systems, computers
Allentown, PA	Production	Semiconductors
Reading, PA	Production	Semiconductors
Nashville, TN	Production	Capacitors
Mesquite, TX	Production	Power supplies
N. Radford, VA	Production	Transformers, inductors
Richmond, VA	Production	Printed circuit boards

Source: AT&T
Dataquest
November 1988

DATAQUEST CONCLUSIONS

Dataquest believes that AT&T is a fully vertically integrated company with all the right strategic elements it needs to survive. With its laboratory, components, equipment, network, and service divisions, we believe that the company has the expertise it needs in-house to develop and manufacture any product or system necessary to support its fundamental business of information movement and management.

AT&T is also a company that is still in transition from a regulated to a deregulated business environment. Prior to the 1984 divestiture of its local telephone services business, the company was not allowed to compete in the merchant market. Prior to 1984, it made sense for AT&T to have as many of its suppliers located in as many different political jurisdictions as possible, for example, because it was regulatory personnel who made the key external decisions that affected AT&T's profitability. Today, many of the key external decisions affecting the company's profit and loss are being made by industrial customers who are free to choose between AT&T and any of AT&T's competitors. Hence, the company is striving to become more marketing oriented, and, in our opinion, AT&T has made the right decision to do so. The company must now offer its customers the best deal competitively to win their business. To do this, AT&T must determine how to lower its costs; an important part of this cost-reduction thrust has been to reduce the supplier base. As an example of the transition that is under way, AT&T as a company is learning to apply a different set of criteria today when making a choice of suppliers.

In addition, the world has become smaller and the economies of the various nations are more linked together today than ever before. In its new deregulated position, AT&T recognizes this fact and now is pursuing both markets and manufacturing locations in the broader international arena. Dataquest also believes that, in doing so, AT&T is headed in a direction that will make the company more competitive.

Roger Steciak

Dataquest
a company of The Dun & Bradstreet Corporation

Research Newsletter

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1988-39
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THIRD QUARTER ELECTRONIC EQUIPMENT UPDATE

SUMMARY

Dataquest forecasts that North American electronic equipment production will grow 8.5 percent in 1988, up slightly from 8.3 percent growth in 1987. We expect growth in 1989 to slow to 7.6 percent, as U.S. economic growth decelerates and saturation continues in end-use equipment markets.

This newsletter presents an overview of business activity and trends in the six semiconductor application markets. It also discusses implications for semiconductor consumption. Forecast application market activity is summarized as follows:

- Data processing equipment production is expected to grow 13.4 percent in 1988, driven by personal computer production, and 11.3 percent in 1989. Computer chip consumption is expected to continue to drive the North American market.

- Consolidation and long-term plant and equipment investment in the communications industry should translate into moderate but relatively steady growth through 1992.

- Investment in manufacturing automation systems is expected to pace industrial electronic equipment production, resulting in 11.2 percent growth in 1988. We expect this growth to slow to 5.6 percent in 1989, reflecting deceleration in economy-wide capital spending.

- Consumer electronics growth will remain lackluster, despite a resurgence in personal electronics.

- Increasing electronic and semiconductor content in military systems will counter slower defense spending, resulting in real growth of military electronic equipment production.

- Rising pervasiveness of automotive electronic systems should result in transportation electronic equipment production outpacing automobile production.

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OUTLOOK FOR APPLICATION MARKETS

Table 1 and Figure 1 show Dataquest's most recent North American electronic equipment forecast. We expect the electronic equipment industry to grow 8.5 percent in 1988, to $271.3 billion. This compares favorably with 1987, when the industry grew 5.6 percent. Data processing applications, fueled by PC production, are expected to lead the pace with 13.4 percent growth in 1988. We expect data processing applications to have a compound annual growth rate (CAGR) of 10.2 percent through 1992.

Table 1

North American Electronic Equipment Forecast (Millions of Dollars)

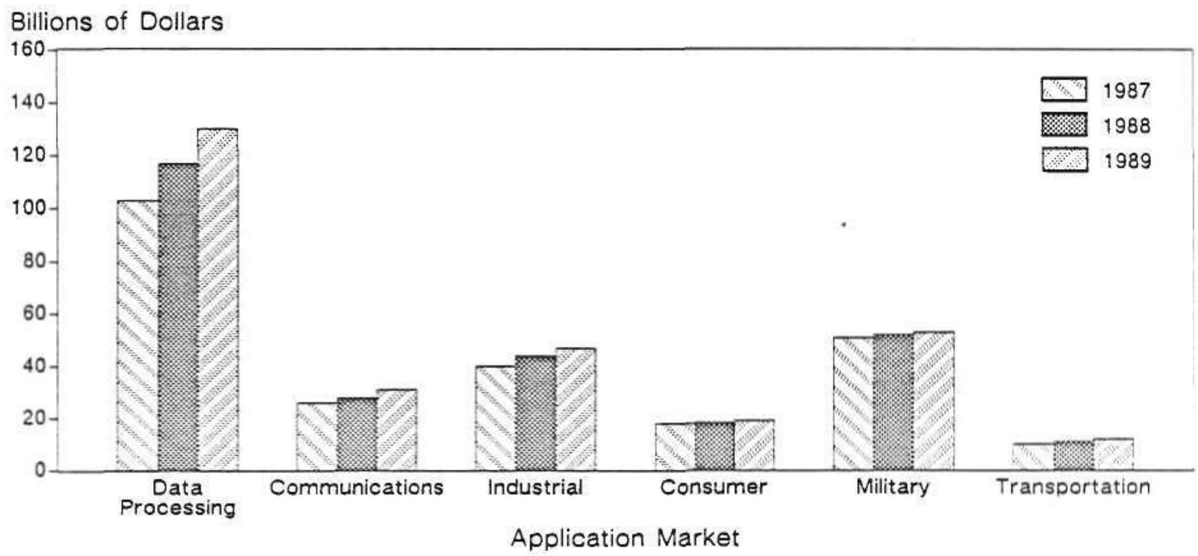
	1987	1988	1989	1990	1991	1992	% Change 1987-1988	CAGR 1987-1992
Data Processing	$103,552	$117,434	$130,662	$143,519	$157,180	$168,372	13.4%	10.2%
Communications	26,367	28,380	30,504	32,430	34,517	36,449	7.6%	6.7%
Industrial	40,384	43,866	46,990	49,759	53,974	58,074	8.6%	7.5%
Consumer	18,063	18,294	18,863	19,560	20,650	21,710	1.3%	3.7%
Military	51,549	52,345	52,968	55,348	57,842	60,454	0.4%	3.2%
Transportation	10,199	10,964	12,042	13,281	14,809	16,314	7.5%	9.9%
Total	$250,113	$271,282	$292,029	$313,897	$338,971	$361,372	8.5%	7.6%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
November 1988

Figure 1

North American Electronic Equipment Forecast



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Source: Dataquest
November 1988

As shown in Table 2 and Figure 2, we believe that the data processing sector will continue to be the largest and fastest growing consumer of semiconductors. Personal computers, expected to account for 11.1 percent of total North American semiconductor consumption in 1988, remain the driving force and the volatile factor underlying the forecast.

Table 2

North American Semiconductor Consumption by Application Market (Millions of Dollars)

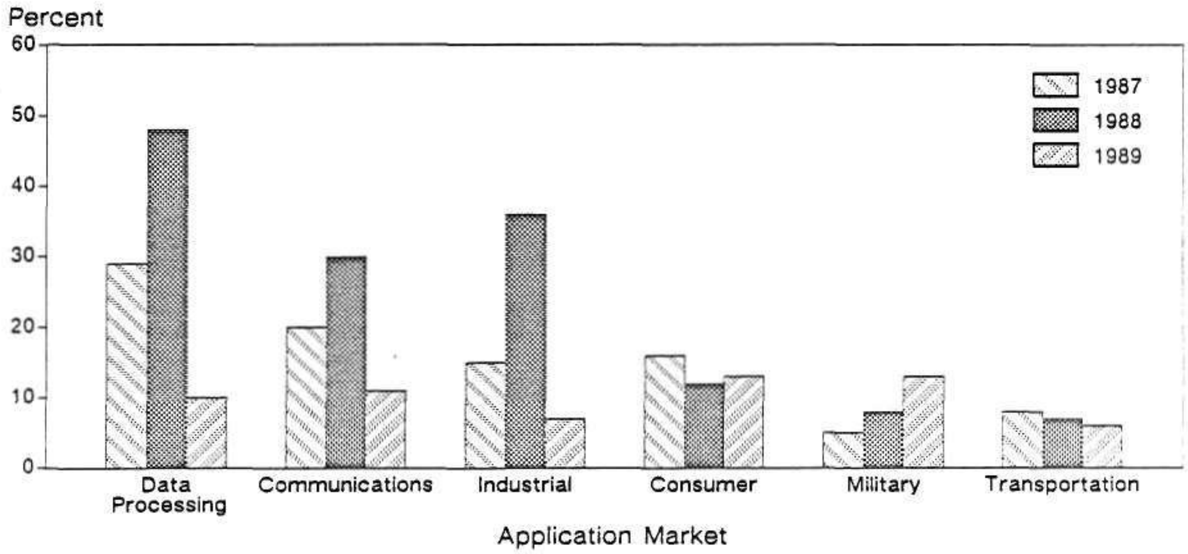
	1987	1988	1989	1990	1991	1992	% Change 1987-1988	CAGR 1987-1992
Data Processing	$ 4,913	$ 7,295	$ 7,997	$ 8,000	$ 9,550	$12,006	48.5%	19.6%
Communications	1,716	2,214	2,463	2,452	2,813	3,338	29.0%	14.2%
Industrial	1,847	2,512	2,685	2,671	3,189	3,954	36.2%	16.4%
Consumer	844	941	1,057	1,029	1,166	1,367	11.5%	10.1%
Military	1,631	1,751	1,970	2,106	2,280	2,456	1.4%	8.5%
Transportation	918	987	1,052	1,195	1,372	1,664	0.6%	11.1%
Total	$11,869	$15,700	$17,224	$17,452	$20,370	$24,785	32.3%	15.9%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
November 1988

Figure 2

North American Semiconductor Consumption by Application Market



0001881-2

Source: Dataquest
November 1988

Data Processing

Dataquest expects the North American data processing industry to grow 13.4 percent this year, up from 12.4 percent in 1987 and slowing only slightly to an 11.3 percent pace in 1989. Business' purchases of PC systems, in addition to new product introductions such as IBM's AS/400 Silverlake business system, have contributed significantly to this year's growth and should provide a foundation for next year's expected performance.

The importance of PC production in driving the current semiconductor expansion is easily seen when one considers the following: According to the Semiconductor Industry Association, July year-to-date total U.S. semiconductor shipments are up 28 percent over year-earlier levels. However, total U.S. shipments less memory shipments are up 13 percent; and total U.S. shipments less memory and microdevice shipments are up only 4 percent. Given that single-user PCs ($1,000 to $10,000) account for 11.1 percent of North American semiconductor consumption, a major growth change in this market would probably send a chilling correction throughout the industry.

One factor mitigating against an industry correction to the extent that occurred in 1985 is the fact the computer manufacturers are capable of producing more mips (i.e., computing power) than users can absorb. Major opportunities that meet user needs while absorbing mips include the following:

- Imaging and Graphics—Today's graphics, voice, and imaging applications require higher levels of mips to satisfy users' performance needs.
- Desktop Standards—Two likely operating systems in the battle for supremacy include OS/2 and UNIX.
  - Once standards are established, users will work in an environment of common user interfaces, common communications interfaces, and enhanced applications software interfaces.
  - Established standards should lead to increased penetration into the work environment.
- Knowledge-based Systems—The adoption of knowledge-based systems is bound to make new tasks feasible, enabling real-time collection and analysis of data.

Meeting these goals will require more computing power, accomplished by greater semiconductor power. Thus, the continued rise in semiconductor pervasiveness should help stave off an abrupt industry contraction.

Communications

Would that the typical workplace could get its desktop computers and peripherals to "talk" to one another. Conceptually, this is a simple yet elusive notion, but progress is being made. Dataquest expects the North American local area network (LAN) industry to grow 58.3 percent in 1988, to $2.6 billion, and 40.3 percent in 1989, to $3.6 billion. We believe that the LANs of choice will be Xerox's Ethernet and IBM's Token-Ring.

Industry consolidations and product competition have placed pressure on prices, constraining industry growth. But data communications equipment is providing some industry relief, while growth in public telecommunications systems (e.g., central office switching equipment) remains sluggish. Overall, Dataquest estimates that North American communications systems shipments will be up 7.6 percent in 1988 and up 7.5 percent in 1989.

Industrial

We forecast the industrial electronic equipment industry to grow 8.6 percent in 1988, slowing to 7.1 percent in 1989. Electronic manufacturing systems sales are setting the pace.

Performance in the industrial application market is tied more closely to overall capital equipment spending in the economy than performance in the other application markets. We believe that this year's capital spending boom will lead to 8.6 percent growth in industrial electronic equipment in 1988, with manufacturing systems setting the pace at 12.5 percent expected growth. As the capital spending boom begins to subside next year, shipments of industrial systems will likely follow suit.

Consumer

North America started to lose the consumer electronics battle years ago. Since then, most production has shifted to Japan and Asia. But certain niche markets, such as electronic games, remain a North American stronghold. Overall, however, the consumer electronic equipment market is forecast to grow a lackluster 1.3 percent in 1988, going up only 3.1 percent in 1989. Growth is being constrained by a mild rate of new product introductions and the high saturation rate of appliances per household.

On September 1, the Federal Communications Commission (FCC) issued high-definition television (HDTV) guidelines. The guidelines stipulate that, although only HDTV sets will display the sharper image, conventional TV sets must be able to receive high-definition signal transmissions.

We believe that the FCC action will discourage the implementation of any of the proposed incompatible foreign HDTV standards. Furthermore, the FCC action should encourage the U.S. consumer electronics industry's participation in the domestic TV set and TV broadcasting equipment markets, which are now dominated by foreign companies.

The implications for the semiconductor industry are far reaching. Richard Elkus, Chairman and CEO of Prometrix Corporation, observed at the recent Semiconductor Industry Association/Dataquest conference that, in the same way that Japan's domination of the worldwide VCR market has led to domination of interrelated systems and semiconductor industries, the nation (or nations) that dominates the HDTV market will reap similar but enormously larger rewards as the world's stock of video equipment is revamped. Not only will HDTV systems open up a new market for semiconductor manufacturers, but spinoff products will likely find uses in data processing, communications, medicine, and military applications.

Dataquest believes that an unusual opportunity exists for U.S. manufacturers to reclaim some of the consumer electronics market over the next 5 to 10 years.

Military

For defense contractors, the bad news is that worldwide military spending has slowed as growth in the U.S. defense budget, which accounts for about 50 percent of the free world's defense spending, slows. (Assuming that the U.S. inflation rate remains in the 4 percent neighborhood, which is likely, this implies declining real defense spending growth.) The good news is that the electronic and semiconductor content of new military systems, as well as upgrade programs, is growing and should continue to increase well into the next century.

For the period 1987 through 1992, military electronic production is expected to grow at a 3.2 percent CAGR. Military semiconductor consumption is expected to grow at an 8.5 percent CAGR.

Transportation

Detroit's Big 3 automobile manufacturers have recently raised their fourth quarter U.S. production forecast, according to Automotive News, boosting the industry's estimate of unit production of cars and trucks by 8.7 percent over the fourth quarter of 1987. U.S. automakers expect that a healthy economy—coupled with an unexpected recent surge in car sales—will continue. In the third quarter, U.S. automakers increased production by 12.6 percent from year-earlier levels. Nonetheless, unit sales are expected to decline 0.1 percent, from 7.094 million units in 1987 to 7.086 million units in 1988.

We believe that continued automotive electronics systems pervasiveness will translate into automotive electronic systems growth, even in view of expected sluggish U.S. automobile production.

DATAQUEST CONCLUSIONS

For years, the semiconductor industry has been subject to a pronounced boom/bust cycle. The cycle's wide swings may finally be damping, however. For example, as North American semiconductor consumption heads toward what we believe will be the next cyclical trough in 1990, we further expect that positive, albeit very slow, growth will be maintained. Should this occur, it would be a far cry from the collapses that the industry experienced in 1975 and 1985.

Dataquest believes that better inventory control and closer supplier/user relationships are helping mitigate wide industry swings. If inroads continue to be made in these two areas, the industry may be headed for even smoother times in the years to come.

Terrance A. Birkholz

Dataquest
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Research *Newsletter*

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IBM 8514/A GRAPHICS: THE NEXT VGA?

EXECUTIVE SUMMARY

When IBM introduced its PS/2 line of computers in 1987, the VGA quickly became the popular graphics standard. However, as is de rigueur in the PC graphics world, one year's popular standard is the next year's entry-level product. Eventually, another adapter will replace the VGA as the product of choice. Dataquest believes that in the 1989 to 1991 time frame, this adapter will be IBM's 8514/A display subsystem (or a close cousin).

A number of factors favor the trend toward the 8514/A, but other factors add uncertainty. Probably the most important factor is IBM itself, but only in terms of defining the details of the product. Left to its own devices, the market is headed toward higher resolution, just as it is headed toward faster processors and higher-capacity drives.

Another positive development is in fact due to IBM and is one that even the Japanese have not been able to accomplish thus far: the ability to bring higher-resolution monitor prices within the reach of the office user.

The anticipated availability of higher resolution at a low price, coupled with the imminent desire for higher-quality (resolution, color, and speed) graphics under OS/2, translates into a trend in favor of something like the 8514/A.

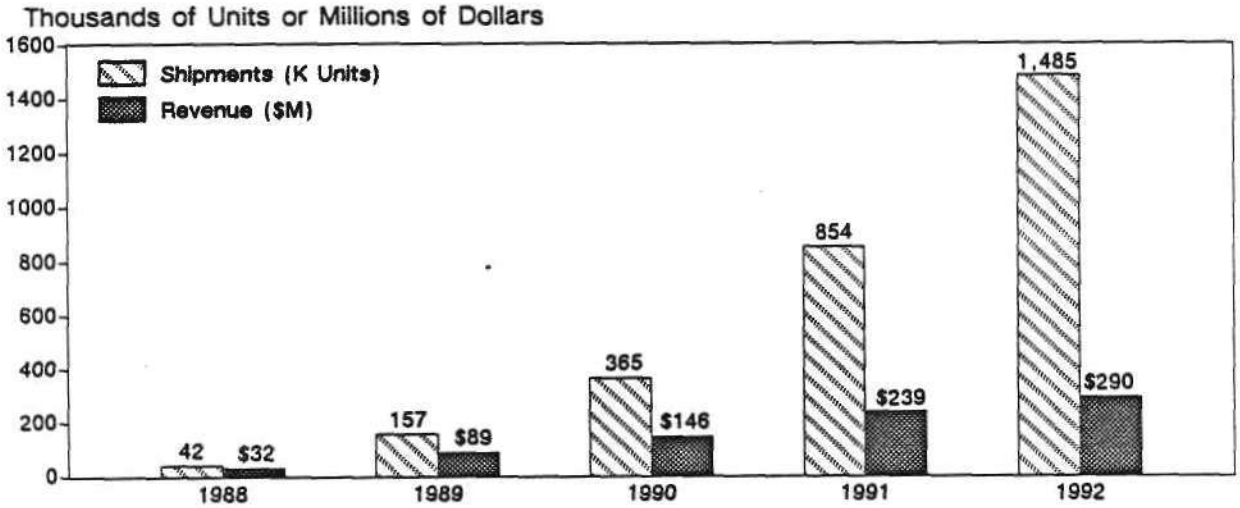
Our forecast for the 8514/A-compatible market is fairly optimistic (see Figure 1). IBM seems to be on its way to achieving the total shipment level by itself in 1988 through its retail channel alone. We expect to see clone vendors making a contribution to this forecast beginning in the second quarter of 1989, both for the PC AT and for the microchannel bus.

The uncertainties of this market pertain to how Microsoft and the application software community interfaces with IBM's hardware, as well as how IBM implements future versions of the 8514/A. We expect that both the software and hardware issues will evolve over time—and that they will affect the competition every day.

However, in the shifting sands of the PC graphics market, the opportunities are ripe for the quick and the vigilant. The vendors that have good distribution channels will be the lucky ones as high resolution moves out of the niche market and into the mainstream.

Figure 1

8514/A–Compatible Products Forecast
Shipments and Revenue
1988–1992



Source: Dataquest
October 1988

BACKGROUND

DQ Definition of PC Graphics: A Brief Note for the Uninitiated

Graphics is considered a subsystem of the PC, a module such as disk storage or communications. It has its own memory, and can be implemented either as a chip-set, which is resident on the main PC motherboard, or as an add-on card. The monitor connects to the graphics subsystem. The monitor itself has no intelligence; it is essentially a sophisticated piece of glass, with driver electronics.

Graphics capability is of two basic types: the intelligent controller, or the dumb frame-buffer. If it is a frame-buffer, the host CPU does most of the graphics computation, drawing, and manipulation of pixels. With multiple colors available for each dot and millions of dots on the screen being rapidly updated, the graphics computation can be cumbersome for a host CPU, depending on the application.

An intelligent graphics controller can process commands and carry out drawing functions and thus free the host from this chore.

Dataquest refers to frame-buffers as low-end products and intelligent controllers as high-end products. The low end comprises products like the Hercules Graphics Adapter (HGA) as well as the CGA, EGA, and VGA adapters. High-end products include a variety of proprietary graphics boards, including IBM's 8514/A.

THE PRE-8514/A AGE

The first graphics adapter for the PC was the Hercules product. This product was followed by low-end color products from IBM and others. For higher performance and color resolutions, a select group of third-party graphics vendors such as Control Systems, Number Nine, Vermont Micro, and Verticom started selling proprietary graphics boards. Even IBM sold what it called the Professional Graphics Controller (PGC) board that it purchased from Vermont Micro under an OEM contract. These products were sold mostly to design professionals and offered resolutions of up to 1,280 x 1,024 and 256 colors.

The high-end market has remained small (only 110,000 units in 1987), however, for the following reasons:

- Products were aimed primarily at design professionals (not a large market).
- Products were very expensive (the board and monitor price easily exceeded $4,000).
- No standard graphical interface was available to encourage use of graphics.
- No viable high-end graphics standard was forthcoming from IBM, which in turn precluded any broadbased software support.

Now, however, the industry is beginning to progress in terms of hardware and software products and standards. We welcome, in advance, the belated arrival of the high-end graphics environment for the IBM-compatible market.

THE 8514/A MONITOR AND BOARD

The IBM 8514/A graphics board for the PS/2 microchannel machines is a medium-resolution (1,024 x 768, 256 colors) product. It has a software interface (the Adapter Interface Function Set) that allows the host system to off-load most of the drawing tedium to the graphics processor. The product has the following features:

- A set of graphics primitives (commands) for text/symbols, alphanumerics, images, lines, and areas (but no arc primitives)
- User-defined hardware-assisted line types
- Bit block transfer (BITBLT) for rapid screen updates

- Color and color mix control and use of look-up tables (LUTs, a 262,000-color palette)

- Comparative and arithmetic raster operations

It has two basic modes in the output section. When displaying 640 x 480 dots, (whether using its own memory or the motherboard resident VGA bit map), 31.5 kHz at 60Hz refresh, noninterlaced output is supported. When displaying 1,024 x 768 dots, 35.5 kHz at 43.5Hz interlaced refresh is supported.

The monitor is a medium-slow phosphor, 16-inch display. Only moderate flicker is seen in flourescent light; conversely, little or no ghosting is detected.

THE CRITICAL QUESTION: HOW DOES SOFTWARE TALK TO HARDWARE?

Perhaps the most critical uncertainty for the 8514/A market is this: will independent software vendors (ISVs) drive the graphics through the documented Adapter Interface Function Set (AIFS), or, will they directly access registers, like they do now with VGA products?

Although we believe that both AIFS and direct access will be used, the following questions are pertinent:

- Is the software mostly "vector" based, in which line or polygon end-points are specified, as is common with CAD software? If so, the AI interface is reasonable.

Or, is the software more "raster" oriented, such as is the case where an area is "painted," an approach commonly used with business graphics and "paint" programs? In the latter case, access to the registers is favored, thereby improving performance many times over. The AIFS software interface imposes a significant burden on graphics throughput.

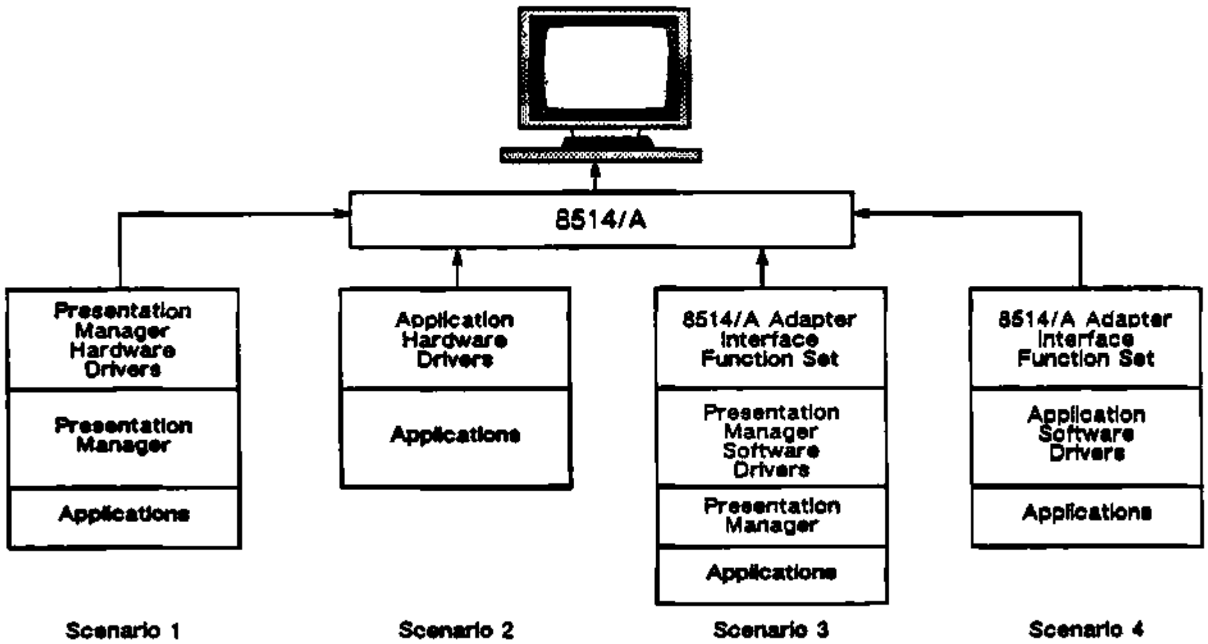
- How does Microsoft deal with the 8514/A under Presentation Manager (PM)? (See Figure 2). If PM communicates directly with the hardware, then a potential bottleneck is removed. But will application software running under PM remain "well behaved" and make graphics calls only through PM drivers? And, will the resulting performance be acceptable?

Dataquest believes that even if IBM and Microsoft persuade many ISVs to use PM for their graphics calls, not all software is going to be well behaved. And, it is those few programs that do NOT run that can cause hardware vendors the most headaches.

It is our opinion that scenario number 3 in Figure 2 is not very likely and that scenario number 4 is probably only acceptable for line-oriented software. That leaves scenarios 1 and 2, both of which require hardware vendors to be register-level compatible with IBM's product.

Figure 2

8514/A and Compatibles Addressing Scenarios



Source: Dataquest
October 1988

DATAQUEST FORECAST

Table 1 is the forecast for the IBM 8514/A and compatibles.

Table 1

Preliminary Worldwide Forecast
High-End PC Graphics Boards—8514/A Type
1987–1992

	1987	1988	1989	1990	1991	1992	CAGR 1987-1992
Unit Shipments (K)	9	42	157	365	854	1,485	212%
Percent Change	N/M	369%	272%	133%	134%	74%	
Average Selling Price (Boards)	$839	$713	$570	$399	$279	$196	
Revenue ($M)	$ 8	$ 30	$ 89	$146	$239	$290	137%
Percent Change	N/M	299%	197%	63%	64%	22%	
Year-End Installed Base (K)	9	50	203	557	1,383	2,810	

N/M = Not Meaningful

Source: Dataquest
October 1988

ASSUMPTIONS BEHIND FORECAST, OR WHY HI-RES?

A frequently asked question is: why would users want to climb up to higher resolution?

Dataquest believes that there are some good and some not-so-good reasons in favor of higher resolution. However, even the not-so-good reasons have an effect, especially in concert with the good ones, as discussed in the following subsections:

The View Is Better

Studies have shown that for a given viewing distance (for example, 18 inches from the screen) and a given luminance value (which factors in ambient lighting conditions), humans can perceive smaller and smaller dot sizes, up to a limit (which is far from reached in conventional displays). Effectively, it means that higher resolution is not only more aesthetically pleasing (less jaggies), but allows the user to receive more information from the same display, thereby increasing productivity.

In addition, software vendors are interested in their programs looking significantly more attractive, especially against their competition. Porting to higher-resolution hardware enhances the presentation of software. Furthermore, if the hardware is the new standard from IBM, then that in itself is a favorable reason to port to such hardware.

Hardware Vendors Want to Make Money

In the highly competitive graphics hardware business, board prices erode very quickly. Vendors must constantly add more features and functionality to their products in order to keep price erosion at a manageable level or to increase the average selling price. Because it is significantly more expensive than the low end (VGA), the 8514/A is a good technique for achieving better revenue and margins.

Monitor vendors face a similar situation. Although the multisynch product has had good profit margins (it made NEC the envy of the industry), this market is being threatened from below by VGA monitors, and may be affected from above by 1,024 x 768-resolution monitors. Consequently, multisynch vendors are being forced to move up to the 1,024 x 768 resolution (either at 35 kHz, or 48 kHz), without significantly increasing their costs. One good way to minimize costs is to make a monitor that has only two or three discrete resolutions or frequencies, as discussed in the following subsection.

It Is There

The Critical Monitor Question

The high price of 1,024 x 768 monitors is the one issue that has caused us to remain skeptical about future growth.

Although IBM's 8514 monitor is interlaced, it represents a fairly good compromise in terms of the amount of flicker associated with such screens. Furthermore, although the IBM monitor is considerably less expensive than 1,024 x 768 (48 kHz) monitors have been, its price is still somewhat prohibitive at $1,560. (Note: The cost of IBM's monitor is estimated to be $350, so there is ample room for price flexibility.)

More importantly, however, is the effect that this situation is having on monitor suppliers in the Far East, who have not reduced their high-resolution monitor prices to the mainstream level, i.e., to less than $1,000. IBM has turned up the heat for such monitor suppliers, who are now scrambling to offer high-resolution monitors priced at less than $1,000. The latest announcement was the Seiko 1830. This 8514/A-compatible, Sony Trinitron-based monitor lists for $999—which translates into a lower "street" price. We believe that less-expensive monitors can be produced.

Dataquest expects to see a flurry of monitors priced at less than $1,000 in the next 12 months; some of these should be dual-synching (640 x 480, and 1,024 x 768) monitors, targeted at IBM's 8514/A or 8514/A clones.

The Graphical Interface

The graphical interface is (finally) becoming a reality on the IBM platform. It used to be that not all PC users needed graphics. However, more and more programs started driving bit-mapped graphics, and now, the window/icon-type "power-up graphics" is expected to become a standard feature on the IBM PCs by late 1989. Currently, the Microsoft Windows program is setting the stage for the widespread use of this interface.

Why Not a 1,024 x 768 VGA?

Under the VGA, the host processor does most of the graphics work, but this task gets much more demanding as both spatial and color resolution are added to the bit map. It has been argued that this is not a problem, since faster host processors are constantly being offered.

However, screen update performance can increase at a much higher rate if graphics tedium is off-loaded to a processor—not just in graphics drawing, but also while scrolling text or spreadsheets. Furthermore, multitasking is another reason to keep the host CPU free, while a graphics processor does what it does best. Therefore, keeping the future in mind, a sensible approach would be to select a graphics "module" that is responsible for its own performance.

But there is another practical reason why it is not a good idea to stretch the current VGA to higher resolution: IBM. Nonstandard resolutions are not currently supported on the IBM VGA and are not expected to be supported in the future. This situation has resulted in inadequate software support.

It has been interesting to see graphics chip/board vendors offer higher-than-standard resolution on their VGA products. This was also done for EGA products. It was our contention then, as it is now, that these nonstandard resolutions are seldom used. However, it seems that such capabilities are required for competitive advertisements.

DATAQUEST ANALYSIS

Dataquest views the 8514/A as IBM's living, evolving, PS/2 graphics standard. Therefore, we expect that in the future, IBM will take the following steps:

- Reduce the cost of the board (The two-board set can be reduced to half a card, or integrated into the motherboard.)

- Add functionality and performance (These may require new device drivers.)

- Offer compatible monochrome products (A product for image management has already been announced.)

- Offer compatible higher-resolution color products

The question frequently arises concerning which vendors will be offering 8514/A compatibles. The answer is—all vendors that can afford the development resources. We expect vendors that have high-end graphics controller design talent in-house to develop products as soon as they can determine how to develop them. But first, a few complexities must be worked out; such as: how compatible is compatible, or, is register-level compatibility really necessary?

Datquest's view is that there is not enough compatibility without register-level compatibility. Even then, we believe that in the PS/2, it is very easy for IBM to "unruffle" the best of clone designs. Furthermore, we expect that future IBM derivatives of the 8514/A will not be fully register-level compatible with the current 8514/A. IBM may not only decrease manufacturing costs and further miniaturize this product, but it may also enhance functionality (add new graphics primitives, offer higher resolution, etc.), depending on the specific application.

To continue to evolve the product is one way to keep the competition on their toes. But if this renders future derivative products less than register-level-compatible with the current one, then why should the competition develop the current version? The following reasons may be pertinent:

- Vendors that have experience with the original design would be in the best position to adapt the original design to newer ones, as these designs become available.

- For system (PC and/or PS/2 clone) companies, graphics is an integral part of the system—and the 8514/A is expected to follow the VGA to the PS/2 motherboard. When this integration occurs (sometime in 1989 or 1990), it will be possible to couple graphics more closely to the system logic. It may be an asset for the system vendor to have this graphics capability in-house.

- It is practically impossible to be 100 percent compatible with IBM's 8514/A. Vendors may want to compensate for some incompatibilities, as well as have the flexibility to offer higher performance and more features. For reasons of compatibility, features, and performance, system vendors may require their own versions of OS/2 or DOS operating programs. (Some vendors already require their own version of DOS.) In that case, they may replace Presentation Manager or Windows device drivers with their own drivers.

Another complexity in cloning the 8514/A is its formidable BIOS. Ideally, a vendor would want to design a BIOS in-house that is optimized for its own hardware, rather than purchase the BIOS from Phoenix Technologies or Award Software. With chip or board companies, however, design talent is often fully applied toward hardware design.

Other arguments against in-house development of the 8514/A persist. To undertake such a product at the register-compatibility level is difficult. A vendor that does not have expertise in graphics VLSI design may be better off obtaining the 8514/A chip set from someone that does—much like vendors that buy VGA chip sets. If a company's strength is its marketing and distribution channels, this approach may be sensible. After all, 1,024 x 768 color products are expected to move into mass-market channels in the 1989 to 1990 time frame.

We believe that the make or buy (the chip set) decision depends on a company's business model. The key question is: does the company want to take the risks associated with being dependent on the chip supplier and focus its resources on packaging and marketing to applications, or, would it rather be in the graphics chip business? For a systems company, however, the need for in-house development or customization of graphics products is of tactical importance.

Clearly, high-resolution graphics for the mainstream is just around the corner. And, in the fast lane of PC-graphics, the industry must learn to turn fast.

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Terrance Birkholz
Sohail Malik

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Research *Bulletin*

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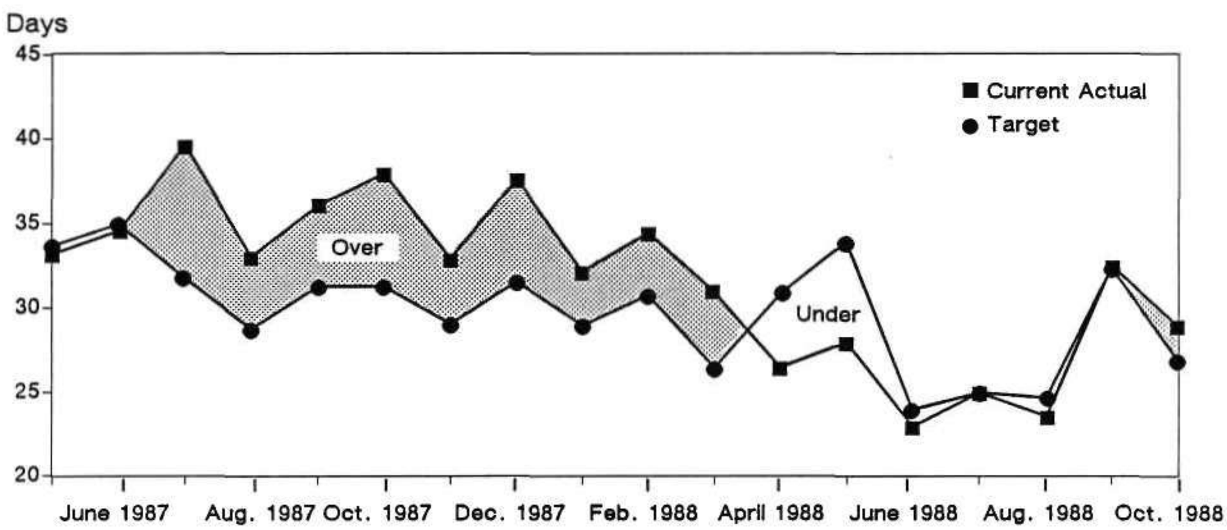
OCTOBER PROCUREMENT SURVEY: INVENTORY CONTROL CONTINUES AS BOOKINGS FOR PARTS LEVEL OFF

Respondents to this month's survey are closely watching inventory levels and are quickly adjusting buying rates in line with inventories. Overall electronic system sales are expected to remain healthy, with the only softening currently being seen in the military segment. As seen in Figure 1, both target and actual inventory levels have declined slightly, with the overall target now at 27 days and the current level above that target at 29 days. Although above target, the lowering of overall levels is an improvement over last month's results and reflects the diligence of both buyers and sellers of semiconductors to keep communication lines open.

Figure 1

Current Actual versus Target Semiconductor Inventory Levels (All OEMs)



Source: Dataquest
October 1988

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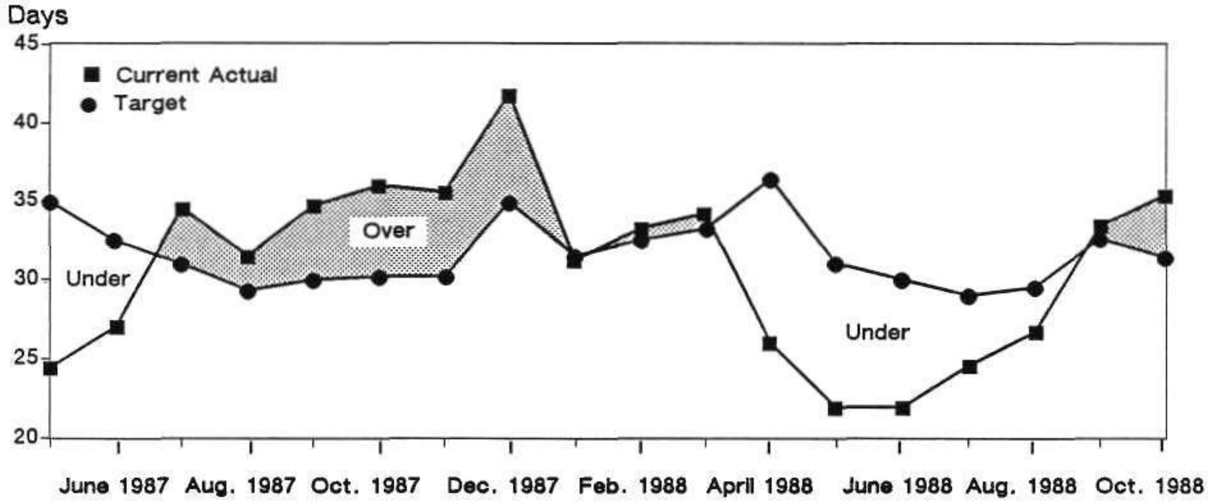
Actual computer OEM inventories have also overshot lower targeted levels as adjustments to booking rates continue. The lower inventory target of 31.4 days versus the higher current level of 35.4 days shown in Figure 2 illustrates how inventory adjustments often do not immediately correlate.

Figure 2

Current Actual versus Target Semiconductor Inventory Levels (Computer OEMs)



Source: Dataquest October 1988

Pricing of semiconductors has remained stable or has declined since our last survey, while lead times continue to come down. Orders to distributors have remained unchanged. The ongoing problem with memory availability (low-density SRAMs in particular) continues, with improved 1Mb DRAM availability the only bright spot in this bleak picture. Surface-amount packaging, for the most part, is no longer a major problem, but some users still find it difficult to obtain high-speed memory or high-pin-count chip carriers.

DATAQUEST ANALYSIS

The ongoing inventory adjustment programs are putting companies' forecasting and procurement systems to task as the industry shows signs of downshifting from overdrive into fourth gear. Increasing 1Mb memory supplies combined with the leveling of demand and good buyer-vendor communications will result in tempering any down market spiral since inventory levels are still historically low. We expect this adjustment period to continue for the next two to three months as system market growth levels stabilize.

Mark Giudici

1987–1988 SAM Newsletter Index

The 1987 SAM Newsletter Index is a quick reference guide to the SAM newsletters. It is structured as follows:

- Titles are organized by both keyword and company.
  - Page 2 is a company list, e.g., LSI Logic.
  - Pages 3 through 5 are a subject list, e.g., Economy.
- The newsletter type, month, and year follow each title listing in the index. Refer to the month tab to locate a specific newsletter.

This index will be updated quarterly.

1987–1988 SAM Newsletter Index

Company	Newsletter		Date
CHIPS AND TECHNOLOGIES INC.			
The Clones are Coming: Chips & Technologies Introduces First PS/2 Model 30 Chip Set		SAM	July 87
COMPAQ COMPUTER CORP.			
Impact of the Compaq Deskpro 386: How the 32-Bit PC Market is Shaping Up (And Implications for IC Manufacturers)		SAM	Mar. 87
IBM			
Storage Impact of the PS/2 Announcements: An Analysis After the Settling of the Dust		SAM	July 87
Dataquest Looks Inside IBM's New PCs		SAM	Apr. 87
Reality versus Hype: The Impact of the Intel 80386		SAM	Jan. 87
INTEL CORP.			
Impact of the Compaq Deskpro 386: How the 32-Bit PC Market is Shaping Up (And Implications for IC Manufacturers)		SAM	Mar. 87
Reality versus Hype: The Impact of the Intel 80386		SAM	Jan. 87

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January-March

The following is a list of the newsletters in this section:

(continued)

(continued)

January-March

Dataquest
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Research Newsletter

SAM Code: 1987-1988 Newsletters: January-March
1987-10

MINISUPERCOMPUTERS--JAPANESE STYLE

SUMMARY

Japanese vendors are major participants in many high-technology industries and markets. U.S manufacturers have jealously watched the Japanese make great strides in such diverse fields as automobiles, semiconductors, and consumer electronics. Within technical computing, Japanese companies are active market participants in most of the product segments that are analyzed by Dataquest, including mainframes, superminicomputers, and technical workstations. Although they have entered all of these markets later than their American counterparts, these Japanese companies have managed to secure a strong presence in each.

One technical systems market segment in which Japanese manufacturers do not currently compete is minisupercomputers--systems that offer at least one-tenth the computational power of a supercomputer for a corresponding fraction (or lower) of the price. Dataquest believes that minisupercomputer-class systems are, in fact, active projects at several Japanese companies, where they are used internally but may never be vigorously marketed.

This newsletter will briefly review the worldwide market for minisupercomputers and examine the driving force behind Japanese efforts in this area: world leadership in high-performance supercomputers and next-generation systems. Minisupercomputers will aid in the design of such products by providing cost-effective computational power to Japanese engineers and designers using proprietary, state-of-the-art IC CAD tools.

DEFINITIONS

Minisupercomputers

The standard Dataquest classification scheme categorizes technical computer systems into seven performance classes (see Tables 1 and 2). Minisupercomputers are aimed at the performance gap between supercomputers and superminicomputers, and they must meet the criteria for

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Class VI systems. Minisupercomputers are used in a variety of scientific and engineering applications, with major emphasis on mechanical and electronic design automation, graphics and image processing, and software development. Dataquest projects that the market for such systems will enjoy solid growth through 1990 (see Table 3).

Table 1

DATAQUEST PRODUCT CLASSIFICATION TESTS

Class Specification*	I	II	III	IV	V	VI	VII
CPU Test							
CPU Bit Width	4-32	16-32	16-32	32-48	32-64	32-64	64
Approximate MIPS Rating**	<0.5	0.5-0.8	0.5-1.5	0.8-2.5	2.0-6.0	5.0-10.0	>10.0
Approximate MFLOPS Rating (Peak)	N/A	N/A	N/A	N/A	<10.0	10.0-100.0	>100.0
Memory Test							
Maximum Physical Memory Capacity (Mbytes)	≤2	≤16	≤16	≤32	≤48	≤128	≤256
CPU-to-Memory Data Path Bit Width#	4-16	8-16	16-32	32-48	32-64	32-64	64
I/O Test							
Maximum Number of Users##	≤8	8-16	16-64	32-256	64-1,024	N/A	N/A
Maximum Disk Capacity (Mbytes)	200	≤600	≤10G	≤500G	≤1T	N/A	N/A

*Specified, not theoretical, limits
**Serial MIPS (million instructions per second); single processor only
#Including cache memory
##Active, simultaneous users
G = gigabytes, T = terabytes
N/A = Not Applicable

Source: Dataquest
March 1987

Table 2

TCSIS PERFORMANCE CLASSES

Performance Classes	Computer Product Segments
I	Low-performance minicomputers and microcomputers, and personal computers
II	Medium-performance minicomputers and microcomputers and low-end technical workstations
III	Low-performance superminicomputers, and high-end technical workstations and minicomputers
IV	Midrange superminicomputers and low-end mainframes
V	High-performance superminicomputers and midrange mainframes
VI	Very high-performance superminicomputers and minisupercomputers
VII	Supercomputers and high-performance mainframes

Source: Dataquest
March 1987

Table 3

WORLDWIDE MINISUPERCOMPUTER MARKET ESTIMATES--1985-1990
(U.S. Vendors)

	1985	1986	1987	1988	1989	1990	CAGR 1986-1990
Worldwide Revenue ($M)	$190	$369	$500	$677	$906	$1,176	33.6%
Unit Shipments	233	350	522	818	1,231	1,865	51.9%

Source: Dataquest
March 1987

The primary driving force behind the acceptance of minisupercomputers is that they help to shorten the time to market for a variety of end products. Such an influencing force knows no international boundaries; scientists, designers, and engineers in any country can more quickly and cost effectively complete their projects by using minisupercomputers. In Japan, minisupercomputers will play a key role in the design of future supercomputers and next-generation systems.

Supercomputers

Supercomputers can be defined simply as those systems that offer the greatest computational capability at any given time. In terms of peak performance, modern supercomputers typically deliver more than 100 MFLOPS for prices starting at between $2 million and $5 million. Supercomputers fall into Dataquest's Performance Class VII.

Dataquest forecasts that the worldwide market for supercomputers also will enjoy healthy growth through 1990 (see Table 4). Fueling this growth is the practically insatiable demand for computational power that can be supplied by nothing less than the most powerful systems available. In the past, supercomputers were most commonly sold to government laboratories and universities, where they have become indispensable research tools in such applications as aerodynamics, meteorology, nuclear physics, and seismology, as well as in classified defense-related projects. Supercomputers have also been used commercially for petroleum reservoir simulation, computational fluid dynamics applications, and electronic circuit simulation and testing. The growth of new application disciplines, such as computational physics and chemistry, are spurred by the development of ever more powerful systems. According to the National Science Foundation, "Computers are no longer just tools for measurement and analysis, but large computers in particular have become the means for making new discoveries."

Table 4

WORLDWIDE SUPERCOMPUTER MARKET ESTIMATES--1986-1990

	Installed	Unit Shipments				
	Dec. 1985	1986	1987	1988	1989	1990
Cray	115	45	56	67	86	109
CDC/ETA	30	6	8	11	12	14
Others	20	8	11	12	13	16
Total	165	59	75	90	111	139

Source: Dataquest
March 1987

In addition to two U.S. companies (Cray and CDC/ETA), three Japanese companies offer supercomputer-class systems: NEC, Fujitsu, and Hitachi. These manufacturers have arrangements with Honeywell, Amdahl, and National Advanced Systems, respectively, to market their systems in the United States. Driven by the prospects of increased future sales in new and existing application areas, active development of more powerful systems is under way at each firm. In addition, the Japanese manufacturers benefit from the nurturing effects of a government that helps to bring together research efforts across company lines in long-term projects that are essential to the general health of Japanese commerce and industry.

JAPANESE MINISUPERCOMPUTER DEVELOPMENT

MITI-Sponsored Projects

In 1981, Japan's Ministry of International Trade and Industry (MITI) announced the much-publicized "Super-Speed Computer" project. The goal of this effort is to build a 10-GFLOPS (billions of floating-point operations per second) system. The three Japanese supercomputer makers have cooperated with Toshiba, Mitsubishi Electric, Oki, and Nippon Telegraph and Telephone (NTT) to provide resources for this project. MITI has assigned research responsibilities to the various companies as shown in Table 5.

Table 5

MITI SUPERCOMPUTER PROJECT TASKS
1981-1989

	Fujitsu	Hitachi	Mitsubishi	NEC	Oki	Toshiba
Semiconductors						
Josephson Junction	X	X		X		
GaAs Digital IC			X	X		X
HEMT	X				X	
ECL Logic		X	X			
Systems						
Architecture	X					
Large-Capacity Storage				X		
Parallel Processors			X		X	X
Software		X				

Source: Dataquest
March 1987

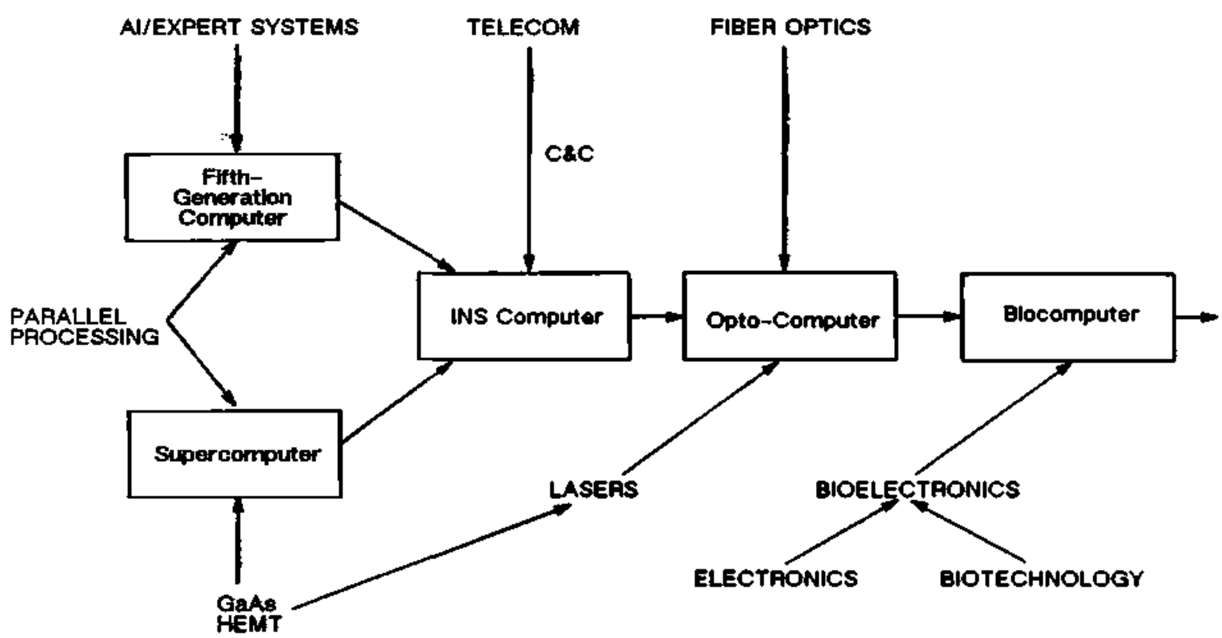
A separate effort, commonly known as the Fifth-Generation Computer Project, brought the same companies together with Sharp and Matsushita in 1982 under the direction of the Institute for New Generation Computer Technology (ICOT), to begin work on a 10-year research project into radically new computer technology and artificial intelligence. In addition to these undertakings, NTT is developing a new system (the INS computer) for its $150 billion fiber optics/satellite telecommunications network, and MITI has established several other efforts, including the Biocomputer, Optoelectronic, and Future Electronic Devices projects.

Why are the Japanese doing this? MITI official Sozeburo Okamatsu is quite blunt: "Because we have only limited resources, we need a Japanese technological lead to earn money for food, oil, and coal. Until recently we chased foreign technology, but this time, we'll pioneer a second computer revolution. If we don't, we won't survive." (This statement was quoted in The Fifth Generation Project, 1983, by E.A. Feigenbaum and P. McCorduck.)

Developments in one project will provide technological building blocks for future efforts. For example, the gallium arsenide research for the supercomputer project will probably be used in future opto-computer work, and the results of current parallel processing development will find their way into future research. This integrated approach to R&D, guided by MITI and ICOT, will ensure that the next generations of Japanese systems will have roots in currently active projects (see Figure 1).

Figure 1

JAPAN'S NEXT-GENERATION COMPUTERS



Source: Dataquest
March 1987

Minisupercomputers--Powerful Design Tools

Obviously, to design a modern computer system of almost any complexity requires the use of a computer. For many years, software and hardware systems have been commercially available to aid engineers and technicians in creating both the operational or functional product design (computer-aided engineering, or CAE) and the physical portion of the design (computer-aided design, or CAD).

The next generation of such high-performance products as multimegabit DRAMs and three-dimensional integrated circuits, among others, will require extensive simulation of mechanical phenomena, such as thermal properties, as well as electronic design and analysis capabilities. These requirements have spurred the development of new CAD/CAE software and high-speed systems to run the software. Fujitsu, Hitachi, and NEC are now developing and using their own CAD tools. Minisupercomputers are ideal platforms for these tools (see Figure 2), as they can free existing supercomputers to be used in more productive endeavors.

Japanese companies have been quite circumspect about releasing the details of new systems. Though no specifics on features are available, we believe that recent and near-term (1987) future systems will probably be extensions of current supercomputer lines.

What will be the results of Japanese minisupercomputer development? Certainly, the Japanese companies will test their minisupercomputers sufficiently to ensure that the products will be thoroughly debugged and highly reliable. Furthermore, an extended product line can offer a way for supercomputer customers of NEC, Fujitsu, and Hitachi to migrate to new low-end systems as their application requirements evolve. Finally, as further research into parallel processing yields useful results, future Japanese minisupercomputers will employ these architectures as well.

Other Japanese Manufacturers

It is clear that NEC, Fujitsu, and Hitachi have the capabilities to produce a minisupercomputer-class system. Other Japanese companies doing work that may lead to minisupercomputer-class products include:

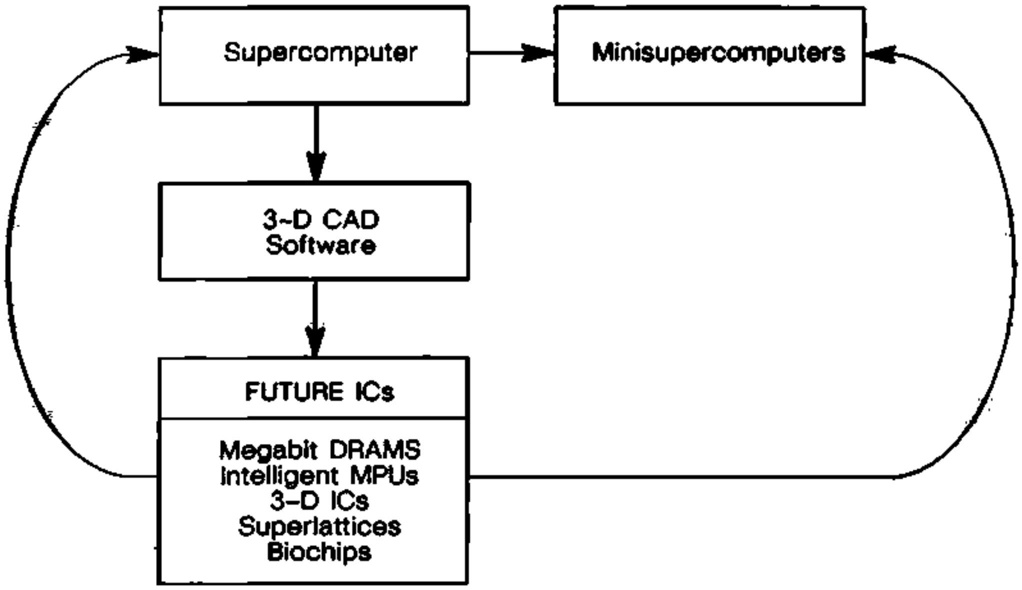
- Toshiba's GX series of 32-bit systems is headed by the G8050, an 18-mips multiprocessor computer. A new, higher-performance system may be announced as a result of ongoing parallel processing research.

- As an outgrowth of the Fifth-Generation Project, Mitsubishi has developed the PSI, a 64-bit system for use in AI development. A multiprocessor PSI is expected later this year.

- Matsushita is working on a very high-speed graphics processor that employs a parallel CPU architecture. This product is still under development.

Figure 2

SUPERCOMPUTER CAD TOOLS



Source: Dataquest
March 1987

DATAQUEST CONCLUSIONS

For the following reasons, we believe that Japanese manufacturers will not enter the market with their own minisupercomputer systems during 1987:

- The potential revenue is still relatively small compared to the combined technical and business markets for other corporate resource computers, such as supercomputers and mainframe systems (see Tables 3 and 6).

- The market for minisupercomputers is still new. Japanese vendors seldom enter markets as technological innovators, preferring to let other firms do the work of market pioneering.

Table 6

ESTIMATED U.S. MARKET FOR CORPORATE RESOURCE COMPUTERS
TECHNICAL AND BUSINESS APPLICATIONS
1986-1991

	1986	1987	1988	1989	1990
Annual Unit Shipments	2,418	2,476	2,635	2,755	2,837
Total End-User Revenue ($M)	$9,119.2	$9,334.5	$10,002.5	$10,453.0	$10,808.0

Source: Dataquest
March 1986

In addition, barriers to entry into the market for minisupercomputers are forming. In particular, the "market window" for new entrants is starting to close. By early 1988, aspiring vendors should either have a product ready for sale or be prepared to face at least two obstacles:

- A successful track record of profitable sales has led to increased momentum by U.S. companies like Convex and Alliant. It will be more difficult for new entrants to gain a significant worldwide market share.

- Vendors of popular third-party applications software packages must be convinced of the benefits of porting such software to new systems, and the best way to convince such vendors is to demonstrate the potential for robust unit sales. Such an undertaking is especially challenging to late entrants into a market.

During 1987, we expect Japanese companies to be net purchasers of U.S. minisupercomputers. One way for them to do this is through direct purchase of systems from U.S manufacturers through their Japanese distribution channels, primarily for use in mechanical and electronic design automation. Another way is through attainment of equity positions in U.S. start-up firms. Dataquest believes that several Japanese companies not directly participating in MITI-sponsored research may have a "shopping list" of potential acquisitions in several high-technology industries in the United States, including telecommunications, CAD software, and minisupercomputers. The recent $20 million equity investment in Dana Computer of Sunnyvale, California, by Kubota Ltd., a $2.5 billion industrial equipment manufacturer, illustrates this phenomenon.

Japanese investment can bring much-needed capital to U.S start-up companies. We estimate that approximately $30 million is required for a new minisupercomputer venture to progress from company formation to product introduction. Japanese firms can benefit from such investments in several ways:

- Transfer of American hardware and software technology to Japanese companies.

- Eventual use of minisupercomputers by the investing firm (Heavy manufacturing firms have both the need and the talent to use advanced computing systems.)

- Diversification into high-growth industries (Coincident with the high Japanese trade surplus and the strengthening yen, many Japanese firms have considerable cash available to spend on new firms participating in high-growth market opportunities.)

- Avoidance of the "closing window" entry barrier into the minisupercomputer market (Several U.S. companies that could potentially team up with Japanese partners can deliver products during 1987.)

A Myth Exploded...

Japanese advances in high technology are often dismissed with facile explanations by Westerners. One such rationalization is the notion that the Japanese are wonderful at copying earlier strides taken by companies in other countries but contribute few innovative techniques and products. The intensity with which the Super-Speed Computer and Fifth-Generation projects are being undertaken provides sufficient evidence to indicate the vision and creativity of Japanese engineers and businessmen.

The same myth deserves to be debunked about Japanese work in minisupercomputers. Japanese activity here can be viewed as a means to an end, rather than a product to commercialize and rapidly exploit for profit. Minisupercomputers are one part of an integrated approach to the design and eventual manufacture and sale of future high-performance Japanese systems. This is in distinct contrast to U.S. minisupercomputer development, which has been characterized by young companies with innovative product architectures. Such systems often offer "solutions in search of a problem," because of the lack of useful application software and productivity/conversion tools that can maximize the benefits of the architecture.

...And a Lesson Learned

We observe that at least some elements of the integrated Japanese development style have been adopted by one new U.S. computer manufacturer. ETA Systems of St. Paul, Minnesota, was founded in August, 1983, as a spin-off of Control Data Corporation. ETA's goal was to foster an entrepreneurial environment in which advanced supercomputers could be rapidly designed, developed, and brought to market. Two tactics that are reminiscent of the Japanese have been implemented at ETA:

- Integrated CAD tools--A suite of proprietary IC CAD software that runs on CDC Cyber-205 systems is fiercely guarded and is considered to be the "company jewels."

- Application development--The company has established a Supercomputer Applications Laboratory (SAL) at the University of Georgia to develop applications software support, which will provide users with tools for becoming more quickly productive on the ETA-10 system.

Because the worldwide market for minisupercomputers is still relatively new and small and because of emerging entry barriers, we do not expect Japanese manufacturers to offer such systems in 1987. Instead, minisupercomputers will serve the internal or "captive" market within the companies where they are being developed. As a result of ongoing private and government-sponsored research, Japanese firms will eventually produce and use minisupercomputer systems based on new techniques, such as parallel processing. We do not expect these new computers to be commercially available before 1988. At any rate, an integrated approach to minisupercomputers, involving extensive internal use and concurrent development of software, can provide an advantage to companies that follow the Japanese lead.

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Dataquest
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Research Newsletter

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1987-09

THE TOP TEN: DATAQUEST'S VIEW OF FAST-GROWING EQUIPMENT MARKETS

Telecommunications equipment leads Dataquest's list of fast-growing North American electronic equipment markets; 7 of the 10 fastest-growing equipment markets fall into this market segment. This newsletter lists Dataquest's ranking of the 10 fastest-growing equipment markets in Table 1, briefly discusses the top 5, and analyzes the significance of these markets to the semiconductor manufacturer.

Table 1

DATAQUEST'S TOP 10 FASTEST-GROWING ELECTRONIC EQUIPMENT MARKETS
(Millions of Dollars)

Rank	Equipment Type	Estimated Equipment CAGR 1986-1990	Estimated 1986 Base Equipment Revenue	Estimated 1986 Semiconductor Consumption	Estimated 1990 Semiconductor Consumption
1	Voice Messaging	39.9%	$ 260	$ 13	$ 53
2	T-1 Multiplexer	25.1%	$ 291	$ 15	$ 38
3	Single-User Enhanced Computer Systems	24.3%	$1,457	$ 77	$198
4	Graphics Terminals	22.9%	$1,000	$ 68	$160
5	Private Packet Data Networks	21.7%	$ 279	$ 16	$ 39
6	Integrated Voice/Data Workstations	21.5%	$ 139	$ 17	$ 42
7	Cellular Mobile Radio Base Stations	20.9%	$ 380	$ 17	$ 42
8	Video Teleconferencing	19.1%	$ 87	$ 6	$ 15
9	Modems	19.0%	$1,545	$165	$406
10	Robot Systems	18.0%	$ 564	$ 17	$ 39

Source: Dataquest
March 1987

Dataquest, Incorporated, 1290 Ridder Park Drive, San Jose, CA 95131-2398, (408) 971-9000, Telex 171973

THE TOP FIVE

Voice messaging, the highest-growth equipment area, will obtain most of its growth from PBX integrated systems, while standalone voice messaging system sales are expected to decline at an 11.2 percent compound annual growth rate (CAGR) from 1986 to 1990. Growth in the voice processing market is being driven by the decreasing cost of speech synthesis technology, increasing use of (800) telephone numbers in which large volumes of telephone calls are processed each day, and increasing user familiarity with recording his or her voice on a machine. Voice messaging system semiconductor consumption is forecast to grow at a 42.5 percent CAGR from 1986 to 1990 and to reach $52.8 million in 1990.

The growth of T-1 multiplexers over the next four years will be positively affected by an increasing need for multiplexing systems that can handle both voice and data communications for private corporate networks. Growth will also be affected by AT&T's continued lowering of its price for T-1 facilities for long-haul communications. Dataquest expects T-1 multiplexer semiconductor consumption to grow at a 26 percent CAGR from 1986 to 1990 and to reach $38.4 million in 1990.

Single-user enhanced computer systems, which typically are intended for dedicated use in a technical application, have experienced extremely high growth in the past and are expected to grow rapidly in the future. Growth has been fueled mainly by the continuing transition from shared-logic, host-based systems to distributed, 32-bit workstations. Estimated semiconductor consumption for single-user enhanced computers is expected to grow at a 26.6 percent CAGR from 1986 to 1990 and to reach $198 million in 1990.

The graphics terminal market's fastest-growing segment is imaging, where Dataquest expects a 29.2 percent CAGR from 1986 to 1990. The largest graphics segment is concept design, where we expect a 20.6 percent CAGR from 1986 to 1990. Total graphics terminal semiconductor consumption is expected to grow at a 23.8 percent CAGR from 1986 to 1990 and to reach $160 million in 1990.

Dataquest expects growth for packet switching equipment due to the economies associated with packetizing data and the expected value-added services from the Regional Bell operating companies. We expect semiconductor consumption by private packet data networks to grow at a 25 percent CAGR from 1986 to 1990 and to reach $39.1 million in 1990.

DATAQUEST ANALYSIS

The markets displayed in Table 1 do not represent the consumer-oriented drivers that the semiconductor industry has seen in the past, such as calculators, digital watches, video games, and personal computers. During their respective heydays, each of these products represented a unique product that was heavily dependent upon semiconductor technology and was aimed at the individual consumer. The products displayed in Table 1 do not fit this scenario. Voice messaging, for example, is a fairly new concept that is very dependent upon semiconductor technology, but its potential unit volume is not even close to the total available market (TAM) that electronic watches were blessed with when they were introduced.

Dataquest's list of the 10 fastest-growing electronic equipment markets does represent fast-growing niche markets for a limited number of semiconductor manufacturers. We believe that products like smart cards, digital television sets, and personal communications have the potential volumes to drive the semiconductor industry. Since these products are being developed outside North America, however, semiconductor procurement for these products is most likely occurring outside the United States. The significance is that U.S. semiconductor market growth could lag the rest of the world until a market driver is developed in the United States.

David G. Norman

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Research Newsletter

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1987-08

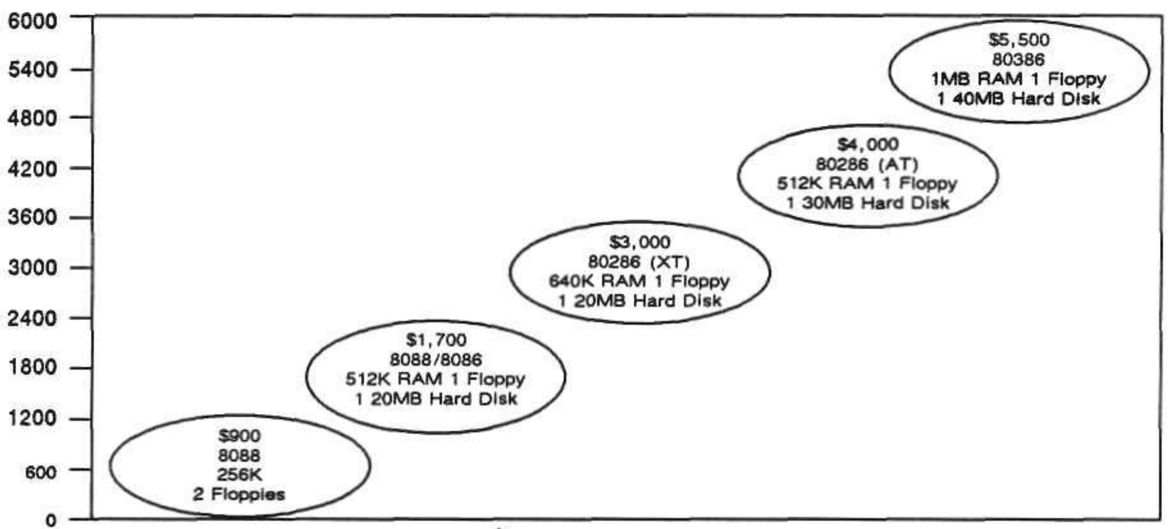
IMPACT OF THE COMPAQ DESKPRO 386: HOW THE 32-BIT PC MARKET IS SHAPING UP (AND IMPLICATIONS FOR IC MANUFACTURERS)

INTRODUCTION

In September 1986, Compaq introduced the first PC based on Intel's 80386 microprocessor. Its base model, the Deskpro 386 Model 40, with a list price of $6,499 not including a graphics card or display, outperforms by two to three times its high-performance predecessor, the IBM PC AT (with a price differential of 30 percent). The AT, in turn, at its time of introduction, provided price/performance advantages several times those of its predecessor, the PC XT. Figure 1 illustrates the migration of price versus performance in the personal computer market.

Figure 1

PC PRICE/PERFORMANCE MIGRATION



Source: Dataquest
March 1987

Dataquest Incorporated, 1290 Ridder Park Drive, San Jose, CA 95131-2398, (408) 971-9000, Telex 171973

While semiconductor price erosion has indeed played a significant role in fueling this cycle of higher performance at lower relative prices, perhaps more influential have been advances in chip technology and system architecture. Emerging standards in bus structures, graphics, storage technologies, and operating systems have allowed old and new semiconductor vendors to target integrated circuit development to the PC market. The resulting growth of application-specific ICs, custom as well as commercial chip sets, has likewise enabled a large number of new companies to enter the PC business.

To provide some insight as to where these developments have brought us and where they may lead tomorrow, Dataquest has examined the inner workings of a Deskpro 386 as well as a competitively positioned PC built around the Chips & Technologies Inc. (C&T) integrated 386 chip set.

BACKGROUND

Who Needs a 32-Bit PC, and Is Intel's 80386 the Right Processor?

Before proceeding, it seems to make sense to ask: Is it really time for a 32-bit PC? While some may argue that the only real reason for having 32-bit computers is similar to that which spurs the sales of Ferraris, there are some very good reasons to justify the existence of these PCs.

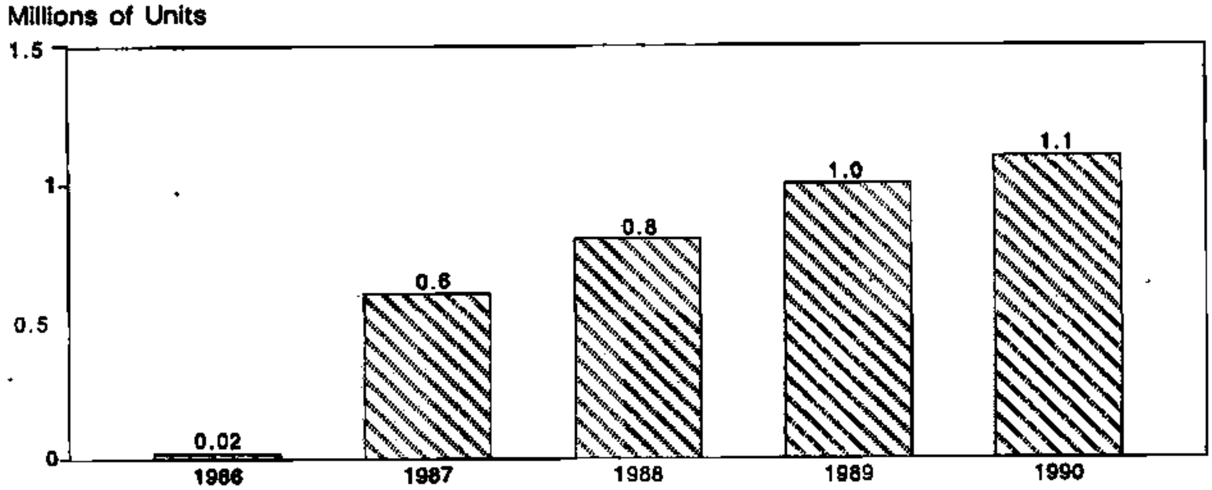
The 32-bit PCs bring into grasp powerful, low-cost platforms for electronic publishing, office automation and networking, technical and graphic-intensive applications, and artificial intelligence development. In the technical computer systems environment, in fact, PC ATs already reign as the leading computing platform. Leaping the mips performance barrier with 80386 processors, PCs are well positioned to gain even greater dominance in this arena. Intel argues also that the 32-bit machine will provide a platform for development of processor-demanding, user-friendly operating system shells that will spur the growth of PCs in the consumer market.

In any case, the 32-bit PC market is destined for growth, and it appears that Intel's 80386 will be the processor of choice for two good reasons. Foremost, of course, is the backward compatibility of the Intel chip, providing continued support for the billions of dollars already invested in DOS software. Second, tied to Intel's previous dominance in the PC market, is the virtual assurance of massive new software and hardware development around the 80386. As always, there will be no shortage of programs or alternative PC choices for the cost-, performance-, or reliability-conscious buyer.

As shown in Figure 2, Dataquest estimates that 80386-based PCs will grow to an installed base of more than 3.5 million units by 1990. This figure many be even higher, depending on the timeliness and capabilities of new support hardware and software. While the present forecast represents only 15 percent of the estimated total of 23 million installed PCs by that year, it remains a significant number representing hundreds of millions of dollars in hardware and software sales.

Figure 2

80386-BASED PC FORECAST



Source: Dataquest
March 1987

A New Generation of PCs

Truly, the introduction of the Compaq Deskpro 386 begins a new era in personal computing, not only because of the raw performance implications with its use of a fast 32-bit microprocessor (16 MHz today and 20+ around the corner), but perhaps more so due to new capabilities for multitasking and vast memory addressability--characteristics, of course, made possible by the use of Intel's 80386.

The memory-handling capabilities of 80386-based machines are staggering enough for any commercial computer, let alone a PC: 4 gigabytes of addressable physical memory and 64 terabytes of potentially addressable virtual memory. For those working day in and day out in the world of picoseconds and submicrons, numbers tend to lose significance, but consider this: A terabyte is a trillion bytes, a million megabytes--in other words, the equivalent of 50,000 20-megabyte hard disks. Of course, the support structure (operating system, software and storage interface/devices) is far from being in place to take full advantage of its memory potential; however, the platform now exists for development (much of which is well under way) and implementation of a virtually limitless memory bank.

In terms of multitasking, at least two companies have already introduced versions of a "386-DOS" and claim concurrent execution of up to 25 tasks each for up to 25 concurrent users running existing DOS applications. When the true 386-DOS finally arrives, spurring endless new software developments, multitasking and multiuser capabilities should be great indeed. UNIX operating environments will be ported onto the same 32-bit PC as well, allowing concurrent execution of UNIX and DOS applications. Or, as AT&T states, DOS will run as a subroutine under UNIX. AT&T's partnership with Microsoft (originators of MS-DOS) to develop Xenix as the leading flavor of PC UNIX, should bring some interesting new capabilities to the PC market.

Application processing speed will remain the least impressive feature of 80386 machines until the industry standard 32-bit bus and operating environment are established. Currently, existing DOS software runs about two to three times faster on the 80386 machine than on a PC AT; this is all right, but probably it is not justification enough for replacing already installed ATs. When the new standards are set and Intel's new 20-Mhz 80386 gets designed in, however, performance improvements of up to 10 times the PC AT are not improbable.

ANALYSIS OF COMPAQ'S DESKPRO 386 AND C&T-BASED 386 CLONES

Features of a Typical 32-Bit PC

Standard with the Compaq Deskpro 386 Model 40 are the following features, which are typical of other 32-bit PCs:

- Memory--1MB RAM, one high-performance 40MB hard disk, one 1.2MB diskette drive, Compaq's Expanded Memory Manager (CEMM)

- Communications--Multipurpose fixed disk controller board with standard interfaces for a parallel printer and serial/ asynchronous communications, two available expansion slots for 8/16-bit boards, and three expansion slots for 8-bit boards (An additional 8-bit slot is used for the EGA graphics card and another 16-bit slot for the controller board.)

- Miscellaneous--Compaq enhanced keyboard, real-time clock, security keylock, and a socket for an 80287 coprocessor

Again, these features appear to be the norm in most newly introduced 32-bit PCs, with differentiations being made in price, peripherals, and, to a lesser extent, speed and memory capabilities.

Compaq System IC Analysis

Dataquest believes that Compaq's overriding goal in designing the Deskpro 386 was simply to introduce the first 32-bit PC to the market. No doubt Compaq's stated objective of absolute compatibility with the PC AT was critical as well. For either or both reasons, though, Compaq used a very conservative design approach that resulted in a relatively high IC count as well as a reduction in potential system features.

Compaq's base system, which, again, is priced without a graphics controller or terminal, includes three boards: the motherboard covering the entire base of the AT-size box, a full-length memory board, and a roughly three-quarter-size controller board.

Compaq's motherboard houses the 80386, its support circuitry (including DMA and Interrupt control), and the proprietary system ROM BIOS chips, along with the seven expansion slots previously described. It also houses the system's only 32-bit slot, dedicated to Compaq's memory subsystem. All told, in terms of semiconductor content, the motherboard comprises some 82 integrated circuits, of which 64 are small- to medium-scale (SSI/MSI) standard logic devices, 9 are micro-devices (controllers and the 80386), 2 are memory chips (EPROMs) used for the ROM BIOS, and the remaining 7 are application-specific ICs (ASICs).

By designing a separate memory subsystem, Compaq was able to immediately market two memory add-on boards (a 1MB to 2MB board with 1MB of 256K static-column RAMs for $849, and a 4MB to 8MB board that is sold with 4Mb of 1MB RAMs for a list price of $2,999). Compaq elected to use static-column RAMs that are actually forms of dynamic RAMs (using page memory) which in some ways perform like static RAMs. A spokesperson from NMB, one supplier of Compaq's static-column RAMs, describes the parts as providing SRAM-like performance at DRAM-like prices. While the static-column RAMs do not actually match the performance of SRAMs, they are priced like any other DRAM (less than half that of SRAMs). The use of 100-nanosecond static-column RAMs seems to provide Compaq with the best price/performance solution, given its design. In terms of chip content, the base memory board contains 25 SSI/MSI standard logic devices, 2 RAM controller chips, 36 static-column RAMs, and 3 PAL devices--for a total of 66 ICs.

A multipurpose controller board, which includes a serial and parallel port and both the Winchester and floppy disk controllers, completes Compaq's base system. The IC content consists of 26 SSI/MSI standard logic devices and 3 controller chips for a total of 29 ICs.

All told, then, Compaq's base system contains about 177 integrated circuits on three boards measuring a total of approximately 280 square inches. A detailed summary of the Deskpro 386 chip count is provided in Table 1.

Table 1

COMPAQ SYSTEM ANALYSIS

Description	Motherboard	Memory Board	Disk Controller	Total Base System
SSI/MSI (units)	64	25	26	115
Standard Logic				
Estimated Cost	$ 23.37	$ 7.05	$ 6.89	$ 37.31
Memory				
Static-column RAM (units)	0	36	0	36
EPROM (ROM BIOS)	2	0	0	2
Estimated Cost	$ 8.00	$108.00	0	$116.00
ASICs				
PAL/PLA	7	3	0	10
Estimated Cost	$ 14.00	$ 6.00	0	$ 20.00
Microdevices				
80386	1	0	0	1
DMA Control	2	0	0	2
Interrupt Control	2	0	0	2
RTC+RAM Upgrade	1	0	0	1
RAM Control	0	2	0	2
Peripheral Control	1	0	3	4
Counter/Timer	2	0	0	2
Estimated Cost	$273.40	$ 9.50	$14.75	$297.65
Total System ICs (units)	82	66	29	177
Total System Cost	$318.77	$130.55	$21.64	$470.96

Source: Dataquest
March 1987

C&T 386 Clone System IC Analysis

To date, several 386 clones built around C&T chip sets have already been introduced. For this analysis, Dataquest visited C&T and examined its version of a 386 system, which is quite similar to most C&T clones.

The C&T-based computer line examined consists of only one board (excluding graphics), which integrated into just seven VLSI ASICs most of the system logic required to control the entire 386 machine. Included in C&T's CS8230 chip set is one 82C301 bus controller, one 82C302 page/interleave memory controller, one each of 82A303 and 82A304 address bus interfaces, two 82A305 data bus interfaces, and an 82A306 control signal buffer. An additional C&T ASIC, the 82C206 integrated peripherals controller, incorporates two 8237 DMS controllers, two 8259 interrupt controllers, one 8254 timer/counter, one MC146818 real-time clock, a 74LS612 memory mapper, and several other TTL SSI interface logic functions. The rest of the board consists of 31 SSI/MSI standard logic devices used for bus control, two EPROMs (for ROM BIOS), one Intel 8042 keyboard controller, Intel's 80386, and, finally, on the same XT-size board, 72 Texas Instrument 120-nanosecond 256K dynamic RAMs. All told, then, using the same memory configuration as Compaq's base system (1 megabyte of RAM), the C&T PC consists of 79 integrated circuits on less than 100 square inches of board space. Table 2 presents an IC count of the C&T systems.

Table 2

CHIPS & TECHNOLOGIES SYSTEM ANALYSIS

Description	Mother-board*
SSI/MSI	
Standard Logic (units)	31
Estimated Cost	$ 8.68
Memory	
Dynamic RAM (units)	32
EPROM (ROM BIOS) (units)	2
Estimated Cost	$ 80.00
ASICs	
386 Chip Set (units)	8
Estimated Cost	$110.00
Microdevices	
80386 (units)	1
Keyboard Control (units)	1
Estimated Cost	$260.00
Total System ICs (units)	79
Total System Cost	$458.68

*All functions included on Compaq's motherboard, memory board, and disk controller board are integrated onto C&T's motherboard.

Source: Dataquest
March 1987

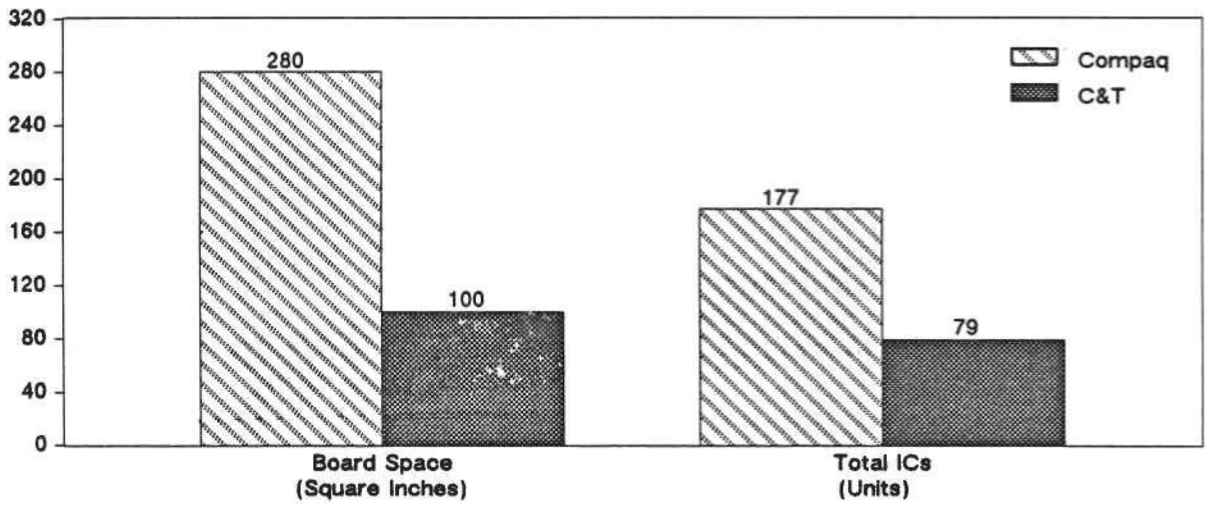
COMPARISONS--COMPAQ VERSUS C&T CLONES

First-Round Summary

Based on system design and price, therefore, it appears that C&T has won the first round. C&T, with the use of its seven-part chip set, was able to more than double the integration of the Compaq machine. Additionally, C&T users were able to offer their clones at significantly lower costs. Shown in Figure 3 are comparisons of total board space and IC counts for the Compaq and C&T computers.

Figure 3

COMPAQ VERSUS C&T



Source: Dataquest
March 1987

Of course, market leadership is established by a number of other factors besides smaller boards and fewer ICs. Compaq has clearly made its mark in the PC market, largely because of its conservative yet proven design techniques. Again, Compaq's strategy was that of being first rather than being best--at least for the first round. On the other hand, Chips & Technologies has managed to build an impressive reputation in the clone marketplace and clearly has a design approach to be reckoned with.

The Next Round

With the undefined development of many 386-based software and hardware products, much uncertainty surrounds the 32-bit PC market. Based on some recent announcements by Intel and clues from Chips & Technologies, however, a scenario such as this might unfold for the next round: Compaq maintains its allegiance to an Intel-based architecture. As a result, Compaq's new machine uses Intel's 20-MHz 80386 along with its new 32-bit, 20-MHz support chips including the 80387 math coprocessor, the 82380 integrated system peripheral chip (which combines direct memory access DMA control and major processor support functions), and the 82385 cache controller (which eliminates the current processor wait states). The result could be the market's fastest 32-bit PC with a much higher level of integration than previously seen by Compaq--potentially one board, although most likely two, to continue to allow a variety of add-on memory configurations.

We expect Chips & Technologies, of course, to look toward faster parts as well. But more importantly, C&T will continue to base its strategy on that which has already brought it success--increased density. And with density will come the benefits C&T customers seek--the fastest possible design cycle with the highest possibility for first-time design success--along with the lowest overall system design cost. These goals, in fact, which are the mainstay of ASIC design, will continue to allow C&T to charge a premium of up to two times the cost of off-the-shelf ICs. Look for the C&T machine to migrate to a single board (including graphics), possibly with programmable features within the ASICs.

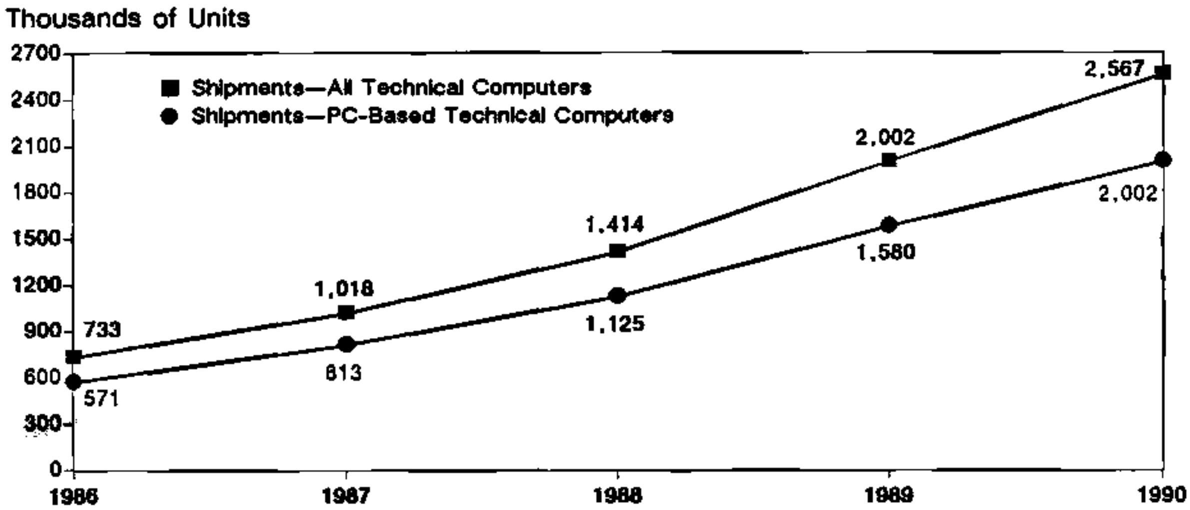
DATAQUEST CONCLUSIONS

32-Bit PC Trends

Regardless of the features and/or flavors of the next round of PCs, several trends are emerging in this market. Clearly, the gap is diminishing between the traditional capabilities of the dedicated workstations and the PC "workhorse." Intel claims, in fact, that PCs using all of its new 20-MHz chips will outperform Sun Microsystem's Sun 3/120 workstation and Digital Equipment Corporation's VAX 8600 superminicomputer. Certainly, dedicated workstations based on very high performance 32-bit processors such as Motorola's 68030 family, Fairchild's CLIPPER, and National's 32032 are making great leaps in performance, too. In fact, some machines using these chips are already in production performing in the 5+ mips range, dwarfing older Digital and Sun systems. But as illustrated in Figure 4, in terms of units, the PC is already the most-used platform for technical computing, and the introduction of the 32-bit PC is certain to elevate its status.

Figure 4

WORLDWIDE SHIPMENTS OF TECHNICAL COMPUTERS



Source: Dataquest
March 1987

With the increase in its use as a technical workstation, the PC is seeing movement toward specialized applications such as desktop publishing, computer-aided design and manufacturing (CAD/CAM), and artificial intelligence (AI) development among others. With these specialized uses, increasing demands will be made on the PC's processing speed, memory capacity, and transfer rates, as well as graphics capabilities. Each of these requirements, then, will have great impact on all of the peripheral support industries as well as on the PC manufacturers themselves.

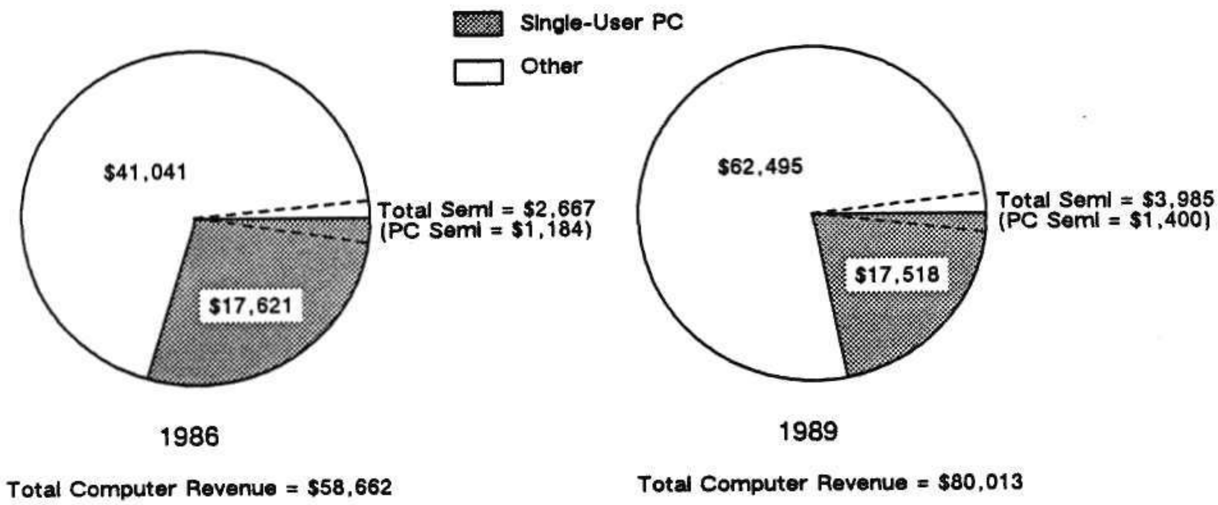
Implications for IC Manufacturers

Overall, the growth of semiconductor revenue for the computer marketplace is looking healthy. Figure 5 illustrates Dataquest's forecast for revenue from shipments of all computers (with personal computers as a subset) as well as the related semiconductor revenue. Note that the ratio of semicondutor revenue to computer revenue will remain constant at around 5 percent for the market as a whole (around 7 percent for just PCs).

In light of the outlined trends resulting from the 32-bit PC analyses and the direction of computer revenue as shown in Figure 5, Dataquest believes that the greatest opportunities for integrated circuit manufacturers servicing the personal computer market will lie in several areas.

Figure 5

WORLDWIDE COMPUTER INDUSTRY
(Shipment Revenue in Millions of Dollars)



Source: Dataquest
March 1987

The first area is continued growth in application-specific ICs. As PC manufacturers attempt to introduce smaller, faster, and less expensive machines, the demand for highly integrated chips is inevitable. Not only ASICs directed at integrating traditional motherboard logic, but also those maximizing peripheral controller functions and high-resolution graphics capabilities, hold great promise. Along with the application-specific logic chips are apertures for dedicated processors and microcontrollers, particularly in the areas of computer graphics and storage.

Additionally, as notorious memory munchers, these 32-bit machines will require faster and denser memory ICs. Static RAMs and static-column RAMs as well as traditional DRAMs with densities of 1 megabit and above will be consumed in ever greater ratios within PCs. It is likely that, within the next year or so, an even faster 80386 will appear (32 MHz?). With this will come demand for even faster ICs (using processes such as submicron CMOS and BiMOS) with yet even higher levels of integration.

Surely, PCs represent just one product in a very large electronic marketplace, but Dataquest believes that these trends are universal and that the movement toward VLSI-based systems is still in its infancy.

Nanci J. Magoun

Dataquest
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The Dun & Bradstreet Corporation

Research Newsletter

SAM Code: 1987-1988 Newsletters: January-March
1987-07

SECOND ANNUAL PROCUREMENT SURVEY--THE ISSUE IS COST

THE PRELIMINARY RESULTS ARE IN

Early results of our second annual procurement survey were announced at Dataquest's Semiconductor User and Application Conference held in Tampa, Florida in early February. The most prominent issue raised by major electronic equipment manufacturers was that of cost and competition--it became the theme of this year's survey.

The manufacturers that make up the Electronic Business 200 participated in our annual data and trends gathering project, which takes a look at what semiconductor buyers are saying. This year, the nearly 50 percent response rate indicates that users expect to increase their 1987 semiconductor purchases by more than 13 percent. This is up from last year when they projected that 1986 purchases would grow by only 7 percent--that projection was met by within one percentage point by year-end 1986.

The Survey's Structure

Each year Dataquest's SAM industry service gathers information for semiconductor manufacturers about their customers and markets in the United States. Our target audience is manufacturers listed in a comprehensive annual ranking of the top electronics manufacturers, which is published by Electronic Business.

Last year we estimated that our respondents accounted for more than 45 percent of North American semiconductor consumption.

The original list of 200 companies was pared to eliminate semiconductor and other types of component manufacturers that do not buy semiconductors for use in their electronic systems and subassemblies. We also eliminated distributors from the survey audience. We telephoned

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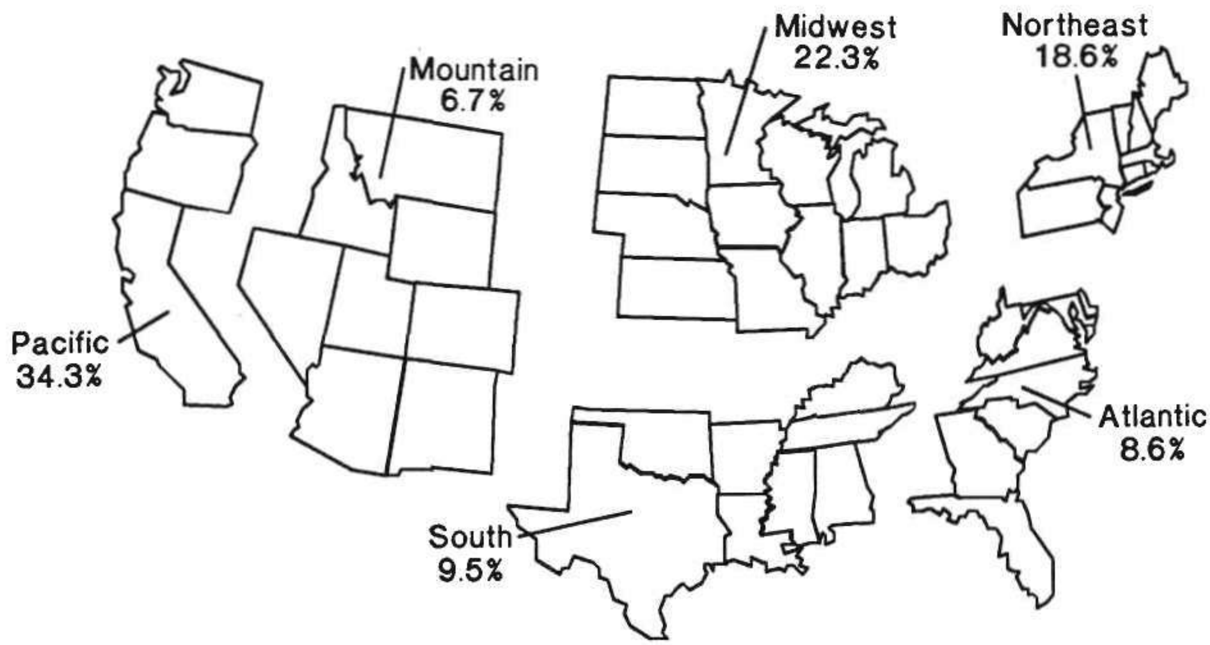
each location and interviewed individuals who are buyers, purchasing directors, or who are in material or corporate contract management. So far, more than 205 surveys have been completed.

Figure 1 shows the geographic locations of our survey respondents. These regions closely mirror the geographic distribution of the entire survey audience, leading us to believe that our survey had adequate representation across all regions. We have also checked the data that we gathered about the overall mix of their semiconductor purchases against Dataquest's 1986 estimates; Figure 2 shows how closely they reflect one another.

Figure 1

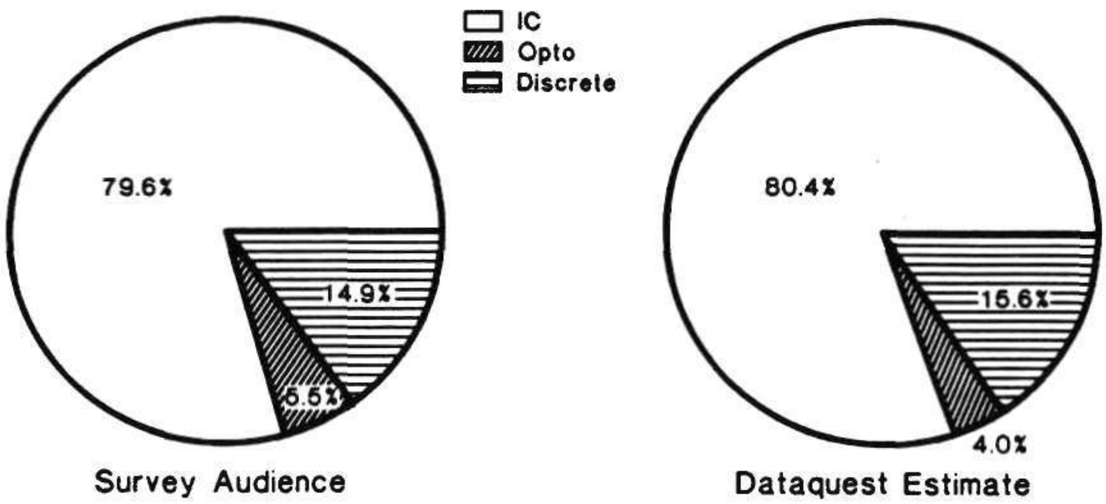
PROCUREMENT SURVEY RESPONDENTS
(Percent of Total)



Source: Dataquest
March 1987

Figure 2

1986 SEMICONDUCTOR MIX
(Percent of Total Dollars)



Source: Dataquest
March 1987

ASSESSING GLOBAL IMPACT

Once again statistics were gathered about the regional base of semiconductor suppliers. We defined the regional base as the semiconductor company's country of origin and found that not too much has changed since last year. About 83 percent of purchases were made from U.S.-based semiconductor manufacturers. Japan and Europe came in at 14 and 1 percent, respectively. The ROW companies grew from 0.5 to 1.8 percent of this year's total. We found that the amount of components bought from non-U.S. suppliers was directly related to the type of equipment the electronic equipment manufacturer produced. Data processing and automotive manufacturers purchased much more than the average from Japan, because of the high use of MOS memory in data processing and the stringent quality requirements demanded by the automotive industry.

When asked about buying components offshore for U.S.-based equipment production (regardless of the supplier base), the data processing, consumer, and auto manufacturers were the most in favor of this procurement method.

Shifts Offshore

Table 1 shows the result of our question about shifting electronic equipment production offshore. Just less than half of the respondents expected some or a great deal of shift in their production activities. It is encouraging to note that many did not expect any shift at all.

Table 1

ANTICIPATED SHIFT TO OFFSHORE PRODUCTION
(Percent of Total Respondents)

	1985	1986
A Great Deal	8.4%	10.1%
Some	35.9	33.2
Not at All	55.7	56.7
Total	100.0%	100.0%

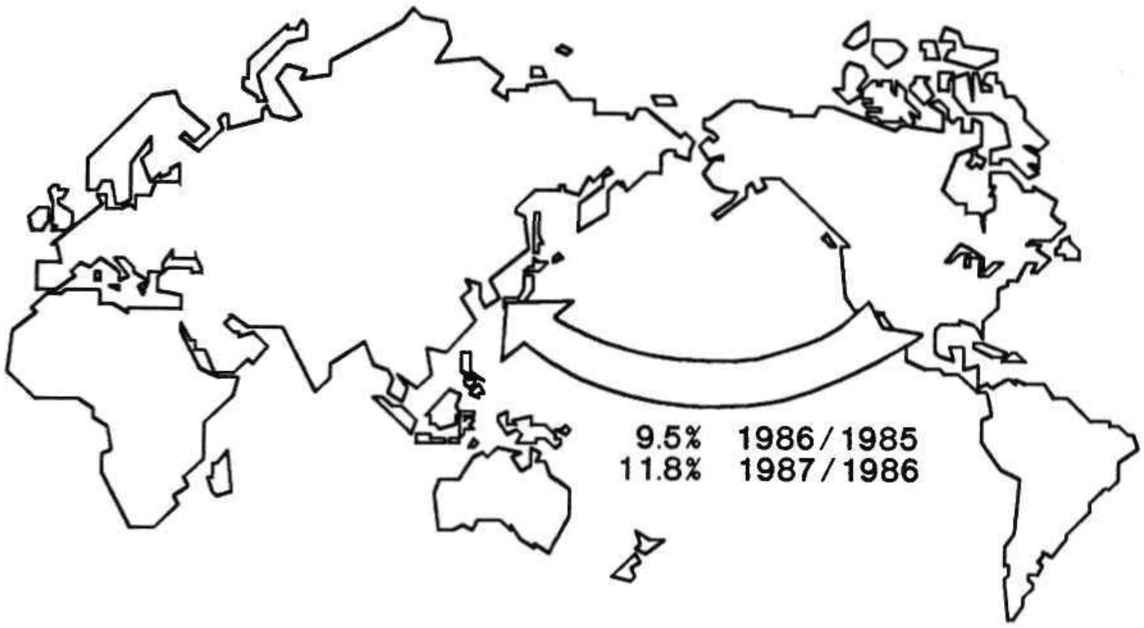
Source: Dataquest
March 1987

The caveat, however, lies in the fact that the respondents in data processing and communications markets were those that expected to shift some or a great deal of their production offshore. These two market segments are led by a few very large electronic equipment manufacturers that have the necessary resources or need to make this move. Because of their weight in the market, these two communities also make up over half of North American semiconductor consumption. The message to semiconductor manufacturers is be a worldwide participant or lose position in the global market.

Figure 3 reflects our attempt to quantify the impact on U.S. semiconductor consumption. We asked each survey respondent for the percent of their consumption that shifted in 1986 and what they believe could shift in 1987. At first, we simply took an average of the percent figures and arrived at about 5 percent in 1986 and 7 percent in 1987. When converted to dollars, however, the estimates were 9.5 percent and 11.8 percent, respectively. This confirmed our belief that it is the large manufacturers who have the resources to shift to offshore manufacturing or the need to do so. They also happen to be the large buyers. We believe that this is one key reason why the long-term growth rate of the industry may drop from historical growth patterns.

Figure 3

ESTIMATED U.S. SEMICONDUCTOR
CONSUMPTION MOVING OFFSHORE
(Percent of Total Dollars)



Source: Dataquest
March 1987

Why the movement? This is where the issues of cost and competition first arose. The most often cited reasons for moving production and, ultimately, semiconductor consumption offshore were as follows:

- Lower manufacturing and labor costs
- Price and quality
- Competition
- Manufacturing moving offshore

- Buying subassemblies offshore
- Manufacturing already offshore
- Technology no longer available in the United States
- Increased production
- Merging divisions
- The U.S./Japan trade agreement

ASSESSING INVENTORY LEVELS

Clients have repeatedly asked Dataquest to assess inventory levels. In particular we were asked to include questions on this subject in this year's survey. Table 2 and Figure 4 show the results of our question concerning the status of target inventory levels. The commonly held belief that inventories are "at an all time low" does not appear to be the case. At first glance it appears that 71 percent of the respondents are at target or below. But 73 percent are at target or above. When faced with an analysis of whether the "glass is half full or half empty," we opted for the conservative approach. Our view was cemented when we looked at the data gathered in Figure 4, which clearly shows that most of the respondents expect to maintain the same or a decreased target inventory level.

Table 2

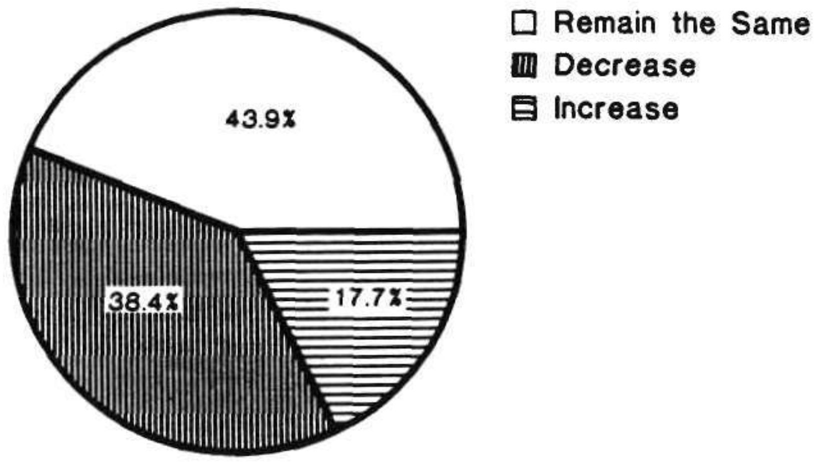
SEMICONDUCTOR INVENTORIES RELATIVE TO TARGET
(Percent of Total Respondents)

Extremely Low	4.9%
Somewhat Low	15.1
At Target	51.7
Above Target	22.0
In Significant Excess	6.3
Total	100.0%

Source: Dataquest
March 1987

Figure 4

EXPECTED CHANGE IN TARGET INVENTORY LEVELS
(Percent of Total Respondents)



Source: Dataquest
March 1987

Dataquest believes that fundamental industry transitions are occurring that are significantly changing manufacturing operations. Shifting production offshore is one, but streamlined operations, automation, and an overall concern about competitiveness are affecting the way manufacturers are doing business with their suppliers. The entire concept of "partnering" may pull in the whiplash affect associated with dramatic swings in inventory. These buyer/supplier links may be all the more entrenched because of the duration of the semiconductor industry recession.

For the skeptical semiconductor manufacturer we cite some interesting statistics recently published in Electronic Business. Xerox has reduced its overall supplier base from 5,000 to 300. A product group within Control Data Corporation has already reduced its supplier base from 1,100 to 300 and is aiming for 200. When Apple Computer opened its Fremont facility, it cut its supplier base in half. At our recent SAM conference, Dataquest noted with interest the comment from one senior executive from Motorola who said, "Our suppliers don't even know or understand the competitive struggle that they are in."

WHAT'S ON THE USER'S MIND

Every year we ask an open-ended question: What are the two major purchasing issues that you are facing. Below is our list in rank order of the twelve issues most frequently mentioned.

- Pricing
- Availability/leadtimes
- Quality/reliability
- On-time delivery
- FMVs/U.S./Japan trade agreement
- Cost control
- Inventory
- Surface mount
- New products/product obsolescence
- ASICs
- Offshore manufacturing and procurement
- Just-in-time delivery

The tone of the user's responses indicated a lot of concern over cost-related issues, much more so than last year. In fact, besides the trade agreement, which wasn't an issue last year, cost control, offshore manufacturing, ASICs, and surface mount did not even make last year's list. Just about every issue listed concerns cost. We believe that the technology-related issues of surface mount, new products, and ASICs, were mentioned because of their positive impact on overall system design, cost, and competitiveness.

DATAQUEST CONCLUSIONS

The time that members of the user community spent with us to discuss their use of semiconductors has provided insight on the dynamics shaping the industry. Overall, we believe that users expect moderate growth in purchases and that shifts in electronic equipment production offshore may have long-term implications for domestic semiconductor consumption.

Inventories are being affected by changing operations and, for the most part, users are dealing with significant business issues that are a function of a competitive global marketplace. Electronic equipment manufacturers need to protect their markets, access technology, and control costs in a win-win environment with their suppliers. Now is the time to cement these relationships.

Anthea C. Stratigos

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RESEARCH NEWSLETTER

SAM Code: 1987-1988 Newsletters, January-March
1987-06

DATAQUEST'S USER CONFERENCE REVIEWS PARTNERING OPPORTUNITIES IN THE GLOBAL ELECTRONIC INDUSTRY

SUMMARY

Dataquest's third annual conference for semiconductor users was held at the Saddlebrook Golf and Tennis Resort in Tampa, Florida, from February 4 to 6. Managers from major electronics and semiconductor manufacturing companies spent three days exchanging their views on the current industry environment and its impact on both industries. Companies represented included major participants from both industries.

Electronic Manufacturers	Semiconductor Manufacturers
AT&T	Fujitsu
Apple Computer	Hitachi
Digital Equipment	IDT
Eastman Kodak	MMI
Emerson Electric	National
Ford	RCA
General Motors	Siemens
Hewlett-Packard	Texas Instruments
Honeywell	Thomson
IBM	
Motorola	
NCR	
Northern Telecom	
Olivetti	
Tektronix	
Teradyne	

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The conference was sponsored by Dataquest's Semiconductor User Information and Semiconductor Application Markets services. The theme was "Partnering in a Global Economy." The conference was organized into four segments:

- Global issues
- Manufacturing strategies
- Customer/vendor relationships
- Dataquest view of industry trends

SPEAKER HIGHLIGHTS

We have summarized each speaker's key points. These speeches provided a variety of perspectives of the industry "in the trenches," where the current focus is in the current global economic battles. The conference agenda is attached for your information.

Global Issues

Impact of the Global Electronics Industry
Fred Zieber, Dataquest

The electronics industry has entered an era of global competition where technology is widely available and many aggressive competitors pursue the available markets. This has created an environment in which computers have become commodities. Alliances have become widely used to achieve competitive advantage and to marshal resources in the slower-growing worldwide markets. Trade issues and protection of intellectual property have complicated the market structures for both customers and their suppliers. Companies that are to compete effectively in the global economy must be world class, adopting worldwide procurement and marketing strategies and effectively using partnerships with their suppliers to remain competitive.

Programs for Competing Internationally
Brad Kroha, Motorola

Global competitors are rapidly switching from conventional purchasing methods to a better approach--supply management. Supply management focuses resources on fewer suppliers in a win-win partnership environment. Supply managers focus on the entire line of supply, looking for the best-in-class suppliers. A major goal of the program is to build supplier expertise into new products. Supply managers also work with suppliers to compress supply lead times in order to improve the responsiveness of the entire supply line to shifts in customer needs.

Supply management is facilitated through commodity management teams. These teams consist of personnel from purchasing, engineering, manufacturing, and other necessary groups. The job of the commodity management team is to set levels of supplier performance in an effort to reduce the supplier base to those best-in-class suppliers who can contribute to the customer's long-term success in the market.

Japanese Perspective on Partnering
Kosei Nomiya, Hitachi

Customer/vendor relationships are an extension of the relationship between a company and its employees. Each is a long-term agreement to achieve mutual goals. As part of this agreement, the supplier is expected to provide the customer with a better product at a lower price and with superior service. In addition, the supplier is expected to accept part of the responsibility for achieving the customer's goal.

One excellent example of this is observed in quality circle teams, which include members from both the customer and the supplier. These teams review incoming inspection, factory floor data, and field data to cooperatively determine how to improve product quality.

In this environment, both parties see themselves as a crew aboard a ship together. If the ship begins to sink, they all act together to save it.

A U.S. Perspective on Partnering
Doug Newman, National Semiconductor

There are three types of customer/vendor relationships among U.S. companies, all of which may be viewed as partnerships at different levels. A buyer/seller or deal-based relationship generally is built around mutual respect of the sales engineer and the buyer, based upon vendor competitiveness and a track record of customer support. The positioning partnership involves confidence in vendor support and technology resulting in a higher-level management relationship and use of existing vendor proprietary products. Partnerships are total commitments based upon mutual trust and mutually beneficial technology and service relationships. In these relationships, the customer and supplier openly examine each other's strengths and needs and identify opportunities for mutual competitive benefit. These relationships require interdependency, long-term commitment, and contributions by both parties. Typically, customers and suppliers can only undertake a limited number of these types of partnerships, but their benefits accrue across the industry. True partnerships require less effort per dollar of sales produced and generally produce greater profits for both parties.

The Benefits of Lead-Time Reduction

Phil Thomas, Thomas Group

The demands of the current global competition require shorter development cycles and improved responsiveness to customer needs. Total corporate cycle time is the key to achieving these thrusts. The service benefits of short cycle times are well known and are being exercised by major customers with their suppliers. A second and less well-understood impact of shortened cycle times is the impact on vendor cost. Experience cost curves are driven by cycles of learning, rather than simple cumulative unit volume. One cycle of learning is the number of days per manufacturing cycle. If a vendor can double the number of cycles of learning for a given production volume, he can move from a 70 percent experience curve to a 60 percent curve, reducing costs at a faster rate than a competitor with a longer manufacturing cycle. This cost improvement coupled with the service benefit can significantly enhance the customer's competitive position.

U.S. Japanese Trade Agreement: Progress Report

Gil Kaplan, U.S. Department of Commerce

Progress by the Japanese government on implementing the trade agreement has been far slower than we expected. MITI's first steps were taken on September 20, seven weeks after the signing of the agreement, when it established a monitoring office and requested Japanese companies not to sell in third countries below cost. Actual monitoring did not start until October 1, using unverified cost figures. They did change export licensing requirements to shipments valued at ¥50,000 down from ¥1 million, effective January 1987.

Japan has made an effort to enhance access to the six largest semiconductor users in Japan, which represent less than 40 percent of the Japanese market. In the last consultation, they agreed to extend these efforts to the top 55 users, which account for most of Japanese semiconductor consumption.

The U.S. government is monitoring prices in third markets very carefully during the next one to two months. If we do not see improvement, we have told Japan that we reserve the right to revert to the dumping penalties that have already been set. MITI and the Japanese government must work to build a consensus to support this agreement, or the U.S. Congress is likely to pass very protectionist legislation that may not benefit either country.

Manufacturing Strategies

Automation's Role in Competition

Dave Penning, Dataquest

Modern manufacturing operations include both the product development and the fabrication function. Successful factory automation requires that companies break down the walls between engineering and production. Automated factories evolve from hand assembly operations to automatic equipment to intelligent factories by progressive application of electronic controls, computerization, and incorporation of sensor technology.

Automation of design, production, and information can produce substantial benefits in reducing design cycle time and costs, inventories, and production lead times, while increasing factory capacity, yield, equipment utilization, and effective sharing of information and decision support. Automated factories will be smaller and will require fewer workers with specific knowledge to operate them.

Modern factories will require substantial investment, new manufacturing methods, and complex implementation. Successful implementation of automation will be necessary to survive in the global competitive environment.

A Worldwide Manufacturing Strategy

Hal Edmondson, Hewlett-Packard

Hewlett-Packard has defined a corporate manufacturing strategy that guides decisions about its manufacturing operations worldwide. Implementation of this strategy leads Hewlett-Packard to establish international activities when it is appropriate to do so.

The advantages of international activities include satisfying market access requirements. They also take advantage of lower operating costs, business incentives, and a broader knowledge base. A number of disadvantages also exist, including duplication of people and equipment, extended lines of control, and purchasing start-up costs.

Hewlett-Packard's approach of including purchasing, manufacturing, and R&D at most facilities has proven to be a successful one for an international corporation.

IBM's New Austin Facility--A Perspective on Automation
Clark Preston, IBM

IBM's Automated Logistics and Production System, called ALPS, is a state-of-the-art flexible automated manufacturing facility. Products produced in this facility are designed for simplified automated assembly. For example, a product comparable to a Selectric typewriter today is assembled from 52 components (a PC card is one of them). The original Selectric had 3,000 parts.

IBM's ALPS has evolved over several years, starting with a vehicle (the Displaywriter) using "islands of automation." This was used as a base project for identifying those characteristics required for automated assembly of a product, and ultimately for designing a product and building a fully automated manufacturing system. ALPS has not yet reached the ultimate level of automation, but continues to be refined and improved as manufacturing technology improves.

The Role of Contract Manufacturing
Gene Sapp, SCI Systems, Inc.

The growth of contract manufacturing has been stimulated by intense competition in the marketplace, shortened product life cycles, asset and capital management considerations, rapidly changing manufacturing technologies, users' demands for quality, and multinational market opportunities. The number of users of contract manufacturing services is growing rapidly as market pressures tighten, technology changes, and the benefits are appropriately analyzed.

Contract manufacturers offer more companies access to state-of-the-art manufacturing facilities and high-volume buying power for components. This can make capital resources available to electronics manufacturers to invest a higher-level facility automation.

The successful contract manufacturing operation of tomorrow will offer fully integrated SMT services, including design for producibility. It will be in tune with the latest processes; its automation will be optimized for low cost, high quality and flexibility; and its customers will rely on it for worldwide support in both material acquisition and multinational market penetration.

Customer/Vendor Relationships

Customer/Vendor Relationships--An International Perspective
Bernard Hadley, STACK

STACK is an association of 11 European and U.S. companies that was formed in 1974. Its purpose is to work together to reduce the cost of ownership of semiconductor components by sharing efforts, particularly in the technical, service, and quality areas.

One concern of the members of STACK is the impact of the U.S./Japanese semiconductor trade agreement. They do not believe that there is any long- or short-term benefit to actions that raise prices to customers. Semiconductor tariffs have done nothing to help the European semiconductor industry.

Some of STACK's key objectives in working with suppliers are to facilitate improved vendor performance in quality and service for members, to encourage the use of electronic data interchange and standard packaging and labeling, and to offer realistic pricing. STACK also attempts to achieve common and more effective computerized device models, realistic ASIC second sources, productive R&D, and, in the end, lower cost of ownership.

The Changing Face of Distribution in Technology Partnerships
Bob Gardner, Hamilton/Avnet

Distributors remain the suppliers of service to 90 percent of the customers in the electronics industry. However, the definition of service is changing rapidly, from simple financial services and value-added component services to sophisticated technical support for VLSI semiconductors and system products. Distribution is positioning itself to provide technical expertise to the broad customer base not served directly by the semiconductor manufacturers.

In a role similar to the third-party design companies, distributors will facilitate the design interfaces from their customers to a variety of semiconductor manufacturers, then provide the services required to deliver the production product to the customer.

Technology Partnerships for ASIC Product
Mike Callahan, MMI

MMI believes that programmable logic devices (PLDs) and logic cell arrays will be used more widely by customers than is currently forecast by Dataquest. MMI's reasons include rapid progression down the experience curve due to the high cumulative volumes per product type, and mask production limitations that will limit gate array and standard cell growth. Standard cell designs will have to be cooperatively designed by customers and suppliers to create families of cell-based arrays that can be used in a variety of customer system designs.

In any customer-specific product program, customer and supplier as partners must understand the costs involved and work together to reduce them. Key factors are manufacturing cycle times and diagnostics. Excellent performance on these can reduce production and nonrecurring engineering charges.

Gate array and standard cell programs do not generally allow for realistic second sourcing. In sole-source arrangements, it is imperative that the customer is assured of receiving his product when he needs it over the long haul and that the supplier is assured of long-term profitability.

Poor Quality--An Expensive Bad Habit
Chuck Harwood, Quality Improvement Co.

In typical companies, the cost of waste caused by poor quality throughout the organization can be 20 to 30 percent of sales. Forty to fifty percent of the white collar worker's time is spent dealing with the consequence of defects, errors, mistakes, or missed promises.

Poor quality is a result of management neglect, and can only be corrected by management attention. An effective quality improvement system involves clear definition of all requirements, quality improvement by defect prevention, and an ultimate goal of zero defects.

Results that have been achieved by effective quality improvement programs are:

- 10x to 100x reduction in defects
- Savings of $7 for every $1 invested
- Savings of one-third of a company's pretax earnings
- Reduction of throughput by a factor of four

Vendor Performance Rating--A Quality Report Card
John Durkin, Unisys

Unisys' Component Engineering and Procurement Organization (CEPO) has developed a supplier quality improvement program. The key elements of this program include a quality council with each major supplier, quarterly senior management reviews, a certification program, and feedback and analysis of manufacturing plants' quality data. Quality performance is measured on the basis of parts per million (ppm) reject rates to Unisys specifications. Quality performance is fed into a supplier effectiveness model that establishes a cost of ownership for each supplier. The model also involves factors for delivery timeliness, delivery volume, and service. A supplier effectiveness factor is calculated that is used to convert unit costs to cost of ownership. Supplier business awards are made using lowest cost of ownership as a deciding factor.

Since first quarter 1985, reject rates have dropped from 8,500 ppm to 500 ppm in the fourth quarter of 1986. In fourth quarter 1986, supplier quality levels ranged from less than 50 ppm to about 1,700 ppm. One supplier out of the 11 suppliers tracked was certified. Unisys' goal is zero defects. This program of shared responsibility, effective communication, and cooperative problem solving has enabled Unisys to make substantial progress toward that goal.

Dataquest View of Industry Trends

1987 Outlook

Gene Norrett, Semiconductor Industry Group

In 1986, the semiconductor industry was affected by large financial losses, slow computer industry growth, continued shift of technology and market leadership to Japan and Asia, and the U.S.-Japan trade agreement. Worldwide semiconductor growth of 23.4 percent was due mostly to the weakening of the dollar against European and Japanese currencies. This and the U.S.-Japan trade agreement drove more companies to shift manufacturing to newly industrialized Pacific Rim countries whose currencies were more closely tied to the dollar. This shift, coupled with growing industrial strength within the countries, caused ROW consumption to grow more than 50 percent. Japanese semiconductor manufacturers gained the top three positions in the world semiconductor competition.

More stable exchange rates are expected to moderate industry growth in 1987 to 15 percent, although North American consumption is forecast to double from 1986. Increasing competition from Japan, Europe, and the newly industrialized countries will keep pressure on prices and keep availability good in 1987.

New growth opportunities that Dataquest expects will drive the market in 1988 and beyond include:

- Smart cards and related electronic systems
- Digital televisions and VCRs
- Personal communications
- 32-bit PCs with speech recognition
- Automotive electronics

Second Annual Procurement Survey
Anthea Stratigos, Semiconductor Application Markets

This survey is conducted annually among the Electronic Business 200--a list of the 200 largest U.S. electronics companies. The survey respondents said that they expect to spend 13.6 percent more on semiconductors in 1987 than they did in 1986. In 1986 they purchased 12 percent of their requirements from distributors. Semiconductor purchases made outside the United States for use in U.S.-based products ranged from 4 percent in communications and industrial segments to 29 percent in the transportation segment.

The shift to offshore consumption continued in 1987 with almost 12 percent of purchases expected to move from the United States to offshore. Buyers indicated that they are generally at or below target inventory levels, but 28 percent said that their inventories were above targets. Almost 40 percent of the respondents said that they are planning to reduce their inventory targets in 1987.

To buyers, the five most important issues in the fourth quarter of 1986 were:

- Pricing
- Availability/lead times
- Quality/reliability
- On-time delivery
- FMVs/trade agreement

Our conclusion from this response is that customers are beginning to feel that vendor quality has improved substantially and that cost and service are prime concerns for remaining profitable in a highly competitive global market.

Capacity and Capital Spending
Bob McGeary, Semiconductor Equipment and Materials Service

Slower end-market growth and overinvestment in semiconductor manufacturing capacity has created an environment where semiconductor manufacturers have reduced their investment plans for new manufacturing facilities during the next few years. Capacity utilization in the United States, Japan, and Europe ranged from 40 to 70 percent in 1985, and is not expected to return to high levels until 1988. This situation will keep pressure on pricing in the short term and keep most products readily available.

We expect the industry to return to near full capacity utilization by 1988, especially in advanced 1-micron and smaller technology. This is expected to return the industry to a strong recovery in 1988 as new products using advanced technology enter volume production.

Application-Specific Integrated Circuits

Stan Bruederle, Semiconductor User Information Service

Purchasing ASICs is a very complex job. A variety of factors are changing the industry and its customers' needs.

Technology improvements drive complexities higher. Customers use PLDs where gate arrays have been used and gate arrays where standard cells once seemed best suited. As a result, customers use a wider variety of ASICs but want to buy them from a limited supplier base.

Different semiconductor companies lead the competition in each ASIC product category. As customers use a greater variety of ASIC products, semiconductor companies have begun to add new families to their product portfolios.

Many of the major broad line suppliers and some of the new entrants offer or plan to offer a variety of gate array, standard cell, and PLD products.

Increasingly complex technology and growing complexity are raising the cost of participating in the ASIC market. We believe that these factors will drive smaller companies out of the industry during the next five years. Mask programmable ASICs will consume huge numbers of mask sets between now and 1990. We expect shortages to occur that will affect suppliers' deliveries of products to their customers.

Prices vary widely, with PLDs being the most expensive but decreasing rapidly as MOS technology becomes more widely used and competition increases. Gate arrays are generally the lowest-cost ASIC approach. Standard cells are the lowest cost at very high complexities and volumes.

Gate array and standard cell companies are entering a race to achieve the single-chip solution, the ultimate ASIC objective.

Successful use of ASICs requires that users have an in-depth understanding of product and technology changes and the developing industry relationships that will affect them.

Microdevice Update

Brand Parks, Semiconductor User Information Service

Dataquest forecasts that by 1990, companies will spend almost $9 billion on microcomponents, or 21 cents of every purchasing dollar. The top five microcomponent suppliers are Intel, NEC, Motorola, Mitsubishi, and Matsushita. The United States is currently the largest consumer of microcomponents in the world. We forecast that by 1991, Japan will be. Other trends impacting the market will be the offering of original products by Japanese companies, the continuing battle over intellectual property, and the emergence of video and graphics as high-growth business opportunities.

Design and development support is becoming very costly for new, highly complex devices, making product selection a very expensive activity. It is essential that users have a complete system perspective when making product decisions. Microperipheral devices are becoming critical parts of total product offerings; they are the essential ingredient for effective performance in specific applications. Corporate involvement is becoming necessary in the strategic selection of microdevices.

Memory Update

Mark Giudici, Semiconductor User Information Service

As a result of very short product life cycles, the memory market is extremely dynamic. Products introduced in 1987 will represent 80 to 90 percent of consumption by 1991. The fastest-growing products include 1Mb EPROMs, 256K SRAMs, 256K EEPROMs, and very high-density ROMs.

The shift to off-shore manufacturing is pulling more memory consumption to the Far East. Dataquest expects the ROW area to represent 8.5 percent of worldwide consumption by 1988, up from 5.1 percent in 1986.

Competition is growing in all product areas, with 15 to 25 companies competing for each important memory market. In every segment except ROMs, the 10 largest suppliers have 88 to 96 percent of the market. Suppliers are introducing a variety of specialty products to provide unique features or offer solutions for specific applications. These products reduce customer system costs while giving suppliers higher average selling prices.

The U.S.-Japan trade agreement has resulted in some short-term price increases in Europe and the Asia/Pacific region, but prices in Japan continue to decline. We expect to see continued price differentials between the United States and the rest of the world.

Anthea Stratigos
Stan Bruederle

1987 SUIS/SAM SEMICONDUCTOR PROCUREMENT CONFERENCE

Partnering in a Global Economy

February 4–6, 1987
Saddlebrook Golf and Tennis Resort
Wesley Chapel, Florida

TUESDAY, February 3

5:00 p.m. to 8:00 p.m.	**Registration**	*Pegasus South Foyer*
7:00 p.m. to 9:00 p.m.	**Cocktails**	*Lagoon Pavilion*

WEDNESDAY, February 4

8:00 a.m.	**Registration Continues**	*Pegasus South Lobby*
	Buffet Breakfast	*Pegasus East*
9:00 a.m.	**Dataquest Welcome and Introduction** Stan Bruederle Vice President, Director, Semiconductor User Information Service Dataquest Incorporated Anthea C. Stratigos Associate Director, Semiconductor Application Markets Dataquest Incorporated	*Pegasus South*
	GLOBAL ISSUES	
9:15 a.m.	**Impact of the Global Electronics Industry** Fred Zieber Vice President, General Manager of Technology Operations Dataquest Incorporated	*Pegasus South*
9:45 a.m.	**Program for Competing Internationally** Brad Kroha Corporate Vice President and Director of Communications Sector Sourcing Motorola, Inc.	*Pegasus South*
10:30 a.m.	**Coffee Break**	*Pegasus South Foyer*
11:00 a.m.	**Japanese Perspective on Partnering** Kosei Nomiya President Hitachi Microsystems International, Inc.	*Pegasus South*
11:30 a.m.	**A U.S. Perspective on Partnering** Douglas H. Newman Vice President, Marketing National Semiconductor Corporation	*Pegasus South*
12:00 Noon	**Lunch**	*Lagoon Pavilion*
1:30 p.m.	**The Benefits of Lead Time Reduction** Philip R. Thomas President Thomas Group, Inc.	*Pegasus South*
2:00 p.m.	**The U.S./Japanese Trade Agreement: Progress Report** Gil Kaplan Deputy Assistant Secretary, Import Administration, International Trade Administration U.S. Department of Commerce	*Pegasus South*
6:00 p.m.	**Cocktails**	*Lagoon Pavilion*
7:00 p.m.	**Dinner**	*Lagoon Pavilion*

(over)

THURSDAY, February 5

8:00 a.m.	**Buffet Breakfast**	*Lagoon Pavilion*
	MANUFACTURING STRATEGIES	
9:00 a.m.	**Automation's Role in Competition** David C. Penning, CMfgE Director, Manufacturing Automation Service Dataquest Incorporated	*Pegasus South*
9:30 a.m.	**A Worldwide Manufacturing Strategy** Hal Edmondson Vice President, Manufacturing Hewlett-Packard Company	*Pegasus South*
10:00 a.m.	**IBM's New Austin Facility: A Perspective on Automation** Clark Preston Manager of Manufacturing Technical Services IBM Corporation	*Pegasus South*
10:30 a.m.	**Coffee Break**	*Pegasus South Foyer*
11:00 a.m.	**The Role of Contract Manufacturing** Gene Sapp President SCI Systems, Inc.	*Pegasus South*
	CUSTOMER/VENDOR RELATIONSHIPS	
11:30 a.m.	**Customer/Vendor Relationships—An International Perspective** Bernard Hadley Managing Director Stack GmbH	*Pegasus South*
12:00 Noon	**Lunch**	*Lagoon Pavilion*
1:30 p.m.	**The Changing Face of Distribution in Technology Partnerships** Robert M. Garner General Manager, Vice President of ASIC Operations Hamilton/Avnet Electronics	*Pegasus South*
2:00 p.m.	**Technology Partnerships for ASIC Products** Michael J. Callahan Executive Vice President and Chief Operating Officer Monolithic Memories Incorporated	*Pegasus South*
2:30 p.m.	**Coffee Break**	*Pegasus South Foyer*
3:00 p.m.	**Poor Quality: An Expensive Bad Habit** Charles C. Harwood Partner Quality Improvement Co.	*Pegasus South*
3:30 p.m.	**Vendor Performance Rating—A Quality Report Card** John Durkin Manager of Procurement and Contracts for Memories and Custom Technology Unisys	*Pegasus South*
6:00 p.m.	**Cocktails**	*Pegasus East 1-4*
7:00 p.m.	**Dinner**	*Pegasus East*
8:30 p.m.	**Dinner Speaker** Christopher Hegarty President C.J. Hegarty & Company	*Pegasus East*

FRIDAY, February 6

7:15 a.m.	**Buffet Breakfast**	*Lagoon Pavilion*
	INDUSTRY TRENDS	
8:30 a.m.	**Industry Forecast** Gene Norrett Vice President and Group Director, Semiconductor Industry Group Dataquest Incorporated	*Pegasus South*
9:00 a.m.	**Second Annual Procurement Survey: The User's View** Anthea C. Stratigos Associate Director, Semiconductor Application Markets Dataquest Incorporated	*Pegasus South*
9:30 a.m.	**The "Supply Side" Effect: Capacity and Capital Spending** Bob McGeary Director, Semiconductor Equipment and Materials Service Dataquest Incorporated	*Pegasus South*
10:00 a.m.	**Coffee Break**	*Pegasus South Foyer*
	PRODUCT AND TECHNOLOGY	
10:30 a.m.	**ASIC Devices** Stan Bruederle Vice President, Director, Semiconductor User Information Service Dataquest Incorporated	*Pegasus South*
11:00 a.m.	**Micro Devices** Brand Parks Industry Analyst, Semiconductor User Information Service Dataquest Incorporated	*Pegasus South*
11:30 a.m.	**Memory Devices** Mark Giudici Industry Analyst, Semiconductor User Information Service Dataquest Incorporated	*Pegasus South*
12:15 p.m.	**Buffet Lunch**	*Lagoon Pavilion*

Conference Adjourns

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RESEARCH NEWSLETTER

SAM Code: 1987-1988 Newsletters: January-March
1987-5

A WORLDWIDE SMART CARD OUTLOOK: EUROPE PIONEERS PRODUCTION

The most dramatic change in the smart card market over the last year is that the market appears more application-driven and likely to grow from a demand-pull. For years the smart card has been a great concept in search of a market--a technology push. Today, smart card technology is able to provide solutions to many problems. This newsletter highlights recent worldwide smart card market activities, Dataquest's current unit production projections, and key developments occurring across the globe.

EUROPE--THE BACKDROP FOR MARKET ACTIVITY

The IC credit card or smart card was pioneered in 1976 by French citizen, Ronald Moreno. Three years later, in 1977, the concept became a reality as a result of collaborative work between Cii Honeywell Bull and Motorola Semiconductors (Europe). Initial production started in 1981 using a single-chip 8-bit microcontroller with 1,026 bytes of EPROM. Today, 10 years on from the first development work, IC cards are running in volume production in Europe in addition to undergoing numerous field trials in a variety of applications.

Table 1 lists Dataquest's world unit production estimates for 1987: nearly 50 million units. Of this 50 million, we expect 45 million or 90 percent of the production to take place in Europe. We estimate that this 45 million will comprise 22 million units of the financial card CP8 and 23 million units of the telephone E^2PROM card being marketed by the French PTT.

Production of the telephone card is exclusively by Thomson Semiconductors and takes place in its Rousset Plant, Southern France. Thomson recently moved a number of MOS processes from the Grenoble Plant to Rousset in order to focus key MOS process development in one center.

The development of E^2, EPROM, and HCMOS processes at this site allows the company to rationalize the production and development resources associated with the telephone and CP8 cards. Dataquest estimates that Thomson will supply approximately 20 percent of worldwide demand on CP8 (8.8 million units) during 1987. The other participants during 1987 are Motorola (Scotland) and Philips (RTC France) with 40 percent and 20 percent of the worldwide production, respectively.

Dataquest expects that the present E^2PROM telephone credit card will be phased out during 1987/1988 to be replaced by a variant of CP8. By 1992, Dataquest estimates that worldwide IC card production will be 525 million units, Europe accounting for 35 percent of the TAM.

Table 1

ESTIMATED WORLDWIDE SMART CARD PRODUCTION*
(Millions of Units)

	1985	1986	1987	1988	1990	1991	1992
Financial	1	7	25	45	70	135	155
Telephone	3	10	22	50	95	185	260
Other	N/A	N/A	3	7	30	55	110
Total	4	17	50	102	195	375	525

*Assumes financial cards have a life cycle of approximately two years. Other cards have a life cycle of six years. Telephone card life cycle is three months.

N/A = Not Available

Source: Dataquest
February 1987

U.S. SMART CARD MARKET ACTIVITY

In the United States the smart card market has centered around entrepreneurial activity and alternative technologies such as that of Datakey, Inc., a Minnesota company focusing on nonfinancial smart card applications. The much-touted financial arena (the most traditionally thought of application for smart cards) had too many barriers to entry--namely ISO packaging requirements and smart card cost. (Other ISO standards activities for the smart card, for example, communications protocols, are still emerging.) Some confuse the unclear standards as a major market barrier. While smart card standards are more complex than for the mag stripe, it is encouraging to note that it took seven years before standards for mag stripe technology were adopted; today nearly a decade later, over 1 billion mag stripe cards are in circulation--for financial transactions alone.

In the past, Dataquest has noted that nonfinancial applications would be the driving force behind smart card development, particularly in the United States because nonfinancial applications:

- Would not be restricted by ISO packaging and communication standards for plastic cards

- Would not be limited by the current infrastructure and manner in which business is currently performed (i.e., working around the already heavy investment in automatic teller machines)

MasterCard International and Visa International, both with very different philosophies, strategies, and approaches to the market, have begun to change this. The nonfinancial market legitimized the technology to a certain extent and acted as a proving ground for smart card technology. Just as Dataquest originally expected, these applications appear to have inspired the financial community to analyze smart card technology with a view toward applications within the financial arena.

MasterCard--Leading the Way

Things changed in 1985 when MasterCard International formally announced its market test, setting off a flurry of interest including a smart card approach announced shortly thereafter by Visa International. Both MasterCard and Visa are outspoken about their approaches to smart card solutions.

We believe that MasterCard has been actively qualifying and discussing vendor participation and we expect an announcement in the first half of 1987 as to who will be the program's major participants and how the program will expand. We believe that MasterCard has been working with as many as six IC manufacturers including NEC and Motorola whose chips are in the cards currently being tested. We believe Motorola is the only U.S. IC manufacturer among the six or so companies. Requirements for multiple sourcing and MasterCard's requirement for state-of-the-art technology are fostering numerous discussions. Another potential boon to semiconductor manufacturers is that MasterCard is considering the testing of biometric identification as a less cumbersome solution than PIN codes. Proposed methods include digitized signatures or finger characteristics.

We believe that MasterCard will begin testing and using a production IC card by the second or third quarter of 1987. MasterCard views the semiconductor industry as a vital support link, necessary to effectively implement the technology. Unconfirmed estimates place MasterCard IC card use at the low hundreds of thousands by mid-1987, the low millions by 1988, and high volume in the late 1989 to early 1990 time frame.

The Visa Approach

Visa International's strategy for smart cards is quite different from that of its counterpart. Visa believes that the current need for the technology comes from improving current bankcard services and providing new services that can produce incremental income. They believe that the current system works and that operating costs and losses through fraud can be reduced. Visa believes that current services are highly profitable and it disagrees with MasterCard that today's bankcard business can justify smart card technology. MasterCard justifies implementation based on reducing losses and authorization costs.

Visa believes that in order to take advantage of new technologies and new services and improve existing services there must be an increase in terminal penetration because different terminals accept different cards. Therefore, by putting the terminal on the card, the industry has a readable card that also becomes the delivery system--no need for a variety of terminals, especially with a single vendor that accepts more than one card.

For the financial community this is truly forward thinking, because the history of banking holds that authority lies in more than one place--to use the analogy of the safety deposit box, the customer brings a key, the banker brings a key, and together they unlock the box. Visa believes that the key and the lock do not have to be in two different places. MasterCard, on the other hand, is approaching the system from a traditional banking operation perspective. In short, Visa views the concept as pocket banking as compared to controlled banking.

Visa's different perspective, namely its cost justification view toward providing new services, and pocket banking concept has thrust it toward development of the next generation of smart card technology--a card utilizing E^2 technology, which Visa refers to as a super card and which falls at the high end of the card evolution spectrum.

Visa is currently testing a small number of cards developed by Smart Card International and manufactured by General Instrument's Microelectronics Division. The main purpose is to evaluate users' needs and attitudes toward the technology. Meanwhile, Visa has commissioned Toshiba to make a production version of the card with the charter of putting the technology on a card that meets ISO standards of 30 mils in thickness. The time frame for completion is the fall of 1987 to spring of 1988.

We applaud Visa's strategy to seek "a gradual transition to the smarter cards of the future while supporting the coexistence of several technologies," and we believe that E^2 technology is the long-term answer to most future smart card applications. MasterCard, however, is taking a more realistic approach in its attempt to use current technology within the current financial infrastructure.

E^2 technology for financial applications is still not as technically feasible. MasterCard's testing of the technology in a large-scale pilot is a manageable approach to making the technology realistically meet the needs of today's bankcard environment. We believe that smart cards can work in the financial community today, without having to wait for E^2 technology in the late 1980s time frame. Testing the system as it exists appears most feasible from a smart card market perspective. MasterCard is chartering U.S. market development in financial applications.

JAPAN'S FOCUS ON SMART CARDS

There has been a surge in Japanese smart card activity over the last year. Dataquest's semiconductor market analysts in Japan have kept abreast of smart card market trends and we believe that there is no question that this market is being assessed and targeted very seriously by many sectors of the Japanese economy--much of this activity appears coordinated and orchestrated at a government level. The development of the smart card market is a lesson in Japanese industrial policy at work; competition is said to be fierce. There are as many as 50 to 75 small tests actively being observed. Applications are numerous and a myriad of technologies are being used. Consensus holds that a large number of small tests will provide the best window on market opportunities.

The most striking aspect of Japan's involvement has been the pace with which the Japanese have taken an active interest in the market. In terms of manufacturing technology, smart cards are similar to calculators and digital watches. Smart cards lend themselves to assembly and production by Japan's large electronic watch and calculator manufacturers.

In Japan, partnerships and alliances appear integral to the market's early development. Manufacturers are aligning with users to secure volume sales of products that conform to a worldwide or manufacturer's standard. This is all part of the coordination and cooperation that is being brought to bear on the Japanese focus on this market.

CONCLUSIONS

We are encouraged by smart card activity overall, and in particular the surge of activity seen in 1986. We believe 1987 will bring continued market opportunities and growth as the market begins its early shift into high gear. Market participants should be positioning themselves now; waiting much longer may mean that the market will be closed just as it begins to ramp up. There are opportunities for many types of IC manufacturers because the market has needs in large scale, high-volume applications as well as within the niches. The smart card market will not be only for those who are capable of withstanding the tremendous competition of commodity markets.

Jim Beverige
Anthea C. Stratigos

Dataquest

Product Offerings

Industry Services

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CAD/CAM

Computer Storage—Rigid Disks

Computer Storage—Flexible Disks

Computer Storage—Tape Drives

Copying and Duplicating

Display Terminal

Electronic Printer

Electronic Publishing

Electronic Typewriter

Electronic Whiteboard

European Semiconductor*

European Telecommunications

Gallium Arsenide

Graphics

Imaging Supplies

Japanese Semiconductor*

Office Systems

Personal Computer

Personal Computer—Worldwide Shipments and Forecasts

Robotics

Semiconductor*

Semiconductor Application Markets*

Semiconductor Equipment and Materials*

Semiconductor User Information*

Software—Artificial Intelligence

Software—Personal Computer

Software—UNIX

Technical Computer Systems

Technical Computer Systems—Minisupercomputers

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The European PC Market 1985-1992

European PC Retail Pricing

PC Distribution in Europe

PC Software Markets in Europe

PC Local Area Networking Markets in Europe

The Education Market for PCs in Europe

Japanese Corporations in the European PC Markets

Home Markets for PCs in Europe

Integrated Office Systems—The Market and Its Requirements

European Market for Text Processing

Korean Semiconductor Industry Analysis

Diskettes—The Market and Its Requirements

Directory Products

I.C. Start-Ups—1987

SpecCheck—Competitive Copier Guide

SpecCheck—Competitive Electronic Typewriter Guide

SpecCheck—Competitive Whiteboard Guide

Who's Who in CAD/CAM 1986

Future Products

- Industry Services
  - Manufacturing Automation
  - Computer Storage—Optical
  - Computer Storage—Subsystems
- Focus Reports
  - Japanese Printer Strategy
  - Japanese Telecommunications Strategy
  - Canon CX Laser—User Survey
  - Digital Signal Processing
  - PC-based Publishing
  - Taiwan Semiconductor Industry Analysis
  - China Semiconductor Industry Analysis
  - PC Distribution Channels
- Directory Products
  - SpecCheck—Competitive Facsimile Guide
  - SpecCheck—Competitive Electronic Printer Guide

*On-line delivery option available

For further information about these products, please contact your Dataquest sales representative or the Direct Marketing Group at (408) 971-9661.

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Conference Schedule

1987

Semiconductor Users/Semiconductor Application Markets	February 4-6	Saddlebrook Resort Tampa, Florida
Copying and Duplicating	February 23-25	San Diego Hilton Resort San Diego, California
Imaging Supplies	February 25-26	San Diego Hilton Resort San Diego, California
Electronic Printer	March 23-25	Silverado Country Club Napa, California
Imaging Supplies	March 25-26	Silverado Country Club Napa, California
Computer Storage	April 6-8	Red Lion Inn San Jose, California
Japanese Semiconductor	April 13-14	The Miyako Kyoto, Japan
Color Conference	April 24	Red Lion Inn San Jose, California
European Telecommunications	April 27-29	The Beach Plaza Hotel Monte Carlo, Monaco
CAD/CAM	May 14-15	Hyatt Regency Monterey Monterey, California
Graphics/Display Terminals	May 20-22	San Diego Hilton Resort San Diego, California
European Semiconductor	June 4-5	Palace Hotel Madrid, Spain
European Copying and Duplicating	June 25-26	The Ritz Hotel Lisbon, Portugal
Telecommunications	June 29-July 1	Silverado Country Club Napa, California
Financial Services	August 17-18	Silverado Country Club Napa, California
Western European Printer	September 9-11	Palace Hotel Madrid, Spain
Manufacturing Automation	September 14-15	San Diego Hilton Resort San Diego, California
Business/Office Systems and Software	September 21-22	Westford Regency Hotel Littleton, Massachusetts
Asian Peripherals and Office Equipment	October 5-8	Tokyo American Club Tokyo, Japan
Technical Computers	October 5-7	Hyatt Regency Monterey Monterey, California
Semiconductor	October 19-21	The Pointe Resort Phoenix, Arizona
Office Equipment Dealers	November 5-6	Hyatt Regency Monterey Monterey, California
Military IC	November 12	Hotel Meridien Newport Beach, California
Electronic Publishing	November 16-17	Stouffer Hotel Bedford, Massachusetts
Asian Information Systems	November 30-December 4	Tokyo, Japan
CAD/CAM Electronic Design Automation	December 10-11	Santa Clara Marriott Santa Clara, California

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RESEARCH NEWSLETTER

SAM Code: 1987-1988 Newsletters: January-March
1987-04

SYSTEM MEMORY: CAPACITIES ARE UP BUT SO ARE PRICES
ARE 900MB TEDDY BEARS IN STORE?

Computer memories are an increasingly important component in technical system sales. Two simultaneous events have confused buyers and computer vendors alike: 1) System memory capacities have increased dramatically due to the introduction of a new memory packaging technique, and; 2) Memory costs have increased dramatically due to a trade agreement between the United States and Japan. This newsletter examines the memory issue with respect to its impact on the technical computer industry.

THE TRADE AGREEMENT

The recent trade agreement between the United States and Japan to have the U.S. Commerce Department set minimum memory prices has left computer makers feeling puzzled and bewildered. The Semiconductor Industry Association (SIA) maintains that the Japanese are engaging in predatory pricing and dumping. As a result, computer companies are now facing significant increases in memory component costs. Higher prices will forestall migration from 256K DRAMs to 1-Mbit chips and give Japanese CAD equipment manufacturers an advantage over U.S. manufacturers (1-Mbit DRAMs are already used internally at Fujitsu, Hitachi, etc.). This kind of government protectionism is what led to the sorry state of the U.S. steel industry.

The flood of low-cost memories occurred for one major reason--a great deal of 256K DRAM production capacity came on-line at the same time the computer industry slumped. This is the crux of the problem.

BIG MEMORIES ARE IN VOGUE

The doubling of memory prices is not conducive to the current trend of computer manufacturers to offer increased memory capacity for newer systems. Digital's VAX 8700, for example, now supports 128MB of main memory. ELXSI announced support for up to 768MB spread across 12 processors in a single system. Minisupercomputers are edging up toward 256MB and a few vendors will soon announce computers with 1-Gigabyte main memory capacities.

Dataquest Incorporated, 1290 Ridder Park Drive, San Jose, CA 95131-2398, (408) 971-9000, Telex 171973, Fax (408) 971-9003

WHY THE INCREASE?

The reason for the sudden increase in main memory capacities is simple. Surface-mount technology enables more memory devices to be contained on a single memory board--roughly four times the amount of boards based on the more common dual in-line packages (DIPs). The smaller device size enables designers to place more memory on the same board space. Computer systems are usually restricted by the amount of memory that can be put into the system cabinets using the existing power system supplies.

WHO NEEDS LARGE MEMORIES?

Users who need faster computing capability can increase performance by keeping as much of a large computational task in physical memory as possible. This reduces time-consuming demand paging to disks.

Applications where large system memories will be used are:

- Design automation
  - Electronics--Logic simulation, PCB routing, circuit simulation design rule checking, component data bases
  - Mechanical--Kinematics, thermodynamics, fluid dynamics, structural engineering, finite element analysis, hydrodynamics, solids modeling, data bases
- Earth resources--Seismic data processing and imaging
- Scientific--Large computational tasks, general simulation
- Software development--Artificial intelligence
- Graphics--Imaging and animation

Design automation and scientific applications are probably the applications that are continually in need of faster systems and more memory capacity. Large memories are also used in technical workstations and graphic terminals to hold pictorial data in a frame buffer.

UNPLAYED CARDS

If the pricing situation does not stabilize, we expect several interesting events to happen. The computer industry is probably one of the most intensely competitive industries in the world. Vendors are not about to sit around and wait for the federal government to figure out all the aspects of the semiconductor industry. Memories are a key component in computers and represent a continual add-on business for manufacturers. Federal obstacles to computer company revenue paths will be undone by creative people.

We have caught wind of a few scenarios that may begin to occur if the memory issue does not stabilize:

- Memory board manufacturing could move entirely offshore. Boards would be manufactured in the Far East where the memories are manufactured and purchased. The trade agreement said nothing about memory boards, only memory components. This would cause a net loss of jobs and revenue for U.S. manufacturers, reminiscent of the core memory business of the 1970s that moved almost entirely to the Far East.

- The computer industry may, for the first time, see the birth of a universal memory board that consists of a busless board with socketted memory chips. Once the board is imported, what is to prevent vendors from removing memory from the sockets?

- The Japanese export a lot of consumer electronics to the United States. Maybe computer companies will be purchasing unusual "Speak-&-Spell" games or perhaps four-function calculators with extended 900MB memory capacity.

- RAM disks could become an importation path.

- Memory chips from Japan could be bought by perhaps a Mexico- or Ireland-based manufacturer, installed in memory boards or other products, and then resold to U.S. vendors.

- Unprobed memory wafers could be imported to the United States, before being tested and packaged for resale.

- Sales by U.S.-based Japanese memory manufacturers (NEC) are not affected; therefore, their sales may dramatically increase and Korean manufacturers may get a new chance in the market.

These hypothetical situations would frustrate the Commerce Department's intentions so completely that several key electronics executives are now pressuring the Commerce Department to reverse its decision.

(This newsletter is reprinted with the permission of Dataquest's Technical Computer System Industry Service.)

David Norman
Brad Smith

Dataquest

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Software—Personal Computer

Software—UNIX

Technical Computer Systems

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Home Markets for PCs in Europe

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European Market for Text Processing

Image Processing in the Office

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Diskettes—The Market and Its Requirements

Directory Products

I.C. Start-Ups—1987

SpecCheck—Competitive Copier Guide

SpecCheck—Competitive Electronic Typewriter Guide

SpecCheck—Competitive Whiteboard Guide

Who's Who in CAD/CAM 1986

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- Industry Services
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  - Computer Storage—Optical
  - Computer Storage—Subsystems
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  - Japanese Telecommunications Strategy
  - Canon CX Laser—User Survey
  - Digital Signal Processing
  - PC-based Publishing
  - Taiwan Semiconductor Industry Analysis
  - China Semiconductor Industry Analysis
  - PC Distribution Channels
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1986

Semiconductor	October 20-22	Hotel Inter-Continental San Diego, California
Technical Computer	November 3-5	Silverado Country Club Napa, California
Asian Peripherals	November 5-7	Hotel Okura Tokyo, Japan
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1987

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RESEARCH NEWSLETTER

SAM Code: 1987-1988 Newsletters: January-March
1987-03

THE 1987 WINTER CONSUMER ELECTRONICS SHOW

INTRODUCTION

"Profitless profitability" is how Dick Lewis of the Newmark & Lewis retail chain described the performance of the consumer electronics industry in 1986. Whether profits exist or not, the innovation and ingenuity the consumer electronics industry is famous for were not missing from the EIA sponsored Consumer Electronics Show (CES). More than 100,000 participants crowded 1 million square feet in Las Vegas (January 8 through 11) to exhibit, buy, or observe a multitude of telephones, toys, stereos, TVs, and electronic gadgets of all shapes, sizes, and colors.

This newsletter will discuss the EIA's consumer electronics forecast, issues the industry will have to face in 1987, and new product trends in the consumer electronics equipment areas followed by Dataquest's Semiconductor Application Markets service.

EIA OUTLOOK FOR 1987

The consumer electronics industry has experienced and is expected to continue experiencing revenue growth. The EIA estimates that in 1986 the industry grew 13 percent and in 1987 it is expected to grow to 4.9 percent reaching $30 billion for the first time. However, the industry faces one major problem according to Frank Meyers, vice president of the EIA's Consumer Electronics Group (CEG), "increased revenue does not mean increased profits." Table 1 displays the EIA estimates for total consumer electronics factory revenue consumed in the United States by product area.

According to Dick Lewis, the cure to profitless profitability is to sell features, quality, and service, not price. A comparison of the total consumer price index against the price indices of television sets and sound systems (Figure 1) shows that television set prices and sound system prices are close to 1967 levels while the total consumer price index is over three times higher than its 1967 level. Considering the new features and products that have been introduced to the television set and sound system markets over the past 20 years, using new features and products to raise prices and profits will be a monumental task.

Table 1

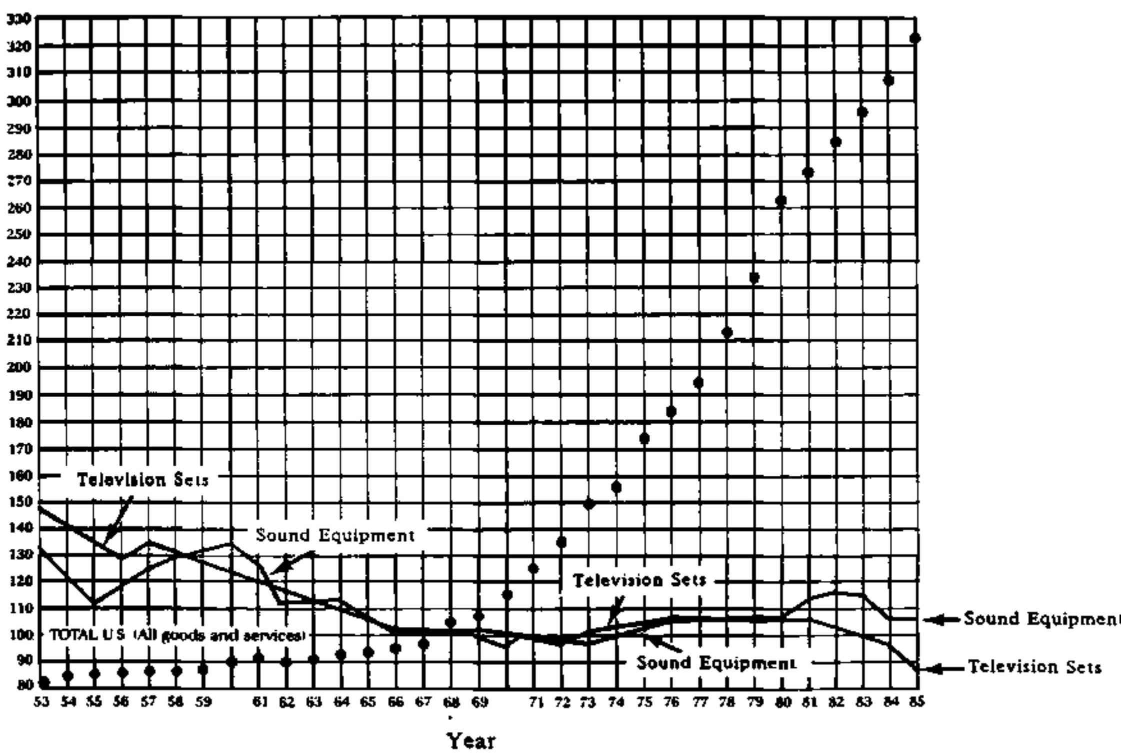
ESTIMATED TOTAL FACTORY SALES OF CONSUMER ELECTRONICS
(Millions of Dollars)

	1985	1986	1987
Video	12,292	13,016	13,690
Audio	6,323	7,185	7,365
Home Information	3,401	4,615	4,605
Related Products	3,278	3,740	4,290
Total	25,294	28,556	29,950

Source: EIA

Figure 1

TOTAL U.S. CONSUMER PRICE INDEX
COMPARED TO TV AND SOUND EQUIPMENT
(1967=100)



Source: Consumer Electronics Annual Review

CONGRESSIONAL PRESSURES

Trade

The consumer electronics industry will be faced with two congressional challenges during 1987: trade policies and, possibly, copyright protection. Senator Strom Thurmond, Republican from South Carolina, stated that "passing trade legislation is a top priority for the Senate during the 100th Congress. Representatives Joe McDade (R-PA), Don Bonker (D-WA), and Toby Roth (R-WI) echoed these sentiments with claims that writing trade legislation would be a high priority in the House also.

The CEG panel on trade consisted of the three above-mentioned representatives and Peter F. McCloskey, president of the EIA. The panel agreed that if some decisive action is not taken in the near future, the United States, as panel member Mr. Roth asserts, will be involved in "severe trade wars."

The panel further agreed that the United States cannot continue approaching the trade problem with a strategy of stamping out brush fires. The consensus of the panel was that general legislation should address the entire trade deficit dilemma.

The three congressmen, however, have fundamental differences as to what should constitute this "general strategy." In any case, whatever form the legislation does take, it promises to be unfavorable to the predominantly Japanese and Southeast Asian consumer electronics manufacturers. Southeast Asia and Japan currently have the largest trade surpluses with the United States and are therefore of the greatest concern to Congress.

Copyright Protection

Whenever new recording technology is introduced the recording industry forces Congress to address the question of copyright protection. Most of the audience at the CEG panel discussion on copyright protection were adamantly opposed to new stiffer restrictions concerning new technology and copyright infringements. The panel consisted of Gary Shapiro from CEG and six congressmen, one Republican and five Democrats.

The issue for discussion was whether or not Congress will propose some type of legislation to tax or disable audio and video recording equipment in order to curb recording of prerecorded material. All six congressmen agreed that this issue is not a top priority in the House or Senate. If, however, the recording and movie industries prove that they have incurred significant economic harm, some action would be taken. Historically the recording industry has not been able to prove that new technology hurts its revenue. In fact in some cases new technology has been proven to increase revenue. Cassette tape is one example. When cassettes were introduced the record industry claimed cassettes would be its death, but records and cassettes continue to sell well today.

In a meeting concerning digital audio tape (DAT) in Vancouver late last year, the recording industry and the equipment manufacturers tried to iron out the recording issue before DAT players are sold to consumers. The recording industry would like to see the player's recording capability taken away or a tax put on blank tapes. The equipment manufacturers find these solutions very difficult to swallow. The meeting ended no closer to a solution or partnership between the recording industry and the equipment manufacturers.

NEW PRODUCTS

Video

The battle over camcorder formats continues into 1987. Currently there are 8mm, VHS, VHS-C, and Beta formats on the market, and at CES, Samsung introduced what many people called the most exciting product of the show, a 4mm camcorder. This camera uses DAT and an LCD TV as a display. The camcorder will start test marketing in Korea late this year and may be introduced to the U.S. market as early as 1988.

A number of manufacturers displayed digital TVs and digital VCRs at CES. Digital technology is expected to be the new growth area for both video and audio equipment in the future. Digital television offers a higher quality picture and the ability to watch two or more programs at once. Companies that currently market digital TVs or VCRs include RCA, Toshiba, Hitachi, NEC, Sony, Panasonic, and Goldstar. Other new features that are expected to help the sales of TVs in 1987 are smaller screens, larger screens, stereo sound, and surround sound.

Audio

A new star has taken some of the glitter away from compact disk players (CD players); digital audio tape (DAT). DATs have sound quality that rivals CDs and DAT players have recording capabilities, which CD players currently do not have. DAT is also at the center of a controversy between the recording industry and equipment manufacturers. There is some question as to whether record companies will release prerecorded material on DAT. The equipment manufacturers are threatening to put digital outputs on CD players so individuals can make direct digital to digital recordings. The conflict may cause a delay of the introduction of DAT players to the U.S. market. Current estimates are that DAT players will reach the U.S. consumer by late 1987 or early 1988. Marketing in Japan is expected to start in the second quarter of this year. Companies that showed DAT players at CES include Sansui, Kenwood, Luxman, Sony, Teac, and Onkyo.

Sales of CD players continued to exceed expectations in 1986. New CD player features to look forward to in 1987 include increased programmability, smaller sizes, and multidisk systems.

Personal Electronics

In 1986, the consumer electronics industry saw a resurgence in sales of video games. Two Japanese firms, Sega and Nintendo, led the way with high priced systems characterized by high resolution graphics. American firms, Atari and Intellivision, rode the new wave of popularity with their low end systems. Robotic stuffed animals, interactive VCR games, electronic watches, and a myriad of other electronic gadgets pervaded CES.

DATAQUEST ANALYSIS

The major consumer electronics manufacturers in Japan and Southeast Asia tend to be vertically integrated companies producing everything from the semiconductors that go into the products to the cases that enclose them. However, increasing trade friction may entice some foreign manufacturers to move production to the United States, and possibly buy components in the United States.

Generally the majority of products displayed at CES were the same old thing: TVs, stereos, and VCRs. Among the 1,400 exhibits, however, there were plenty of innovative new concepts and ingenious twists to old products to excite the American consumer for yet another year.

David G. Norman

Dataquest

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Electronic Publishing

Electronic Typewriter

Electronic Whiteboard

European Semiconductor*

European Telecommunications

Gallium Arsenide

Graphics

Imaging Supplies

Japanese Semiconductor*

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Personal Computer—Worldwide Shipments and Forecasts

Robotics

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Semiconductor Application Markets*

Semiconductor Equipment and Materials*

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The Education Market for PCs in Europe

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Electronic Printer	March 23–25	Silverado Country Club Napa, California
Imaging Supplies	March 25–26	Silverado Country Club Napa, California
Computer Storage	April 6–8	Red Lion Inn San Jose, California
Japanese Semiconductor	April 13–14	The Miyako Kyoto, Japan
Color Conference	April 24	Red Lion Inn San Jose, California
European Telecommunications	April 27–29	The Beach Plaza Hotel Monte Carlo, Monaco
CAD/CAM	May 14–15	Hyatt Regency Monterey Monterey, California
Graphics/Display Terminals	May 20–22	San Diego Hilton Resort San Diego, California
European Semiconductor	June 4–5	Palace Hotel Madrid, Spain
European Copying and Duplicating	June 25–26	The Ritz Hotel Lisbon, Portugal
Telecommunications	June 29–July 1	Silverado Country Club Napa, California
Financial Services	August 17–18	Silverado Country Club Napa, California
Western European Printer	September 9–11	Palace Hotel Madrid, Spain
Manufacturing Automation	September 14–15	San Diego Hilton Resort San Diego, California
Business/Office Systems and Software	September 21–22	Westford Regency Hotel Littleton, Massachusetts
Asian Peripherals and Office Equipment	October 5–8	Tokyo American Club Tokyo, Japan
Technical Computers	October 5–7	Hyatt Regency Monterey Monterey, California
Semiconductor	October 19–21	The Pointe Resort Phoenix, Arizona
Office Equipment Dealers	November 5–6	Hyatt Regency Monterey Monterey, California
Military IC	November 12	Hotel Meridien Newport Beach, California
Electronic Publishing	November 16–17	Stouffer Hotel Bedford, Massachusetts
Asian Information Systems	November 30–December 4	Tokyo, Japan
CAD/CAM Electronic Design Automation	December 10–11	Santa Clara Marriott Santa Clara, California

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RESEARCH NEWSLETTER

SAM Code: 1987-1988 Newsletters, January-March
1987-02

REALITY VERSUS HYPE: THE IMPACT OF THE INTEL 80386

SUMMARY

Press coverage and public attention to the emergence of the Intel 80386 chip belie the reality that there are roadblocks to widespread adoption of this microprocessor in personal computers, engineering workstations, and multiuser business computers. In this newsletter, Dataquest reviews the immediate and longer-term opportunities for systems based on this processor; factors that will either promote it or block it. We also present our forecasts for the size and nature of the impact 80386-based systems will have on existing markets.

THE PERSONAL COMPUTER MARKET

It is not surprising that the personal computer market is the first place where products based on 80386 processors have emerged. As compatible upgrades to 80286-based PCs, there is a natural market for such systems. However, Dataquest believes that the following factors will delay widespread adoption of the new systems:

- Uncertainty as to the nature of IBM's 80386-based product (or products), expected midyear 1987, and the degree to which the widely-anticipated proprietary features of this system will render other products obsolete

- Lack of availability of a version of the MS-DOS operating system that takes full advantage of the 386 architecture until 1989; and awareness that the next major DOS version, due out in mid-1987, will only then support all features of the 80286

- Lack of availability of new applications software packages that will run under the new operating system and take full advantage of its advanced features

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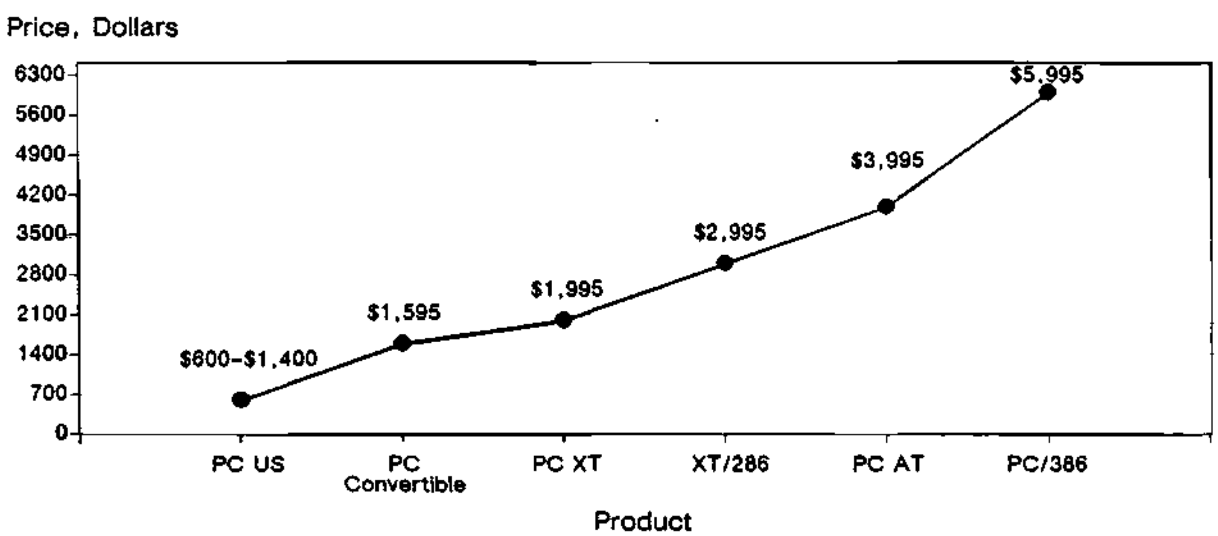
These issues, however, are not inhibiting the early adopters from purchasing the 80386-based PCs that have been announced. Manufacturers such as Compaq have attracted the power users and the customers that want to have state-of-the-art equipment, and have achieved impressive sales rates in this market by not waiting until the above issues are resolved. Early sales are expected to go to PC enthusiasts, engineers, software developers, and customers who plan to use the power of 386-based PCs for file servers and expert systems.

Dataquest anticipates that IBM's 386-based system will be proprietary to the extent that it contains a unique, bundled application environment, (which will be neither TopView nor Windows) and other features that tie its product together with 370-architecture systems such as the 9370 and 4300 (hardware data base support and integral communications). These enhancements, however, will not render the existing library of software incapable of running on the new PC. Therefore, the straight 286-compatibility approach of Compaq, Multitech, Zenith, and others will offer a subset of capabilities rather than being totally incompatible. Figure 1 shows Dataquest's forecasts for the position of IBM's new product in its anticipated 1987 PC product line.

Figure 2 illustrates Dataquest's forecast for sales of 386-based PCs. After the initial impetus by early adopters, the 386 market will grow steadily as software issues are resolved and prices come down to less than $5,000 by 1988.

Figure 1

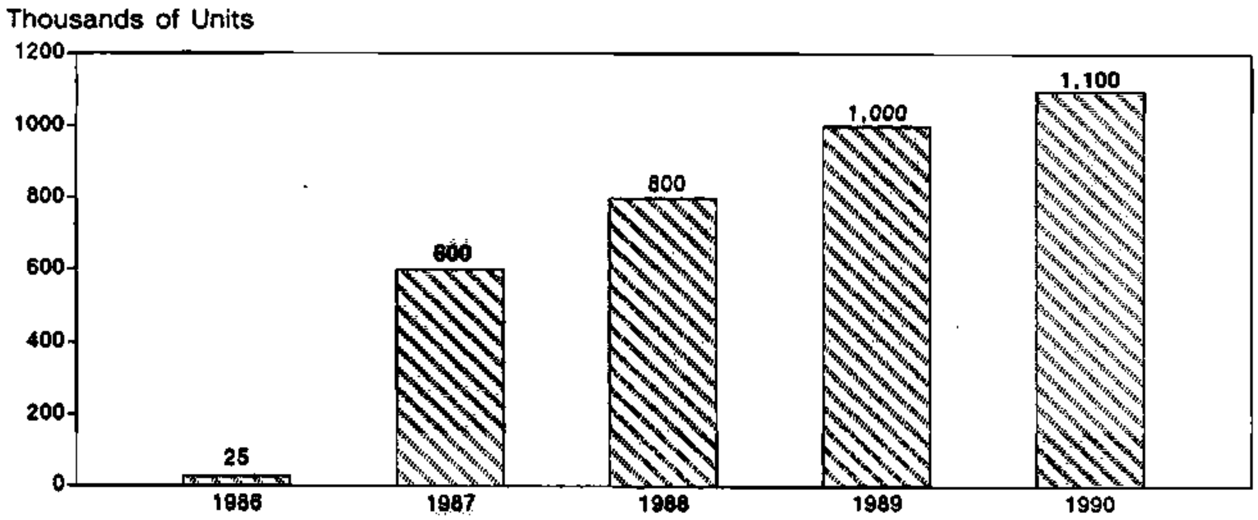
DATAQUEST PREDICTS THE 1987 IBM PC PRODUCT LINE



Source: Dataquest
December 1986

Figure 2

80386-BASED PC FORECAST
ESTIMATED WORLDWIDE UNIT SHIPMENTS



Source: Dataquest
December 1986

MULTIUSER BUSINESS COMPUTER SYSTEMS

Unlike the PC market, there is no natural upgrade market for systems based on the 386 for the multiuser market, except those few AT-compatible systems supporting multiple users running Xenix. The attractiveness of systems using the 80386 is in their ability to run MS-DOS concurrently with Xenix or UNIX, thereby providing access to a wider range of software, making it easier to integrate PCs as workstations on the multiuser system. Hence the impact of 386-based multiuser systems is potentially stronger on supermicros using Motorola 68000-family processors and on low-end proprietary minicomputers.

Considering the existing use of Xenix- or UNIX-based supermicro systems, two developments will make these systems continue to compete successfully with 80386 systems:

- The performance of the Intel 80386 is comparable to that of the Motorola 68020, but the 68030 will give Motorola-architecture systems a speed advantage when the chip starts shipping in production quantities to vendors in the third quarter of 1987.

- Software subsystems such as Locus' Merge (called SimulTask for the AT&T 6300 Plus) are becoming available that enable MS-DOS to run as a task under UNIX, providing a similar multiple operating environment capability on the 80286 as the 80386.

New competition for multiuser business systems will be network servers and file managers using 80386 processors. Many such products use 80286 processors today, so it will be easy for these to be redesigned for the 386 chip. They can then offer substantially higher performance and provide the added feature of background applications processing through the multitasking capability of the 386. Such a product will be difficult to distinguish from a multiuser system; Dataquest foresees these markets converging over the next few years.

The presence of multiuser 80386 systems will exert downward pressure on prices of all work group computer systems, supporting 2 to 10 concurrent users. For example, a complete five-workstation LAN configuration with a 386-based server and 5MB memory, two printers, 130MB disk storage, and software can be purchased today for less than $24,000; an equivalent work group computer system has a list price of $35,600. This illustrates the price gap that the multiuser vendors will have to close as more networking software makes this a viable alternative for a wider range of applications.

There are measures that vendors of multiuser systems can take to increase their competitiveness on grounds other than price. These include:

- Increased sales emphasis on nationwide service and support compared with many PC vendors or resellers
- Better support of the VAR and VAD channels
- Development of software integrating PCs as intelligent workstations in a minicomputer and mainframe network

TECHNICAL WORKSTATIONS AND MINICOMPUTERS

In many respects the impact of products based on the 80386 on the technical workstation market will be similar to the impact on the multiuser business computer market. There will be an immediate interest on the part of engineers using PC AT (or AT-compatible) systems, since the increased speed of the 386 will make a big difference in the performance of graphics- or computationally-intensive applications. Today, Dataquest estimates that 70 percent of technical computer unit shipments are PCs; while this percentage is expected to remain constant, a large portion of shipments will be 386-based over the next two years. However, Dataquest doubts that users of 386-based systems for technical work will experience four times the performance of a VAX 11/780, as might be suggested by the published relative MIPS ratings. The shortfall is due to many factors, including: the differences typically seen between the raw MIPS rating of a microprocessor and the overall system MIPS; the fact that UNIX is usually a performance "hog," and; the requirement for efficient I/O that will not be satisfied by the initial 386-based systems if they use the 16-bit PC AT bus as expected.

Nevertheless, products based on the 80386 will have an increasing impact on the technical systems market, particularly after the software availability issues are resolved. The primary impact will be in the form of price pressure. Ultimately, 386-based (and 68020-based) systems will be able to offer similar functionality to today's $35,000 proprietary products for less than one-third the price. This will be particularly true as the volume of 386 processors increases, driving the unit cost down further. Dataquest anticipates a market by 1988 that is dominated by 386-based products offering system performance of 2.5 MIPS in the $5,000 to $15,000 range, 68030-based products offering 4 MIPS system performance in the $15,000 to $50,000 range, and custom or specialized microprocessor-based products at higher performance levels in the $50,000 to $100,000 range.

Even traditional minicomputers and superminis stand to feel the price pressures brought on by the 386-based products. As an example, today's MicroVAX II offers performance at approximately half the anticipated level of a 386-based system but is priced more than twice as high. Manufacturers of minis running proprietary operating systems will have a dual incentive to meet or beat the price/performance of 386-based UNIX systems: first, to get the immediate system sale; and second, to lock customers into the proprietary line instead of having them get started with UNIX and be unwilling to convert to another operating system later as they grow.

DATAQUEST CONCLUSIONS

On balance, it seems clear that the long-term implications of the emergence of products based on the 386 are much more important than the immediate impact, which will be confined almost exclusively to today's users of 286-based products who want a newer, faster box. Some vendors will see competition from new sources due to the power and functionality potential in this processor, but the nature of the threats is predictable and defenses are both possible and, in most cases, straightforward. For a vendor anticipating competition from 386-based systems, this means cutting costs and taking steps to integrate MS-DOS with its operating environment at least as well as will be possible with a 386-based product. On the part of vendors offering or planning to offer 386-based systems, Dataquest believes that the most successful strategies for the next year will be those that either capitalize on the existing body of 286-based software (while holding out the possibility of later upgrades as they become available), like Compaq, or those who offer proprietary software designed to take advantage of the 386 architecture from the beginning, like Convergent Technologies. In either case, we do not expect the impact of 386-based systems to be fully felt for two years or more, though the release of MS-DOS 5.0 and the announcement of IBM's system in mid-1987 will certainly add more fuel to the fire.

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Anthea Stratigos
Van Weathers

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SAM Code: 1987-1988 Newsletters: January-March
1987-01

QUARTERLY ELECTRONIC EQUIPMENT UPDATE: A DISAPPOINTING YEAR FOR THE U.S. ELECTRONICS INDUSTRY

SUMMARY

Electronic equipment market growth in 1986 was much lower than expected. Dataquest estimates that North American electronic equipment production revenue grew 5.4 percent in 1986. A number of factors are responsible for the slow growth in 1986:

- Defense spending has not increased.
- Foreign manufacturers have increased market penetration.
- North American manufacturing is continuing to move offshore.
- Economic growth has been slow: the GNP increase of 2.6 percent in 1986 is lower than the revised 3.2 percent forecast by the Reagan administration.

Generally, the weakening of the dollar against foreign currencies has helped U.S. industry in foreign markets. The electronics industry is somewhat of an exception to this generalization, however. Many foreign manufacturers have been willing to decrease profit margins to retain market share in the United States and new players from the Pacific Rim are coming on strong in the electronics industry. Cahners Electronic Business Forecast estimates that Taiwan, Korea, Singapore, and Hong Kong accounted for 22 percent of electronics trade into the United States in 1985. In 1986 this percentage increased for two reasons:

- The dollar has not depreciated against the currencies of Hong Kong, Taiwan, Korea, and Singapore as it has in Japan and Europe.
- These countries are very aggressively targeting the North American electronics market.

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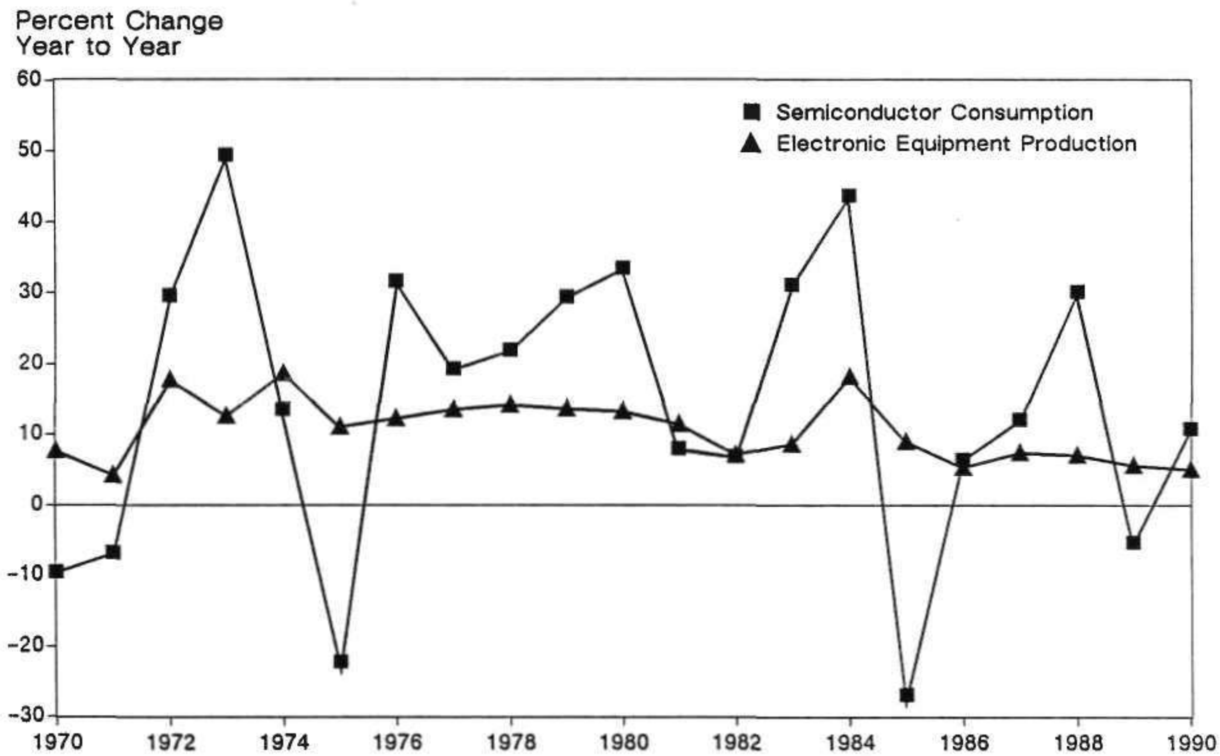
Figure 1 shows the historical relationship (1970 through 1985) between semiconductor consumption and electronic equipment production and includes our forecast through 1990.

Figure 1

COMPARISON OF SEMICONDUCTOR CONSUMPTION AND ELECTRONIC EQUIPMENT PRODUCTION



Source: Dataquest
January 1987

OUTLOOK FOR APPLICATION MARKETS

Table 1 contains our updated revenue forecast by application market for North American electronic equipment production. The following pages highlight the most recent events that are expected to affect the different application markets in the near future.

Table 1

SEGMENT OVERVIEW
NORTH AMERICAN ELECTRONIC EQUIPMENT FORECAST
(Millions of Dollars)

Segment	1985	1986	1987	1988	1989	1990	CAGR 86-90
DATA PROCESSING							
Computers	$56,555	$58,662	$64,846	$73,184	$77,006	$80,013	8.1%
Data Storage Subsystems	13,212	15,180	17,116	17,652	18,259	18,502	5.1%
Terminals	4,411	4,414	4,697	5,079	5,315	5,725	6.7%
Input/Output	7,474	8,279	9,207	9,917	10,357	10,141	5.2%
Dedicated Systems	5,528	5,399	5,404	5,254	5,814	5,964	2.5%
Subtotal	$87,180	$91,933	$101,270	$111,085	$116,752	$120,346	7.0%
COMMUNICATIONS							
Customer Premises	$9,061	$9,675	$10,579	$11,467	$12,584	$13,567	8.8%
Public Telecommunications	6,220	6,727	7,075	7,321	7,845	8,387	5.7%
Radio	4,830	5,369	6,287	7,114	8,067	8,923	13.5%
Broadcast and Studio	1,666	2,016	2,533	2,849	3,461	4,286	20.8%
Other	1,128	1,310	1,590	1,764	2,032	2,295	15.0%
Subtotal	$22,905	$25,097	$28,064	$30,514	$33,989	$37,458	10.5%
INDUSTRIAL							
Security/Energy Mgmt.	$2,237	$2,464	$2,654	$2,768	$2,872	$3,065	5.6%
Manu. Sys./Instrumentation	18,948	20,027	22,716	25,016	25,948	28,172	8.9%
Robot Systems	492	564	646	782	924	1,095	18.0%
Medical Equipment	6,463	7,030	7,699	8,535	9,520	10,430	10.4%
Commercial Aviation	2,141	2,263	2,443	2,616	2,702	2,893	6.3%
Other	5,498	6,124	7,100	7,870	8,746	9,636	12.0%
Subtotal	$35,780	$38,472	$43,257	$47,587	$50,712	$55,291	9.5%
CONSUMER							
Audio	$255	$283	$324	$332	$360	$402	9.2%
Video	4,618	4,656	5,127	5,291	5,647	6,254	7.7%
Personal Electronics	600	641	720	756	794	801	5.7%
Appliances	9,792	10,373	11,068	11,522	12,098	12,891	5.6%
Other	976	1,059	1,116	1,167	1,218	1,270	4.6%
Subtotal	$16,241	$17,011	$18,355	$19,067	$20,117	$21,618	6.2%
MILITARY	$49,300	$49,700	$47,500	$46,900	$46,400	$46,300	-1.8%
TRANSPORTATION	$8,480	$9,580	$10,809	$11,799	$13,812	$15,050	12.0%
TOTAL EQUIPMENT	$219,887	$231,794	$249,255	$266,953	$281,782	$296,062	6.3%

Source: Dataquest
January 1987

Data Processing

In the personal computer industry, the area of activity in the fourth quarter of 1986 is the less than $1,000 market segment; specifically, low cost IBM compatible machines and home computers. Dataquest's Personal Computer Industry Service (PCIS) estimates that consumption of PCs in the less than 1,000 dollar price range grew 20.5 percent in 1986. The reasons for this growth include:

- Consumers rushed to buy "big ticket" items by year end 1986 to take advantage of sales tax deductions from federal income tax that will be discontinued in 1987.
- New software that takes advantage of the more sophisticated features of the latest low cost machines became available.
- Home computer models with new graphics, and audio capabilities were popular in the 1986 home market.
- The introduction of low priced IBM compatibles made the PC many people use in the office affordable for home.

However, after looking at machines actually produced in North America, Dataquest estimates that there was a 25 percent decrease in if-sold revenue from 1985 to 1986. Dataquest believes that the trend to decrease North American manufacturing will persist, as U.S. manufacturers move production of low cost machines offshore and manufacturers from Korea, Hong Kong, Taiwan, and Singapore continue to penetrate the U.S. market. Table 2 shows Dataquest's forecast of end-user, if-sold revenue for North American produced PCs.

Table 2

ESTIMATED NORTH AMERICAN PRODUCED PERSONAL COMPUTER END-USER IF-SOLD REVENUE (Millions of Dollars)

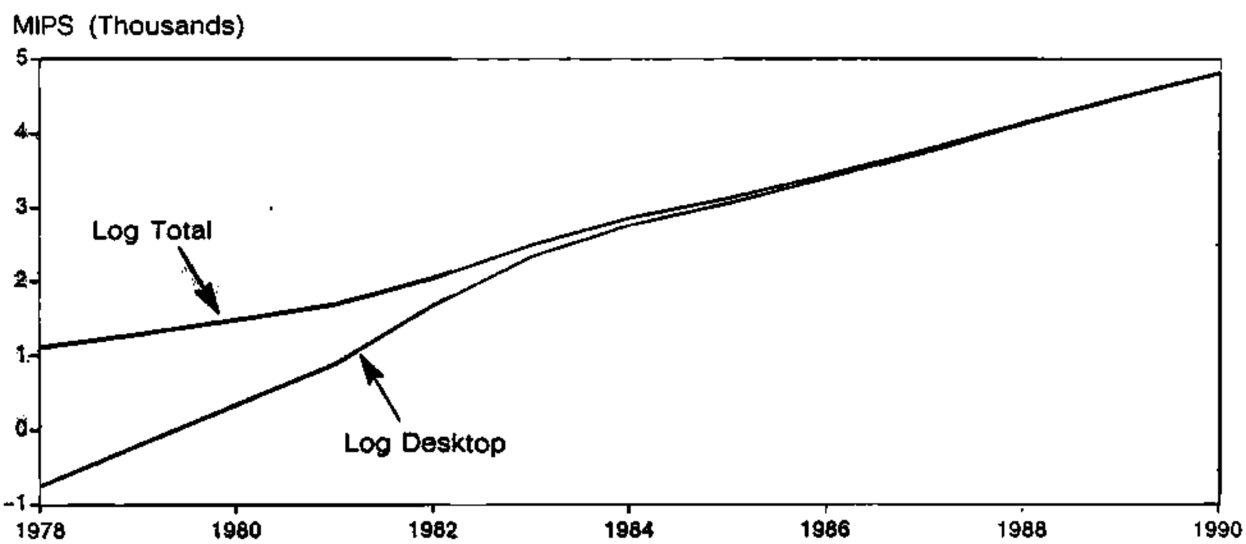
Equipment Type	1985	1986	1987	1988	1989	1990	CAGR 1986-1990
< $1K	$ 1,569	$ 1,184	$ 1,439	$ 1,646	$ 1,715	$ 1,599	7.8%
$1K to $5K	12,054	10,643	12,939	15,494	16,348	15,559	10.0%
$5K to $10K	5,237	5,794	5,641	6,247	4,546	3,960	(9.1%)
Total	$18,860	$17,621	$20,019	$23,387	$22,609	$21,118	4.6%

Source: Dataquest
January 1987

The fast growth of PCs affected the sales of large corporate computer systems in 1986. In 1984 and 1985 corporate America bought a large amount of desktop computing power. In 1986, these desktop machines are performing functions that were performed by the large computers in earlier years. Word processing and financial functions are two examples of applications that have shifted from the mainframe computer to the desktop machine. Mainframe applications are moving toward areas where large amounts of data have to be stored and manipulated. Figure 2 shows one scenario of the growth of MIPS (million instructions per second) of desktop machines versus total computing power. To arrive at this figure, we assumed that desktop MIPS consumption will continue to grow at its historical 100 percent CAGR into the future while mainframe MIPS will continue to grow at a 25 percent CAGR. If this trend continues, by 1988 more than 90 percent of the MIPS consumed would be in desktop machines.

Figure 2

ESTIMATED MIPS SHIPPED
INTO U.S. MARKET



Source: Dataquest
January 1987

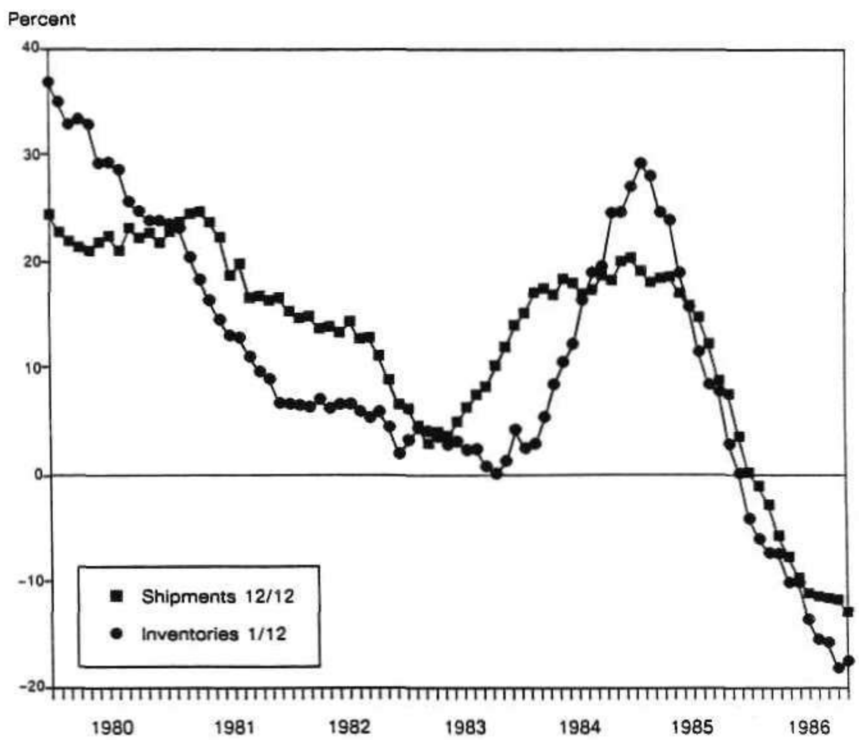
Dataquest estimates that graphics terminal revenue grew 14.5 percent in 1986. The second half of 1986 can be characterized as a time of new product introductions. These products were not limited solely to terminals, PC add-on products were announced as well. Growth in the graphics industry has prompted semiconductor manufacturers to produce graphics-specific integrated circuits (GSICs). These new GSICs are giving a performance shot in the arm to midrange graphics devices. Semiconductor manufacturers that have announced graphics-specific chip sets in 1986 include National Semiconductor, Texas Instruments, and Intel.

Dataquest believes that the software industry and the users have some catching up to do before the proliferation of new hardware in the graphics industry in 1986 can be absorbed.

The most recent Department of Commerce (DOC) data (October 1986) indicate computers and office machines will continue moving sluggishly into 1987. However, the rate of decline of computers and office machines shipments, shown in Figure 3, seems to have stabilized. Bookings, shown in Figure 4, do not indicate a spectacular turnaround for computers and office equipment in early 1987.

Figure 3

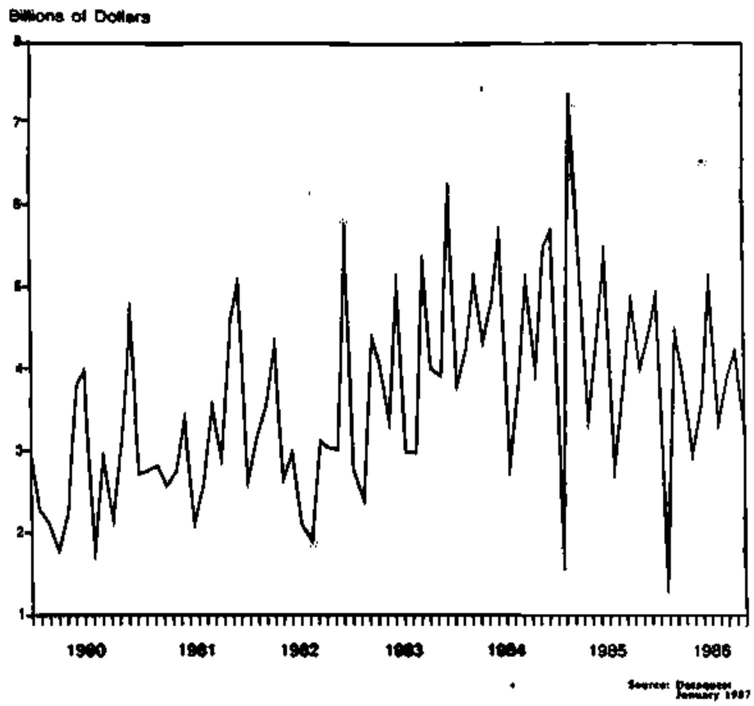
U.S. CONSUMPTION RATES OF CHANGE
COMPUTERS AND OFFICE MACHINES



Source: Dataquest
January 1987

Figure 4

U.S. BOOKINGS
COMPUTERS AND OFFICE MACHINES



The disappointing performance of the computer industry in 1986 has affected growth in related areas as well. The following areas, however, continue to be bright spots in the data processing application market segment: graphics terminals, nonimpact printing technologies (ink-jet, thermal transfer, and page), and small diameter high capacity fixed disk drives. We estimate that the data processing application market segment grew 5.4 percent in 1986 and will grow at a 7 percent CAGR through 1990.

Communications

Dataquest estimates that North American production revenue grew 9.6 percent in the communications application market segment in 1986. The growth is expected to continue at a 10.5 percent CAGR through 1990. Trends in telecommunications include:

- A move to higher bandwidths in the data communications segment
- Consolidation and shakeout of vendors in selected equipment areas
- Strong growth in voice messaging systems, LANs, T-1 multiplexers, and integrated voice/data workstations
- An increase in strategic alliances between computer vendors and PBX manufacturers

Local area networks (LANs) continued to be an area of strong growth in 1986. The buzz word in corporate America today is connectivity. Companies are trying to get the most out of their PCs and people by using LANs to share data and cut down communication and data exchange time. Dataquest estimates that the total LAN market grew 20.1 percent in 1986 and then will slow to a 12.5 percent CAGR from 1986 to 1990. The fastest growing connection area within the LAN market in 1986 was the PC (with 28.6 percent growth over 1985). The PC area will continue to grow fastest through 1990 with a CAGR of 22.6 percent. Table 3 shows Dataquest's Telecommunications Industry Service (TCIS) LAN forecast for U.S. if-sold value from 1985 to 1990.

Table 3

ESTIMATED LOCAL AREA NETWORK
END-USER IF-SOLD VALUE
(Millions of Dollars)

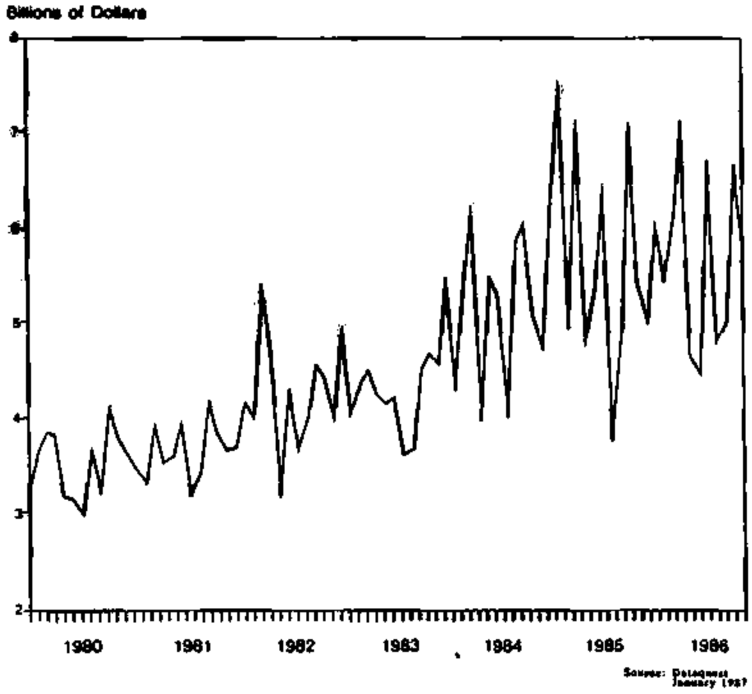
Connection	1985	1986	1987	1988	1989	1990	CAGR 1986-1990
Computer	$ 98.6	$116.4	$135.4	$150.4	$ 163.5	$ 174.7	10.7%
Terminal	190.2	211.1	220.7	221.9	213.0	206.1	(0.6%)
PC	181.7	233.6	291.5	359.7	438.6	528.0	22.6%
Office Workstation	25.1	28.9	30.3	31.3	32.2	33.3	3.6%
CAD/CAE	67.3	85.5	101.2	112.2	122.9	130.9	11.2%
Special	13.8	17.3	21.6	25.6	30.5	35.6	19.8%
Total	$576.7	$692.8	$800.7	$901.1	$1,000.7	$1,108.6	12.5%

Source: Dataquest
January 1987

Figure 5 shows DOC estimates of communications-equipment bookings from 1980 to October 1986. Although bookings decreased in October, the overall trend indicates continued growth into 1987.

Figure 5

COMMUNICATIONS EQUIPMENT BOOKINGS



Industrial

The robotics industry suffered a major blow in 1986 when General Motors scaled down plans for its GM10 car line production. GM decided to open or convert four plants for the new car line instead of the original plan that called for as many as seven plants to be tooled for GM10 production. Along with the scaling down of production plans came the cancellation of orders of robotics equipment. Major manufacturers affected by the cancellations include GMF and Cincinnati Milacron. GM's cancellations decreased GMF's fiscal 1986 revenue by 36 percent ($80 million).

Despite this disappointing news, Dataquest's Robotics Industry Service (RIS) believes that robotics vendors will aggressively pursue other sales opportunities in an effort to reach their future revenue goals. Dataquest estimates that North American produced robotics equipment revenue will grow at an 18 percent CAGR from 1986 to 1990.

In the semiconductor production equipment industry, Dataquest's Semiconductor Equipment and Materials Service (SEMS) estimates that North American semiconductor manufacturers' capital spending for property, plant, and equipment dropped 16 percent in 1986. We estimate that the drop in North American produced semiconductor production equipment revenue was not quite as large (4.7 percent). Dataquest estimates that capital spending and semiconductor production equipment revenue will pick up through 1990 with CAGRs of 8 percent and 11.8 percent, respectively.

Dataquest forecasts that the industrial application market segment will grow at a steady 9.5 percent CAGR from 1986 to 1990, with the robot systems, medical, and other segments leading the pack with CAGRs of 18 percent, 10.4 percent, and 12 percent, respectively. The fast growing equipment types in the other market segment include: nonmedical laser systems, power supplies, and trainers and simulators.

Consumer

The consumer electronics market is dominated by Asian based manufacturing. Dataquest estimates that North American production revenue in consumer electronics grew 4.7 percent in 1986 while North American consumption of consumer electronics grew 13 percent.

U.S. consumption of consumer electronics in selected equipment markets are strong. The EIA estimates that U.S. consumption of VCRs grew 14 percent, projection TVs grew 17 percent, and CD players grew 180 percent in 1986. The EIA believes that U.S. consumption in the consumer electronics area will continue to be strong in 1987. Table 4 shows EIA estimates of U.S. consumption of VCRs, projection TVs, and CD players for 1985 to 1987.

Table 4

ESTIMATED U.S. CONSUMPTION
(Millions of Dollars)

	1985	1986	1987
CD Players	$ 225	$ 630	$ 850
VCR	$4,738	$5,395	$5,767
Projection TV	$ 488	$ 570	$ 620

Source: EIA
Dataquest
January 1987

The only black cloud on the horizon of the consumer electronics market is the continued squeezing of profits. Competition is fierce in this area causing prices to go down, while the strength of the yen is causing Japanese vendors' profit margins to decrease. The strong yen is also creating a window of opportunity for non-Japanese Pacific Rim vendors to undercut Japanese prices and create market share. Two Korean manufac- turers aggressively following this strategy are Samsung and Goldstar.

Military

Initially our forecast for total military expenditures in 1986 was $54.8 billion. We have revised that down to $49.7 billion. The cumulative result of the change in defense spending is an $83.3 billion decrease over the period from 1986 to 1990.

The decrease in the defense budget projections is attributable to two political factors:

- Congress is determined to slow the military buildup started by the Reagan administration.

- Congress is serious about maintaining the deficit level goals set by the Gramm-Rudman Act.

Even with the essentially flat growth in Department of Defense spending from 1986 to 1990, Dataquest believes that there will be plenty of opportunity for semiconductor manufacturers over the next five years. There is discussion of building a DOD/semiconductor industry cosponsored research center. Right now the Defense Science Board recommends that industry put up the first $250 million and the DOD will spend $200 million each year thereafter for the next five years. It is estimated that over the next five years the DOD will pump almost $2 billion into the semiconductor industry and semiconductor related research at the university level. The Defense Science Board reasons that the defense of the United States is highly dependent upon semiconductor-based electronics: If foreign companies become the leading-edge manufacturers in the semiconductor industry the defense of the United States may depend on foreign sources for state-of-the-art semiconductor technology.

The defense industry as a whole is in a state of flux at this time. The slowing of defense spending will cause consolidation. However, there will be areas of opportunity in the future.

Transportation

Even though 1986 North American automobile production is estimated to have decreased 5 percent in 1986, Dataquest estimates that electronic equipment in the transportation application market segment finished the year at 13 percent above 1985.

The most notable change in auto production in 1986 came from Nummi, a joint venture between Toyota and General Motors that increased U.S. production more than 230 percent in 1986. General Motors had a disappointing year with U.S. production dropping 14 percent in 1986. American Motors decreased U.S. production a staggering 56 percent. Table 5 shows North American car production by manufacturer from January to December for 1985 and 1986.

Table 5

NORTH AMERICAN AUTO PRODUCTION
(Units)

	January 1 to December 28, 1985	January 1 to December 27, 1986	% Change 1985-1986
U.S. Car			
American Motors	109,082	48,336	(55.7%)
Chrysler	1,243,051	1,284,085	3.3%
Ford	1,605,595	1,747,471	8.8%
GM	4,754,916	4,082,387	(14.1%)
Honda	142,349	233,440	63.0%
Nissan	42,695	63,061	47.7%
Nummi	58,139	193,362	232.6%
Volkswagen	94,691	82,347	(13.0%)
Total U.S. Car	8,050,518	7,734,489	(3.9%)
Total Canada Car	1,085,209	1,056,145	(2.7%)
North American Car	9,135,727	8,790,634	(3.8%)
North American Truck	4,250,443	4,254,335	0.1%
Total North American Car and Truck	13,386,170	13,044,969	(2.5%)

Source: Automotive News
Dataquest
January 1987

The forecast for automotive electronic equipment growth in 1986 takes into account the increasing pervasiveness of electronics in the automobile. This trend of increasing use of electronics in the automobile industry is exemplified by Ford's announcement that it will use "smart power" devices in some 1988 model year automobiles. The use of "smart power" devices in the Ford suspension control system is a product of a joint effort between Ford and Siemens of West Germany. Ford sees this as a major step in the direction of a fully multiplexed car. GM is moving in the same direction in 1987 with its Cadillac Allante, which is estimated to contain more than $2,000 of electronics, according to Automotive News. Dataquest expects to see the electronic content of automobiles increase through 1990 with electronic equipment in the transportation area expected to grow at a 12 percent CAGR from 1986 to 1990.

David G. Norman

Dataquest

Product Offerings

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Business Computer Systems

CAD/CAM

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Computer Storage—Flexible Disks

Computer Storage—Tape Drives

Copying and Duplicating

Display Terminal

Electronic Printer

Electronic Publishing

Electronic Typewriter

Electronic Whiteboard

European Semiconductor*

European Telecommunications

Gallium Arsenide

Graphics

Imaging Supplies

Japanese Semiconductor*

Office Systems

Personal Computer

Personal Computer—Worldwide Shipments and Forecasts

Robotics

Semiconductor*

Semiconductor Application Markets*

Semiconductor Equipment and Materials*

Semiconductor User Information*

Software—Artificial Intelligence

Software—Personal Computer

Software—UNIX

Technical Computer Systems

Technical Computer Systems—Minisupercomputers

Telecommunications

Western European Printer

Executive and Financial Programs

Corporate Alliance Program

Coporate Technology Program

Financial Services Program

Strategic Executive Service

Newsletters

European PC Monitor

First Copy

Home Row

I.C. ASIA

I.C. USA

Focus Reports

The European PC Market 1985-1992

European PC Retail Pricing

PC Distribution in Europe

PC Software Markets in Europe

PC Local Area Networking Markets in Europe

The Education Market for PCs in Europe

Japanese Corporations in the European PC Markets

Home Markets for PCs in Europe

Integrated Office Systems—The Market and Its Requirements

European Market for Text Processing

Image Processing in the Office

Work Group Computing

Translation Systems

Vendor Support

The IBM 3270 Market: 1986 and Beyond

Korean Semiconductor Industry Analysis

Diskettes—The Market and Its Requirements

Directory Products

I.C. Start-Ups—1987

SpecCheck—Competitive Copier Guide

SpecCheck—Competitive Electronic Typewriter Guide

SpecCheck—Competitive Whiteboard Guide

Who's Who in CAD/CAM 1986

Future Products

- Industry Services
  - Manufacturing Automation
  - Computer Storage—Optical
  - Computer Storage—Subsystems
- Focus Reports
  - Japanese Printer Strategy
  - Japanese Telecommunications Strategy
  - Canon CX Laser—User Survey
  - Digital Signal Processing
  - PC-based Publishing
  - Taiwan Semiconductor Industry Analysis
  - China Semiconductor Industry Analysis
  - PC Distribution Channels
- Directory Products
  - SpecCheck—Competitive Facsimile Guide
  - SpecCheck—Competitive Electronic Printer Guide

*On-line delivery option available

For further information about these products, please contact your Dataquest sales representative or the Direct Marketing Group at (408) 971-9661.

Dataquest

Conference Schedule

1986

Semiconductor	October 20–22	Hotel Inter-Continental San Diego, California
Technical Computer	November 3–5	Silverado Country Club Napa, California
Asian Peripherals	November 5–7	Hotel Okura Tokyo, Japan
Semiconductor Users/ Semiconductor Application Markets	November 10	Sheraton Harbor Island San Diego, California
Electronic Publishing	November 17–18	Westin Copley Place Boston, Massachusetts
CAD/CAM EDA	December 4–5	Santa Clara Marriott Santa Clara, California

1987

Semiconductor Users/ Semiconductor Application Markets	February 4–6	Saddlebrook Resort Tampa, Florida
Copying and Duplicating	February 23–25	San Diego Hilton Resort San Diego, California
Electronic Printer	March 23–25	Silverado Country Club Napa, California
Japanese Semiconductor	April 13–14	The Miyako Kyoto, Japan
Telecommunications	April 13–15	Silverado Country Club Napa, California
CAD/CAM	May 14–15	Hyatt Regency Monterey Monterey, California
Display Terminals	May 20–22	San Diego Hilton Resort San Diego, California
European Semiconductor	June 4–5	Palace Hotel Madrid, Spain
European Copying and Duplicating	June 25–26	The Ritz Hotel Lisbon, Portugal
Financial Services	August 17–18	Silverado Country Club Napa, California
Western European Printer	September 9–11	Palace Hotel Madrid, Spain
European Telecommunications	October 1–2	Monte Carlo, Monaco
Semiconductor	October 19–21	The Pointe Resort Phoenix, Arizona
Office Equipment Dealers	November 5–6	Hyatt Regency Monterey, California
Electronic Publishing	November 16–17	Stouffer Hotel Bedford, Massachusetts
CAD/CAM EDA	December 10–11	Santa Clara Marriott Santa Clara, California

April–June

The following is a list of the newsletters in this section:

(continued)

April-June

(continued)

Dataquest
a company of
The Dun & Bradstreet Corporation

Research Newsletter

SAM Code: 1987-1988 Newsletters: April-June
1987-18

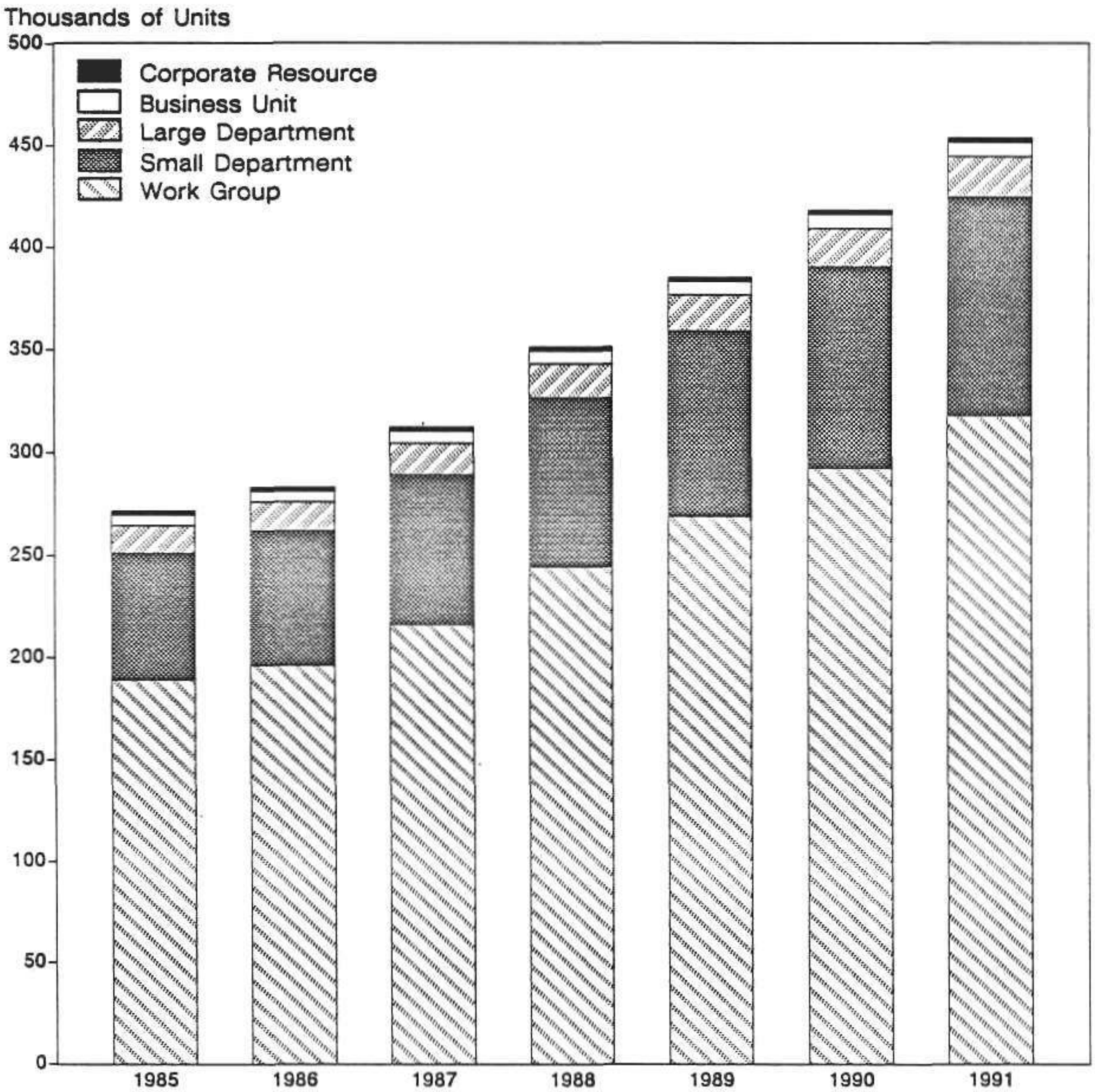
DATAQUEST'S FORECAST FOR BUSINESS COMPUTER SYSTEMS: MODERATE GROWTH FOR 1987 THROUGH 1991

SUMMARY

After lackluster revenue growth in 1985 and 1986, the business computer systems industry should experience a moderate improvement in 1987. Dataquest forecasts that U.S. business computer industry revenue will grow 4.5 percent in the coming year, with a compound annual growth rate (CAGR) of 4.8 percent over the next five years (1987-1991). Figure 1 illustrates growth for unit shipments, and Figure 2 shows the dollar value of those shipments. A detailed numerical presentation of both shipments and dollars for actual performance from 1982 through 1986 and forecast performance for 1987 through 1991 is shown in Table 1. The U.S. market for multiuser business systems in 1986 totaled approximately $19 billion. We expect revenue to reach $24 billion by 1991.

Figure 1

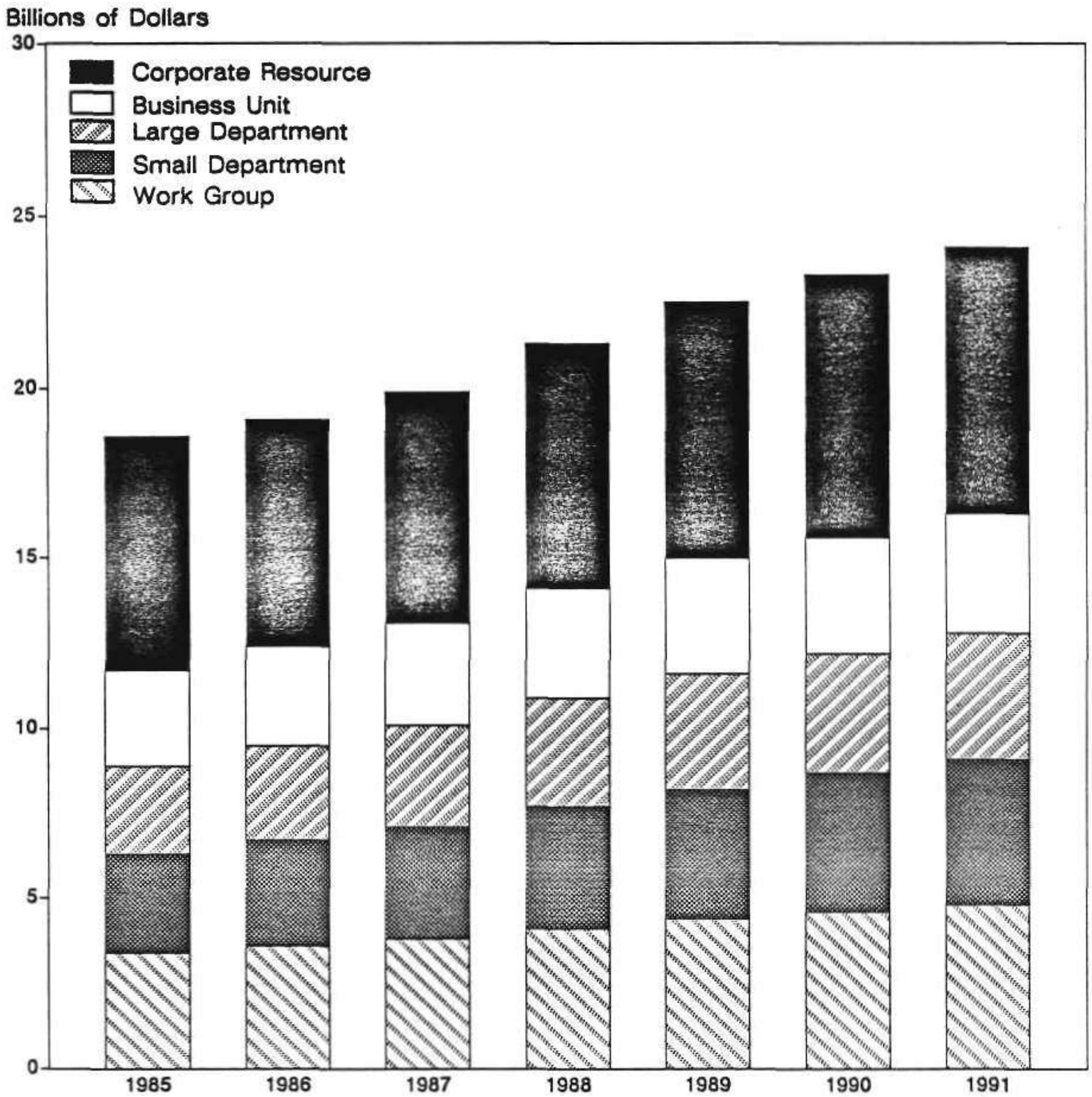
U.S. BUSINESS COMPUTER SYSTEMS
FORECAST UNIT SHIPMENTS



Source: Dataquest
June 1987

Figure 2

U.S. BUSINESS COMPUTER SYSTEMS
FORECAST UNIT SHIPMENT VALUE



Source: Dataquest
June 1987

Table 1

U.S. BUSINESS COMPUTER SYSTEMS
ACTUAL AND FORECAST SHIPMENTS AND VALUE

	Actual					Forecast					CAGR	CAGR
	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1982-1986	1987-1991
Annual Shipments (K Units)	128.6	176.8	236.7	271.8	283.4	312.4	351.2	385.6	418.4	454.0	21.8%	9.8%
Average Selling Price ($K per Unit)	$103.2	$88.9	$76.3	$68.6	$67.3	$63.8	$60.7	$58.2	$55.5	$53.0	(10.1%)	(4.6%)
Total End-User If-Sold Revenue ($B)	$ 13.3	$15.7	$18.0	$18.6	$19.1	$19.9	$21.3	$22.4	$23.2	$24.0	9.5%	4.8%
Revenue Growth	26.7%	18.5%	14.8%	3.3%	2.3%	4.5%	7.0%	5.2%	3.5%	3.5%		
Retirements from Installed Base (K Units)	21.8	45.3	61.8	88.9	121.1	166.8	221.9	252.8	278.5	318.1	53.6%	17.5%
Year-End Installed Base (K Units)	365.2	496.7	671.6	854.6	1,016.8	1,162.4	1,291.7	1,424.6	1,564.4	1,700.3	29.2%	10.0%
Installed Base Growth	41.3%	36.0%	35.2%	27.2%	19.0%	14.3%	11.1%	10.3%	9.8%	8.7%		

Source: Dataquest
June 1987

KEY FACTORS INFLUENCING GROWTH IN MARKET SEGMENTS

As Figures 1 and 2 illustrate, the five market segments of the U.S. business computer system industry: corporate resource, business unit, large department, small department, and work group, will grow at different rates. The higher growth-rate areas are work group and departmental systems. On a segment-by-segment basis, the following sections detail the key factors behind Dataquest's growth projections for 1987 and the successive years through 1991.

Corporate Resource Segment

Table 2 shows the actual and forecast performance for the corporate resource segment, where the largest mainframes are found. After the continued decline in shipments experienced in 1985 and 1986, Dataquest expects 1987 to show relatively flat shipments and a slight gain in revenue due to an abundance of new high-end systems sold by multiple vendors. These systems will be installed during 1987. The following factors are key to this forecast:

- The further acceptance of the expanding 3090 family of IBM products, the XL Series from NAS, and the 5890 family from Amdahl will fuel enhanced revenue while maintaining flat shipment growth.

- Consolidation occurred in 1986 with the mergers of major corporate resource vendors: Unisys (Burroughs and Sperry) and Group Bull (Bull, Honeywell, and NEC). Both new entities (as well as the other corporate resource vendors, CDC and NCR) must prove themselves capable of maintaining market share from encroachment by IBM and the plug-compatible manufacturers (PCMs).

- Dataquest believes that the mainframe market is mature, with small incremental growth potential for revenue throughout the decade due to much higher cost per mainframe mips versus midrange or PC mips.

Business Unit Segment

For 1987, the business unit segment revenue is expected to grow 4.2 percent, as seen in Table 3. The reasons for this include:

- The traditional minicomputer vendors (i.e., Digital Equipment, Hewlett-Packard, IBM, Prime, and Tandem) will continue to dominate and fuel moderate growth with new and existing products.

- Dataquest believes the business unit segment is also a mature market, with only moderate growth forecast for the rest of the decade. As with corporate resource systems, this segment will also suffer as more computing is pushed toward the end user where per mip and communications costs are lower.

Table 2

U.S. CORPORATE RESOURCE BUSINESS COMPUTER SYSTEMS ACTUAL AND FORECAST SHIPMENTS AND VALUE

	Actual					Forecast					CAGR	CAGR
	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1982-1986	1987-1991
Annual Shipments (K Units)	1.8	2.0	2.1	2.0	1.9	2.0	2.1	2.2	2.3	2.3	1.4%	4.4%
Average Selling Price ($M per Unit)	$3.1	$3.3	$3.5	$3.5	$3.5	$3.5	$3.4	$3.4	$3.4	$3.3	3.0%	(1.0%)
Total End-User If-Sold Revenue ($B)	$5.7	$6.5	$7.1	$6.9	$6.7	$6.8	$7.2	$7.5	$7.7	$7.8	4.5%	3.3%
Revenue Growth	35.4%	14.0%	10.1%	(3.2%)	(2.1%)	1.5%	5.3%	4.0%	2.0%	2.0%		
Retirements from Installed Base (K Units)	0.7	0.8	0.8	0.8	0.9	1.1	1.4	1.8	2.0	2.1	5.5%	17.7%
Year-End Installed Base (K Units)	9.8	10.9	12.2	13.4	14.4	15.3	16.0	16.4	16.7	16.9	10.2%	2.6%
Installed Base Growth	12.6%	12.2%	11.3%	9.7%	7.7%	6.1%	4.7%	2.4%	1.8%	1.4%		

Source: Dataquest
June 1987

Table 3

U.S. BUSINESS UNIT BUSINESS COMPUTER SYSTEMS
ACTUAL AND FORECAST SHIPMENTS AND VALUE

	Actual					Forecast					CAGR	CAGR
	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1982-1986	1987-1991
Annual Shipments (K Units)	4.1	4.5	5.0	5.3	5.4	5.7	6.2	6.5	6.8	7.0	7.1%	5.1%
Average Selling Price ($K per Unit)	$651.9	$618.2	$574.3	$523.7	$528.8	$523.6	$518.3	$513.1	$507.9	$502.8	(5.1%)	(1.0%)
Total End-User If-Sold Revenue ($B)	$ 2.7	$ 2.8	$ 2.9	$ 2.8	$ 2.9	$ 3.0	$ 3.2	$ 3.4	$ 3.4	$ 3.5	1.7%	4.0%
Revenue Growth	9.9%	4.2%	2.2%	(2.5%)	2.9%	4.2%	6.6%	5.0%	2.3%	2.3%		
Retirements from Installed Base (K Units)	0.9	1.2	1.8	2.7	3.2	3.7	4.1	5.0	5.3	5.4	36.9%	10.3%
Year-End Installed Base (K Units)	34.3	37.7	40.9	43.6	45.8	47.8	49.9	51.5	52.9	54.4	7.5%	3.3%
Installed Base Growth	10.3%	9.7%	8.5%	6.6%	5.1%	4.5%	4.3%	3.2%	2.8%	2.9%		

Source: Dataquest
June 1987

Large Department Segment

After an encouraging turnaround from flat revenue in 1985 to an increase of 5.1 percent in 1986, the large department segment is forecast to grow 6.8 percent in 1987 (see Table 4). The main forces influencing this segment are:

- Expected volume shipment of the IBM 9370 Series in the third quarter of 1987 for IBM's 9370 Series will be a positive growth factor.

- As networking schemes and departmental computing applications software are made more available during 1987, increased segment growth will result.

Small Department Segment

The emergence of powerful 68020-based systems is fueling an expected 7.8 percent growth rate in 1987's small department revenue (see Table 5). Additional key forces contributing to this segment forecast are:

- Many of the traditional minicomputer vendors are downsizing their products to attack this growth segment, with products such as Digital Equipment's MicroVAX II, IBM's 9370, and Tandem's CLX. These companies are faced with developing new distribution channels for their products, typically through third-party resellers. Through these resellers, the companies are penetrating markets beyond the Fortune 500 and expanding overall volume.

- Some of the work group vendors, such as Altos and Convergent Technologies, are growing their product lines beyond the work group market and are making a stronger showing in the departmental markets.

- Similar to the large department segment, the major industry trend toward distributed computing promotes continued development in this segment.

Table 4

U.S. LARGE DEPARTMENT BUSINESS COMPUTER SYSTEMS ACTUAL AND FORECAST SHIPMENTS AND VALUE

	Actual					Forecast					CAGR	CAGR
	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1982-1986	1987-1991
Annual Shipments (K Units)	12.1	14.1	14.5	13.6	14.1	15.2	16.5	17.6	18.6	19.7	3.9%	6.7%
Average Selling Price ($K per Unit)	$173.5	$178.5	$182.3	$194.4	$196.7	$194.7	$192.8	$190.8	$188.9	$186.3	3.2%	(1.1%)
Total End-User If-Sold Revenue ($B)	$ 2.1	$ 2.5	$ 2.7	$ 2.6	$ 2.8	$ 3.0	$ 3.2	$ 3.4	$ 3.5	$ 3.7	7.2%	5.5%
Revenue Growth	31.3%	20.0%	5.2%	(0.4%)	5.1%	6.8%	7.2%	5.8%	4.5%	4.5%		
Retirements from Installed Base (K Units)	2.1	3.5	5.3	7.6	9.4	11.0	13.5	14.1	15.9	17.2	45.5%	11.8%
Year-End Installed Base (K Units)	41.2	51.8	61.1	67.0	71.7	76.0	78.9	82.5	85.1	87.7	14.9%	3.7%
Installed Base Growth	32.1%	25.8%	17.8%	9.8%	7.0%	5.9%	3.9%	4.4%	3.3%	3.0%		

Source: Dataquest
June 1987

Table 5

U.S. SMALL DEPARTMENT BUSINESS COMPUTER SYSTEMS
ACTUAL AND FORECAST SHIPMENTS AND VALUE

	Actual					Forecast					CAGR	CAGR
	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1982-1986	1987-1991
Annual Shipments (K Units)	26.4	32.1	44.1	62.0	65.6	72.9	82.0	90.3	98.3	107.0	25.5%	10.1%
Average Selling Price ($K per Unit)	$51.5	$53.3	$51.0	$46.4	$46.7	$45.3	$43.9	$42.6	$41.3	$40.1	(2.4%)	(3.0%)
Total End-User If-Sold Revenue ($B)	$ 1.4	$ 1.7	$ 2.3	$ 2.9	$ 3.1	$ 3.3	$ 3.6	$ 3.8	$ 4.1	$ 4.3	22.5%	6.8%
Revenue Growth	7.1%	25.7%	31.6%	28.0%	6.4%	7.8%	9.1%	6.8%	5.6%	5.6%		
Retirements from Installed Base (K Units)	5.4	10.3	15.3	20.7	23.5	26.9	32.0	43.0	59.0	76.9	44.4%	30.0%
Year-End Installed Base (K Units)	91.9	113.7	142.6	184.0	226.1	272.1	322.2	369.5	408.9	439.0	25.2%	12.7%
Installed Base Growth	29.7%	23.7%	25.4%	29.0%	22.9%	20.4%	18.4%	14.7%	10.6%	7.4%		

Source: Dataquest
June 1987

Work Group Segment

Work group revenue is forecast to grow 5.9 percent in 1987 (see Table 6). Also a growth segment for business computers, the work group market will be influenced markedly by the powerful 32-bit microprocessors during the coming years. Principal reasons for the forecast are:

- Market entry by traditional minicomputer vendors--such as IBM's Personal System/2, Model 80, and Digital Equipment's MicroVAX 2000--will expand Fortune 1000 penetration, which to date has been minimal.

- IBM ATs and AT-compatibles running the Xenix operating system flooded the low end of the market in 1986 and produced a new price/performance point for entry systems bringing new users into the computer marketplace.

- The capability of running multiple operating systems, principally UNIX and MS-DOS, will be a positive growth factor. This capability is beginning to emerge during 1987 in the new 80386-based systems. We believe Motorola's 68000 series of micro-processors will offer this capability in the near future.

- Progress has been made to converge on one UNIX standard (e.g., the Microsoft-AT&T agreement to codevelop a POSIX-compliant offering that will replace Microsoft's Xenix and bear the UNIX name). This will reduce confusion and maintenance costs for the market. A second benefit will be expansion of the application software base.

- A factor inhibiting work group system growth is the competition coming from the improving technology and decreasing costs of PC LANs.

Table 6

U.S. WORK GROUP BUSINESS COMPUTER SYSTEMS
ACTUAL AND FORECAST SHIPMENTS AND VALUE

	Actual					Forecast					CAGR	CAGR
	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1982-1986	1987-1991
Annual Shipments (K Units)	84.1	124.1	170.9	188.9	196.3	216.5	244.5	268.9	292.4	318.0	23.6%	10.1%
Average Selling Price ($K per Unit)	$17.2	$17.9	$18.5	$18.2	$18.4	$17.6	$16.9	$16.2	$15.6	$15.0	1.6%	(4.0%)
Total End-User If-Sold Revenue ($B)	$ 1.4	$ 2.2	$ 3.2	$ 3.4	$ 3.6	$ 3.8	$ 4.1	$ 4.4	$ 4.6	$ 4.8	25.6%	5.7%
Revenue Growth	50.6%	53.6%	42.4%	8.7%	4.8%	5.9%	8.4%	5.6%	4.4%	4.4%		
Retirements from Installed Base (K Units)	12.6	29.5	38.6	57.2	84.1	124.1	170.9	188.9	196.3	216.5	60.7%	14.9%
Year-End Installed Base (K Units)	188.2	282.7	415.1	546.8	658.9	751.3	824.8	904.9	1,001.0	1,102.5	36.8%	10.1%
Installed Base Growth	61.3%	50.3%	46.8%	31.7%	20.5%	14.0%	9.8%	9.7%	10.6%	10.1%		

Source: Dataquest
June 1987

OVERALL MARKET FORCES

Dataquest expects data processing budgets to grow 4 to 5 percent in 1987. A major portion of the budget increase will be spent on networking and application software, leaving little room for systems hardware growth. Incremental growth will come, to a large degree, from increased market penetration of companies outside the Fortune 1000.

Dataquest's forecasts were made under the assumption that the U.S. economy will continue the stability shown during the past few years and will exhibit moderate growth in 1987. We expect that tax laws passed in 1986 will have a negligible effect on this market.

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Research *Bulletin*

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SECOND MONTHLY PROCUREMENT SURVEY SHOWS CONTINUED OPTIMISM

Although two data points are a far from adequate basis on which to plot the course for the semiconductor industry's long-term direction, results from the Semiconductor Applications Market's (SAM) second monthly procurement survey of major OEMs are already shedding some optimistic light.

- Sales were up for most equipment manufacturers from the same period last year. Last month's survey showed sales flat from last year's.

- The average semiconductor order expected for the month of June is a healthy $6 million, with the highest numbers reported from computer manufacturers.

- Billings remained fairly stable with those of the previous month.

Of course, with just these indicators, it is still too early to know if the industry will continue on its apparent rebound. But this input, combined with an expected increase of 12 to 25 percent in semiconductor billings for June over May are indeed promising signs.

But all is not perfect, according to our procurement respondents. A number of issues continue to plague buyers, ranging from long lead times to source-control-drawing components. Computer manufacturers lodged the most complaints, citing up to a 10 percent components rejection rate, long lead times, and difficulty in acquiring some devices, including microprocessors, memories, and in one case, application-specific ICs (ASICs). Another computer manufacturer thought the greatest issue facing buyers is the government's policy on DRAMs and EPROMs--a sign that these devices are becoming ever more difficult to acquire.

Additionally, although last month's respondents generally agreed that prices were stable, June's results showed buyers divided on whether prices were up, down, or constant. Answers varied from lower by 22 percent to higher by 7 percent.

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If the industry is indeed moving toward recovery, it is not surprising that some of these difficulties and apparent contradictions are arising. The computer market, which appears to be the catalyst for the market's resurgence, is relying ever more heavily on fast 256K and, soon, 1MB DRAMs, other advanced CMOS-based products, and plastic gull-wing surface-mount packaging--none of which is available in abundance. Dataquest expects, therefore, that as long as these shortages continue, the semiconductor procurement community will continue to experience price and delivery fluctuations, and will continue to build stronger relationships with selected IC manufacturers in an effort to ensure that their long-term procurement needs will be met.

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1986 LAN MARKET SCOREBOARD

THE YEAR IN REVIEW

In review of 1986, connectivity played an important role in reshaping the way many vendors increased revenue, defined long-term strategies, and now compete in this dynamic, highly competitive marketplace. This emphasis on connectivity coupled with a focus on standards helped spur U.S. and worldwide LAN revenue to record highs of $913 million and $1.42 billion, respectively. In addition, the changing market dynamics also serve as our own impetus to evolve and adopt new perspectives on measuring the LAN market for 1986 and future years. This newsletter discusses those changes and also presents 1986 LAN market data.

The Way We Were

Previously, our data base listed as shipments (and revenue from those shipments) only the physical LAN connection element. Types of connections are:

- Host computer backplane boards
- Terminal-to-host interface units (counting each available port as a connection)
- PC interface boards
- Connections to PC file servers, gateways, bridges, and network management units

Network operating system software revenue was included as part of the connection cost if it was sold as a package with the hardware.

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While this emphasis on connections served well in 1985 and earlier, growing end-user interest in such items as gateways to SNA, X.25 or other network architectures, bridges between LANs, PC file servers, and network operating system software created important additional revenue opportunities for LAN vendors. As a result, Dataquest now includes these as revenue sources along with the physical connection. The following is a list of items that are now counted as either a connection, revenue, or both (examples of manufacturers listed in parentheses):

- Host/multiuser computer backplane boards, channel attached connections (Bridge Communications, Communication Machinery, Digital Equipment, Excelan, Fibercom, Intel, KMW-Auscom, Micom-Interlan, Network Systems, Proteon, Xyplex, Wang)

- Terminal interface units (Artel, Bridge Communications, Digital Equipment, Micom-Interlan, Network Systems, Sytek, TRW, Ungermann-Bass, Xyplex, Wang)

- PC adapter boards and required operating system software (Apple, AT&T, Codenoll, Excelan, Fox Research, Gateway Communications, IBM, Nestar, Novell, Proteon, 3Com, Sytek, Ungermann-Bass)

- Independently sold network operating system software--counts only as revenue, not as a connection shipped (Novell, Santa Cruz Operations, Wollongong Group)

- Proprietary PC file servers, includes adapter board for total of one shipment, excludes systems such as PC XTs and PC ATs adapted into file servers with add-on software (Banyan, Corvus, Nestar, Novell, 3Com)

- Bridges, gateways, routers (Bridge Communications, Digital Equipment, Proteon, Sytek, 3Com, Ungermann-Bass, Vitalink).

- Network management (Bridge Communications, Digital Equipment, IBM, Proteon, Sytek, Ungermann-Bass)

- Network extension units, multistation access units--counts only as revenue, not as a connection shipped (AT&T, IBM)

In some cases, the LAN connection is indistinguishable from the computer's processor. Companies such as Apple, Datapoint, and Sun Microsystems, for example, provide systems with a built-in LAN function. Dataquest reports these types of integrated LAN connections as revenue and shipments only when the system is attached to a LAN. Dataquest expects built-in LAN functionality to become more prevalent in the future.

Market Shares

Table 1 lists 29 LAN vendors and their respective 1986 U.S. connections shipped, U.S. revenue, U.S. installed base, worldwide revenue, and the percent of international revenue. It also provides totals for manufacturers and end users in U.S. and worldwide LAN markets.

- All data are based on a calendar year, January 1 to December 31. For consistency and accuracy of reporting, information derived from companies with a noncalendar fiscal year are recalculated into a calendar year based on a month-to-month performance.

- Revenue is listed by company as manufacturing revenue to the first stop in the distribution channel. Any volume discounts are estimated in direct sales to end users and markdowns to the distributor, dealer, or OEM.

- Total end-user revenue is derived from the addition of manufacturing revenue and revenue obtained by indirect distribution channels.

- Revenue derived from network design, network installation, and other nonproduct revenue sources is not included.

Table 1

1986 U.S. LAN MARKET VENDORS

Vendor	Ships U.S.	Revenue U.S. (M)	Installed Base U.S.	Revenue W.W. (M)	Revenue %Intl
AST Research	13,500	$ 5.0	32,000	$ 6.9	28
AT&T-IS	12,700	9.5	12,700	11.9	20
Apple	82,000	3.3	165,000	4.4	25
Banyan Systems	520	8.2	630	10.3	20
Bridge Communications	72,000	30.5	148,600	42.4	28
CMC	4,200	8.9	7,700	10.5	15
Corvus	27,700	9.7	102,000	16.2	40
Datapoint	7,090	3.9	81,200	9.8	60
Digital Equipment	232,000	172.0	397,000	286.7	40
Excelan	9,820	16.6	18,100	19.5	15
Fox Research	7,150	2.4	10,000	6.9	65
Gateway Communications	15,100	6.8	23,000	10.5	35
IBM (PC Network)	4,500	3.3	22,500	5.5	40
IBM (Token Ring)	21,000	19.4	21,000	32.3	40
Micom-Interlan	8,050	9.5	44,200	12.7	25
Nestar	12,400	7.7	55,000	12.8	40
Network Systems	19,500	72.0	53,400	90.0	20
Novell	2,340	75.0	5,500	93.8	20
Orchid Technology	4,900	2.2	16,500	3.3	33
Proteon	21,600	13.2	39,900	16.5	20
Sytek	75,000	52.0	209,000	65.0	20
3Com	102,800	62.5	182,100	82.2	24
TRW	13,300	7.8	17,000	9.2	15
Ungermann-Bass	125,000	74.0	225,000	98.7	25
Vitalink	590	8.5	700	12.1	30
Wang	50,000	21.0	126,000	35.0	40
Wollongong Group	sw 900	10.8	sw 2,700	12.3	12
Xerox	48,200	17.2	136,600	22.9	25
Xyplex	15,490	7.4	28,900	8.7	15
Subtotal	1,008,450	$740.3	2,181,230	$1,048.7	
Others	92,000	75.0	167,000	136.3	
Total Manufacturer	1,100,450	$815.3	2,348,230	$1,185.0	
Total End User		$913.0		$1,420.0	

Source: Dataquest
May 1987

The top 20 vendors ranked in order of U.S. LAN manufacturing revenue are shown in Table 2. As a testament to the popularity of Ethernet, Digital Equipment turned out an impressive performance by shipping 232,000 U.S. connections for revenue of $172 million, a 100 percent increase over its 1985 performance. Digital achieved more than double the revenue of the nearest LAN vendor, Novell.

A note about Novell: Since Novell receives its PC adapter boards from more than a dozen OEMs, they are not listed within our data base as shipments for Novell; other vendors that OEM products are treated similarly. (Novell has stated that its NetWare is running on more than 60,000 file servers, which include PC XTs, ATs, and Novell's proprietary server.)

Table 2

1986 LAN REVENUE MARKET SHARE

Vendor	Revenue U.S. (M)	Market Share U.S Revenue
Digital Equipment	$172.0	21.1%
Novell	75.0	9.2
Ungermann-Bass	74.0	9.1
Network Systems	72.0	8.8
3Com	62.5	7.7
Sytek	52.0	6.4
Bridge Communications	30.5	3.7
Wang	21.0	2.6
IBM (Token Ring)	19.4	2.4
Xerox	17.2	2.1
Excelan	16.6	2.0
Proteon	13.2	1.6
Wollongong Group	10.8	1.3
Corvus	9.7	1.2
AT&T-IS	9.5	1.2
Micom-Interlan	9.5	1.2
CMC	8.9	1.1
Vitalink	8.5	1.0
Banyan Systems	8.2	1.0
TRW	7.8	1.0
Others	117.0	14.4
Total	$815.3	100.0%

*Columns may not add to totals shown because of rounding

Source: Dataquest
May 1987

Table 3 indicates the ranking of vendors by U.S. connections shipped. Digital leads the pack with shipments of 232,000 followed by Ungermann-Bass, 3Com, and Apple. In 1986, Apple emerged as a significant new LAN player: the Apple Macintosh and laser printer desktop publishing combination proved to be a popular setup within Fortune 1000 corporations. However, despite achieving 82,000 shipments, Apple received only $3.3 million in revenue due to a very low connection cost per node.

Table 3

1986 U.S. LAN SHIPMENTS MARKET SHARE

Vendor	U.S. Shipments	Market Share Shipments
Digital Equipment	232,000	21.1%
Ungermann-Bass	125,000	11.4
3Com	102,800	9.3
Apple	82,000	7.5
Sytek	75,000	6.8
Bridge Communications	72,000	6.5
Wang	50,000	4.5
Xerox	48,200	4.4
Corvus	27,700	2.5
Proteon	21,600	2.0
IBM (Token Ring)	21,000	1.9
Network Systems	19,500	1.8
Xyplex	15,490	1.4
Gateway Communications	15,100	1.4
AST Research	13,500	1.2
TRW	13,300	1.2
AT&T-IS	12,700	1.2
Nestar	12,400	1.1
Excelan	9,820	0.9
Micom-Interlan	8,050	0.7
Others	123,290	11.2
Total	1,100,450	100.0%

*Columns may not add to totals shown because of rounding

Source: Dataquest
May 1987

Table 4 indicates U.S. installed base numbers and market share. Again, Digital leads the way followed by Ungermann-Bass, Sytek, and 3Com.

Table 4

1986 U.S. LAN CONNECTIONS
INSTALLED BASE MARKET SHARE

Vendor	Installed Base U.S.	Market Share I.B.
Digital Equipment	397,000	16.9%
Ungermann-Bass	225,000	9.6
Sytek	209,000	8.9
3Com	182,100	7.8
Apple	165,000	7.0
Bridge Communications	148,600	6.3
Xerox	136,600	5.8
Wang	126,000	5.4
Corvus	102,000	4.3
Datapoint	81,200	3.5
Nestar	55,000	2.3
Network Systems	53,400	2.3
Micom-Interlan	44,200	1.9
Proteon	39,900	1.7
AST Research	32,000	1.4
Xyplex	28,900	1.2
Gateway Communications	23,000	1.0
IBM (PC Network)	22,500	1.0
IBM (Token Ring)	21,000	0.9
Excelan	18,100	0.8
Others	237,730	10.1
Total	2,348,230	100.0%

*Columns may not add to totals shown because of rounding

Source: Dataquest
May 1987

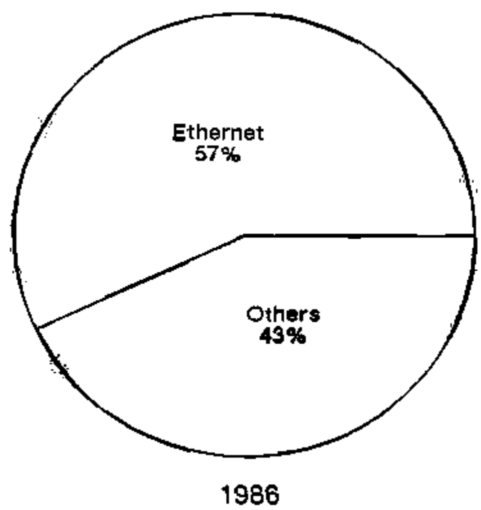
Ethernet Dominates LAN Sales

The sale of Ethernet products easily dominated the 1986 LAN market. Led by Ethernet powerhouses such as Digital, Ungermann-Bass, 3Com, and Bridge Communications, Dataquest estimates that 57 percent of all 1986 U.S. connections shipped were Ethernet (Figure 1). Ethernet's strong performance brings the estimated Ethernet installed base number up to 52 percent (Figure 2), an increase of 7 percent from the estimated 1985 installed base of 45 percent. Figures 3 and 4 illustrate vendor Ethernet market share numbers for shipments and installed base, respectively.

Dataquest places IBM 1986 shipments for Token-Ring boards at 21,000 in the United States and 35,000 worldwide. IBM's performance is noteworthy considering it reflects a partial year of shipments due to a second quarter product roll-out accompanied by the usual production ramp-up cycles.

Figure 1

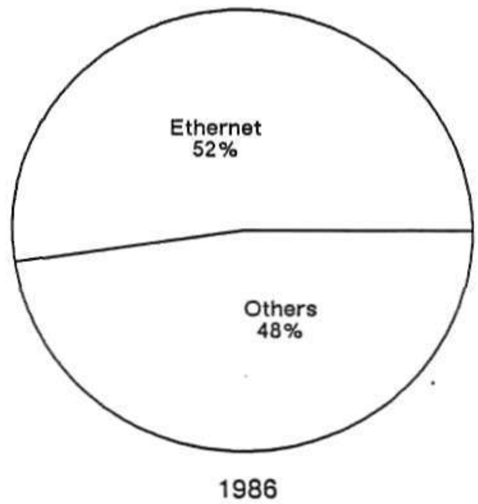
1986 U.S. ETHERNET MARKET SHARE FOR ALL LAN CONNECTIONS SHIPPED



Source: Dataquest
May 1987

Figure 2

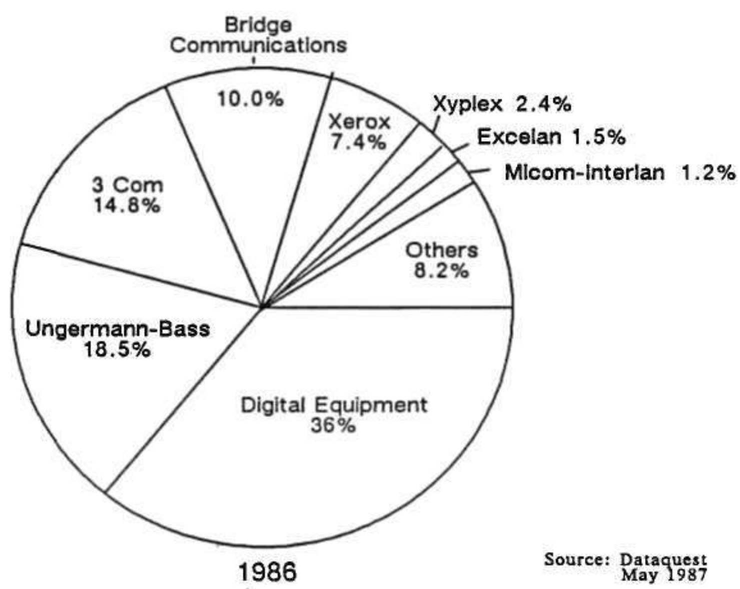
1986 U.S. ETHERNET MARKET SHARE FOR ALL LAN CONNECTIONS INSTALLED BASE



Source: Dataquest
May 1987

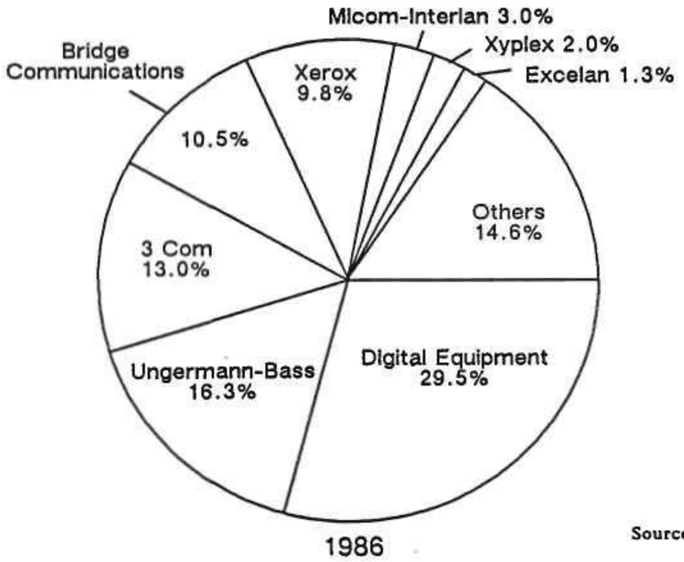
Figure 3

1986 U.S. VENDOR MARKET SHARES FOR ETHERNET CONNECTIONS



Source: Dataquest
May 1987

Figure 4
1986 U.S. VENDOR MARKET SHARE FOR
ETHERNET INSTALLATIONS



Source: Dataquest
May 1987

LAN Vertical Markets

LAN technology is well suited for use in large campus type environments, as indicated by a Dataquest vertical market survey (see Table 5). Installations such as hospitals, universities, and manufacturing sites are typical campus environments that cover a greater than average geographic territory and possess a high amount of users.

Table 5

LAN VERTICAL MARKETS

Vertical Market	Percent
Agr/Mining/Const	4%
Manufacturing	20%
Trans/Utilities	4%
Wholesale/Retail	8%
Banks/Savings & Loan	8%
Finance/Insurance	9%
Business Services	11%
EDP Services	8%
Medical/Education	20%
Government	8%

Source: Dataquest
May 1987

DATAQUEST CONCLUSIONS

Each year for the past several years, the LAN community has trumpeted that this year would be the so-called "Year of the LAN." And like clockwork the year would end with critics and nay-sayers providing numerous derisive comments that it had, once again, failed to materialize. Although no one has yet defined the plateau that must be reached to obtain this elusive and albeit meaningless "Year of the LAN" status, we believe that 1986 was the year by any measure.

Several events combined to make it happen. The LAN market received a helpful boost simply by IBM's Token-Ring entrance. By announcing its product strategy in the October 1985 announcement, IBM released potential customers who were waiting to make purchase decisions. Ultimately, many planned on implementing Token-Ring, while others would go with alternative technologies.

An unwavering allegiance to Ethernet and a disciplined product strategy paid off for Digital as it grabbed 24 percent of the worldwide market. Dataquest believes that Digital's success in networking and communications has sparked the competitiveness of Bridge Communications, Hewlett-Packard, IBM, and Ungermann-Bass.

A greater focus on standards and connectivity is winning over Corporate America as the MIS directors and DP managers become comfortable with LAN technology. The standards, de facto or actual, provide the LAN with a longer technological "shelf life." Connectivity increases the options for expandability and provides interoperability among already installed systems.

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David Norman
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Dataquest
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Research *Bulletin*

SAM Code: 1987-1988 Newsletters: April-June
1987-15

LET THE MANUFACTURER AND BUYER BEWARE: LEAD-TIME CONCERN IS APPARENT IN FIRST MONTHLY PROCUREMENT SURVEY

Dataquest's Semiconductor Application Markets (SAM) service began its first monthly semiconductor procurement survey on May 1 to complement the annual procurement survey done each year. Several major electronic equipment companies have agreed to share with us, on a monthly basis, information regarding their semiconductor buying trends. Each month we will survey our team of respondents and report on tactical industry trends shaping the short-term industry outlook. This bulletin highlights the information gleaned from our first such survey.

Clearly, the single most important procurement issue facing buyers is lead times. Concern arose regarding obtaining DRAMs as well as regarding placing orders soon enough to avoid getting "left in the cold." One respondent was concerned that lead times would continue to stretch, and another respondent's major concern was to obtain lead time agreements with particular suppliers. The average lead time for new orders was nearly 12 weeks.

In general, most respondents said that semiconductor prices were remaining the same; increases mentioned were no more than 5 percent, seen in DRAMs and components purchased overseas. Most users are not having particular difficulty obtaining components in the quantities that they require; however, when difficulties were mentioned, they involved memory, standard logic, and linear devices.

Other information learned from the survey included the following:

- May billings were expected to be flat to slightly up.
- All buyers expected to place orders in May; they estimated that 6 percent of these orders would be placed with distributors.
- Target inventories were in alignment with actual inventory levels, with the average target and actual level being 33 days.

Dataquest, 1290 Ridder Park Drive, San Jose, CA 95131-2398, (408) 971-9000, Telex 171973

- Last month, users rejected an average of 1.9 percent of components because they did not meet specification.

- Most companies were experiencing approximately the same rate of electronic equipment sales as at this time last year. No single application market area seemed to be experiencing either much higher or much lower sales activity.

We can only discern that the business cycle is once again in a state of flux, with many waiting to see if the upturn is here for good. Concern over lead times and availability is one indication that the market is tightening; in our annual survey, users projected that their purchases would increase nearly 14 percent in 1987. Next month's survey will be our first month-to-month comparison--we await the opportunity to plot a monthly course.

Anthea C. Stratigos

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Research Newsletter

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1987-14

QUARTERLY ELECTRONIC EQUIPMENT UPDATE: DATAQUEST LOOKS AT 1987 WITH CAUTIOUS OPTIMISM

INTRODUCTION

Dataquest expects electronic equipment market growth in 1987 to rise slightly above the 4.3 percent growth that the market experienced in 1986--to 4.8 percent in 1987. Although this is not a large increase, elements of this growth should benefit semiconductor manufacturers, because growth rates are accelerating for the data processing, communications, and industrial application areas. Combined, these three application markets represent approximately 70 percent of North American semiconductor consumption.

The increased growth rate in 1987 is the result of a number of factors, including new products replacing mature technology and manufacturers replenishing inventories. Nevertheless, the declining growth of the military electronics market is having a moderating effect on the total electronic equipment growth rate. Figure 1 displays the historical relationship (1970 through 1986) between semiconductor consumption and electronic equipment production and includes our forecast through 1991.

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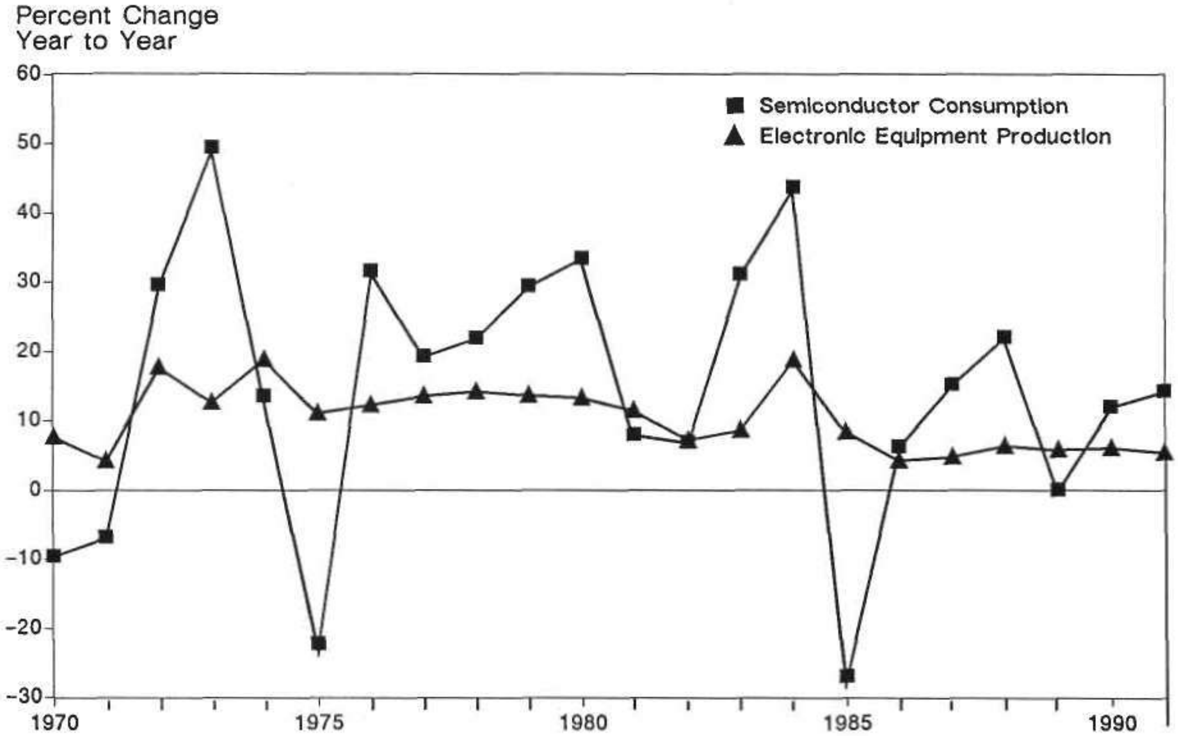
Figure 1

COMPARISON OF SEMICONDUCTOR CONSUMPTION
AND ELECTRONIC EQUIPMENT PRODUCTION



Source: Dataquest
May 1987

OUTLOOK FOR APPLICATION MARKETS

Table 1 contains Dataquest's updated revenue forecast for North American electronic equipment shipments. The following pages discuss each application market forecast, highlighting the most recent events that are expected to affect the different semiconductor application markets in the near future.

Table 1

SEGMENT OVERVIEW
NORTH AMERICAN ELECTRONIC EQUIPMENT FORECAST
(Millions of Dollars)

Segment	1987	1988	1989	1990	1991	CAGR 1987-1991
Data Processing						
Computers	$ 61,397	$ 67,327	$ 72,262	$ 78,284	$ 83,445	8.0%
Data Storage Subsystems	18,177	19,466	21,174	22,122	22,691	5.7%
Terminals	3,588	3,916	4,274	4,494	4,640	6.6%
Input/Output	8,236	8,468	8,514	8,688	8,781	1.6%
Dedicated Systems	3,821	3,473	3,315	3,392	3,451	(2.5%)
Subtotal	$ 95,219	$102,650	$109,539	$116,980	$123,008	6.6%
Communications						
Customer Premises	$ 10,170	$ 11,117	$ 12,142	$ 13,021	$ 14,029	8.4%
Public Telecom-munications	6,834	7,080	7,516	7,881	8,297	5.0%
Radio	6,513	7,608	8,654	9,785	10,556	12.8%
Broadcast and Studio	1,582	1,767	1,892	2,100	2,331	10.2%
Other	1,958	2,010	2,144	2,346	2,575	7.1%
Subtotal	$ 27,058	$ 29,581	$ 32,348	$ 35,133	$ 37,788	8.7%
Industrial						
Security/Energy Mgmt.	$ 2,211	$ 2,388	$ 2,483	$ 2,678	$ 2,905	7.1%
Manufacturing Systems	12,772	14,348	15,021	16,213	17,840	8.7%
Instrumentation	7,235	8,167	8,589	9,197	9,938	8.3%
Medical Equipment	5,345	5,757	6,072	6,432	6,858	6.4%
Commercial Aviation	2,216	2,394	2,582	2,657	2,838	6.4%
Other	5,669	6,291	6,964	7,671	8,466	10.5%
Subtotal	$ 35,447	$ 39,345	$ 41,711	$ 44,848	$ 48,845	8.3%
Consumer						
Audio	$ 324	$ 332	$ 357	$ 395	$ 407	5.9%
Video	5,127	5,291	5,647	6,254	6,577	6.4%
Personal Electronics	720	756	794	801	816	3.2%
Appliances	11,068	11,522	12,098	12,891	13,691	5.5%
Other	1,116	1,167	1,218	1,270	1,325	4.4%
Subtotal	$ 18,355	$ 19,067	$ 20,114	$ 21,611	$ 22,816	5.6%
Military	$ 47,500	$ 46,900	$ 46,400	$ 46,300	$ 46,700	(0.4%)
Transportation	$ 10,809	$ 11,799	$ 13,812	$ 15,050	$ 16,209	10.7%
Total Equipment	$234,388	$249,342	$263,924	$279,922	$295,365	6.0%

Source: Dataquest
May 1987

Data Processing

Forecast

Dataquest estimates that the data processing market segment will grow 6.4 percent in 1987, in contrast to the 5.1 percent growth experienced in 1986. The computer segment will grow at a moderate 6.6 percent in 1987, which is considerably higher than the 4.0 percent growth experienced in 1986; however, a predicted 9.9 percent decline in dedicated systems shipments in 1987 will have a moderating effect on the overall growth rate of the data processing application market. The fastest-growing computer equipment type will be single-user enhanced computer systems, commonly known as technical workstations, with 40 percent growth expected in 1987. Dataquest believes that the following equipment types will be bright spots on the horizon of the data processing application market through 1991:

- Single-user enhanced computer systems

- Three- to four-inch rigid disk drives

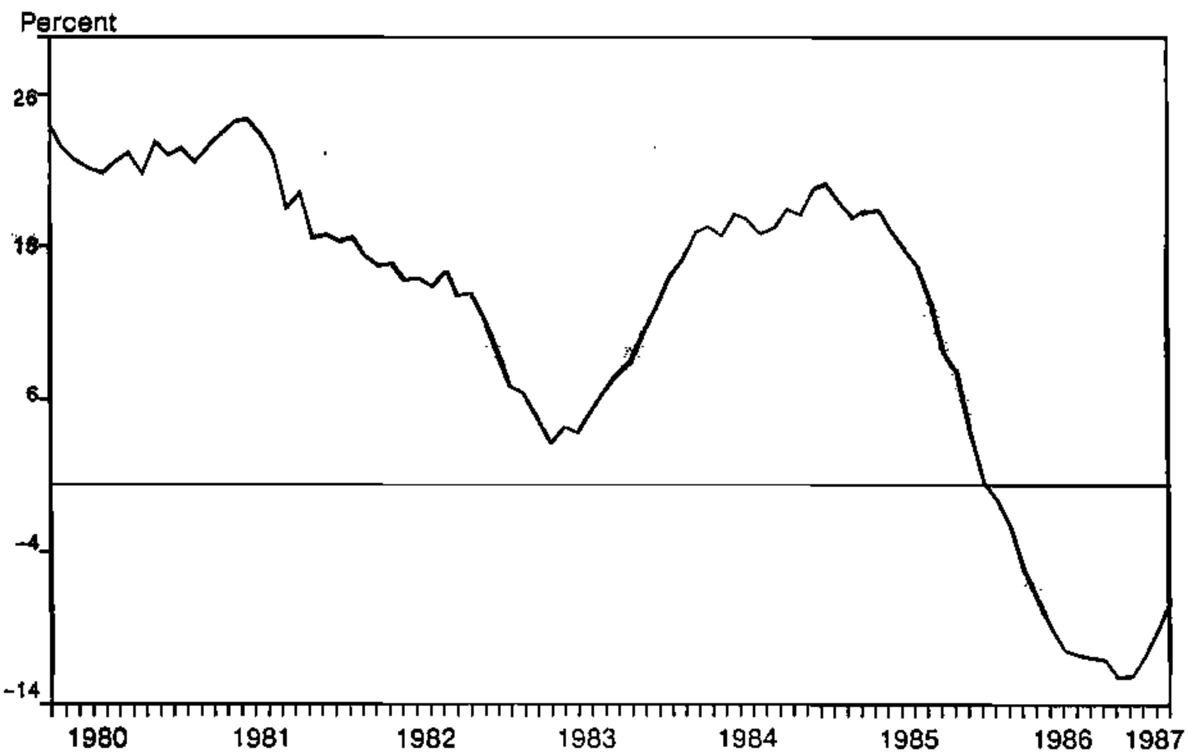
- Write-once, read-many (WORM) optical disk drives

- Ink-jet printers

Although there are definitional differences between Department of Commerce (DOC) data and Dataquest methodology, the DOC monthly data are a good source for aggregate top-level monthly data. The most recent DOC data (February 1987) indicate that computer and office machine (SIC 357) shipments are still below 1986 levels. The rate of decline has turned, however, and if the trend continues, we will see positive growth by mid-1987. Figure 2 shows the rate of change of computer and office machine shipments from January 1980 to February 1987.

Figure 2

COMPUTER AND OFFICE EQUIPMENT SHIPMENTS
(12/12 Rate of Change)



Source: U.S. Department of Commerce
Dataquest
May 1987

Industry Events and Trends

The computer segment of the data processing application market was very active in the first quarter of 1987. New products were introduced by Amdahl, Apple, IBM, Digital Equipment Corporation, and a number of other vendors. In the business and technical computer arena, Digital Equipment announced new products that are aimed at IBM's SolutionPacs software and IBM's 9370 computer systems. Digital's new computers provide 20 to 30 percent more performance at 15 to 20 percent of the price of its previous model. Amdahl also announced a new product aimed at an IBM system, the 5890E, designed for direct competition with the IBM 3090E. Amdahl's machine has a 4 percent performance improvement and a 10 to 15 percent price improvement over the IBM machine.

In the realm of the personal computer, Apple continued to add products to its Macintosh line with the Macintosh SE and the Macintosh II. IBM announced an entire new family of personal computer products. The Personal System/2 (PS/2) family from IBM has the potential to cause major strategy changes for add-on board manufacturers, clone manufacturers, and semiconductor manufacturers. At the add-on board level, IBM has announced that it will publish the specification of its new bus architecture, IBM Micro Channel. This means that board manufacturers do not have to delay product introductions while they reverse-engineer the bus. The effect of the PS/2 product introduction on low-cost compatible manufacturers remains to be seen. IBM has included some of its own ASIC devices, which could mean that compatible manufacturers will have a tougher time designing a fully compatible system. Assuming that the PS/2 family can be cloned, there is some question as to whether or not IBM will take legal action against the clone manufacturers. If IBM manages to prevent the PS/2 family from being cloned, it could close the door on a potentially major market for semiconductor vendors.

How did the PS/2 announcement directly affect semiconductor vendors? IBM used memory devices manufactured by IBM's semiconductor operations. Initially, memory vendors thought a major market had been closed; however, Dataquest believes that IBM's memory approach does not exclude external DRAM vendors. Economics dictate that having multiple sources of DRAMs ensures more competitive pricing and uninterrupted supply. Competition with other vendors also fosters efficiency and technological excellence in IBM's semiconductor operations.

The IBM Personal System/2 family is analyzed in greater detail in SAM newsletter number 1987-13, entitled "Dataquest Looks Inside IBM's New PC."

Along with Apple's and IBM's announcements, many vendors announced PCs based on Intel's 80386 microprocessor in the first quarter of 1987. What do all of these product announcements mean to semiconductor vendors? When new computer products are introduced, they represent the latest trends in semiconductor design. This allows semiconductor vendors to assess their positioning for the future. These trends are discussed in the newsletter mentioned above and another recent SAM newsletter number 1987-08, entitled "Impact of the Compaq Deskpro 386: How the 32-Bit PC Market Is Shaping Up (And Implications for IC Manufacturers)." Although Apple and IBM are fairly mature in their industry and have well-defined sets of semiconductor suppliers, there is still opportunity for semiconductor vendors to second-source components in the new computer products. Overall, the upturn we have seen in North American semiconductor consumption this year appears to be computer driven. We believe that this trend will continue throughout the year.

Communications

Forecast

Dataquest continues to see the communications application market as an area of growth in 1987. We expect the communications market to experience 8.2 percent growth in 1987, just slightly higher than the 7.8 percent growth experienced in 1986. In the long term (1987 to 1991), we forecast the communications market to speed up to an 8.7 percent compound annual growth rate (CAGR). The high growth predicted for 1987 in the radio segment is due to the rapid growth of cellular mobile radio (CMR). We expect CMR telephones and CMR base stations to grow 38.0 percent and 71.8 percent, respectively, in 1987.

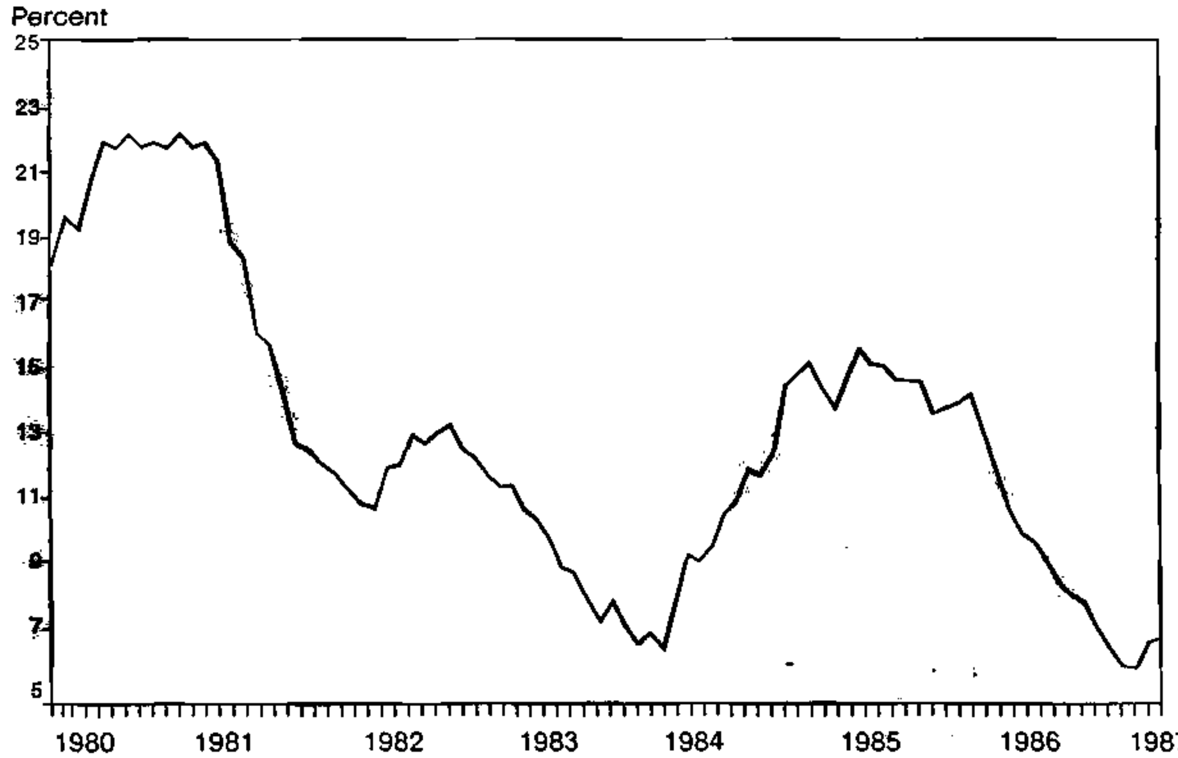
We believe that the following products will experience healthy growth through 1991:

- Integrated voice/data workstations
- Modems
- T-1 multiplexers
- LANs
- Voice messaging systems
- Packet switching equipment
- CMR

The most recent monthly data from the DOC show that the rate of change for shipments is staying fairly constant going into 1987. The DOC data validate our forecast of a slight increase in growth in the communications application market. Figure 3 displays the rate of change of communications equipment shipments from January 1980 to February 1987.

Figure 3

COMMUNICATIONS EQUIPMENT SHIPMENTS
(12/12 Rate of Change)



Source: U.S. Department of Commerce
Dataquest
May 1987

Industry Events and Trends

Work on the Integrated Service Digital Network (ISDN) is continuing to make the concept a reality. USWest, one of the seven Regional Bell operating companies (RBOCs), has planned several comprehensive and ambitious ISDN trials for 1987. The trials will demonstrate and evaluate approximately 35 customer applications, incorporating switching technology from four manufacturers and ten terminal equipment vendors. Eight customers are participating in the trials; they represent a wide range of industry segments including banking, manufacturing, computer development, communications, and government. USWest is conducting these tests to reap the following benefits:

- Better understanding of participating manufacturers' ISDN terminal equipment capabilities

- Encouragement of further ISDN terminal equipment development

- Promotion of ISDN equipment standards

- Evaluation of ISDN compatibility with existing technologies such as packet switching, the public voice networks, dedicated and private lines, and LANs

Semiconductor manufacturers can also benefit from the tests. The test results will show which telecommunications vendors are most competitive, thus allowing semiconductor vendors to analyze their current status in the ISDN field. For semiconductor manufacturers, one outcome of the tests will be an indication of the companies they should focus on for strategic alliances in ISDN. The test may provide new product opportunities as customer needs are analyzed. Table 2 shows the current ISDN alliances between semiconductor manufacturers and telecommunications equipment vendors. Figure 4 displays the USWest ISDN test plan.

Table 2

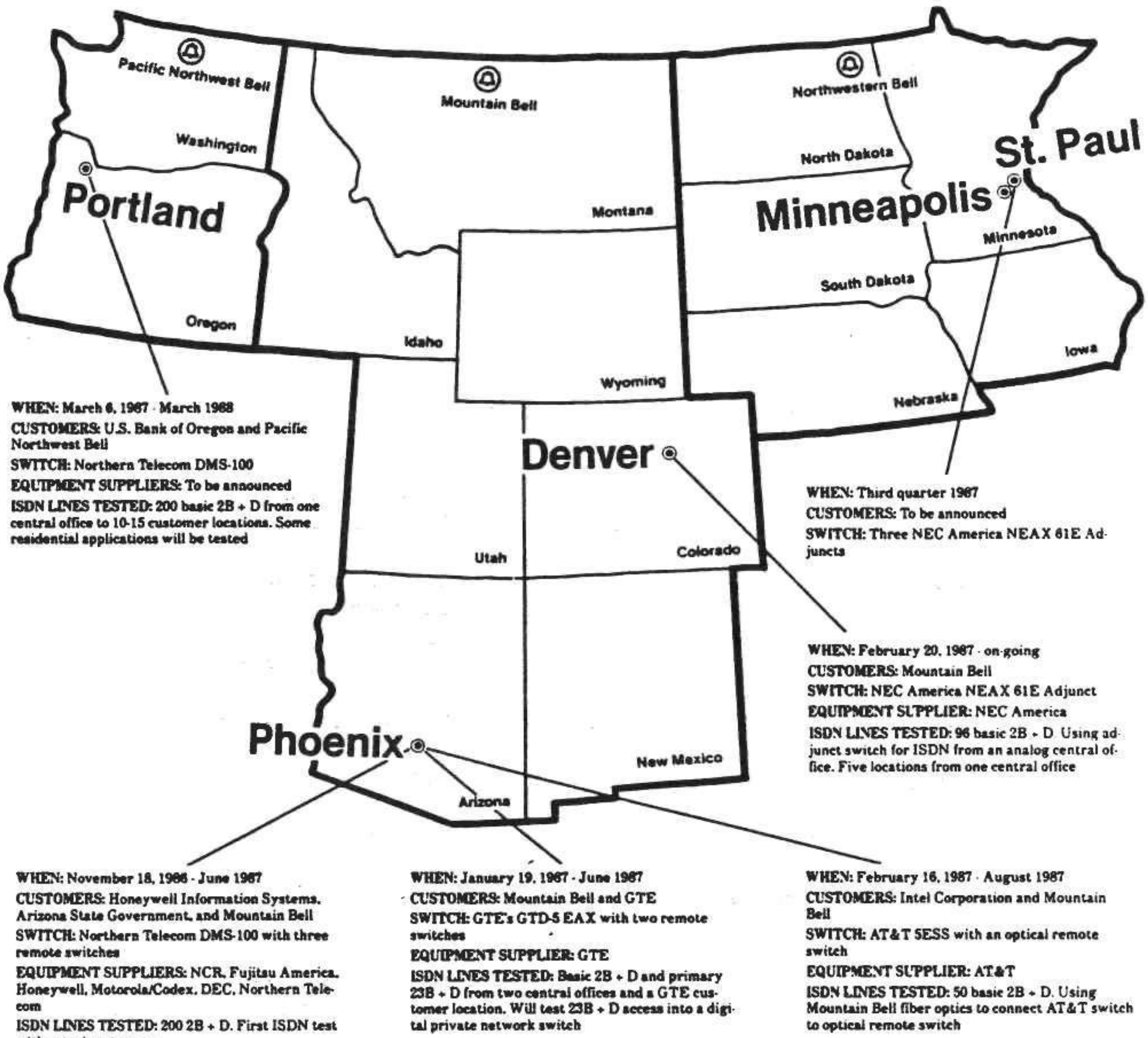
SEMICONDUCTOR MANUFACTURER AND ISDN EQUIPMENT MANUFACTURER PARTNERSHIPS

Semiconductor Vendors	ISDN Equipment Manufacturers
Mitel	Lear Siegler Southern Bell
AMD	L.M. Ericsson Plessey GEC British Telecom
Motorola	Northern Telecom
Intel	AT&T
National Semiconductor	Northern Telecom
Texas Instruments	Ericsson

Source: Dataquest
May 1987

Figure 4

USWEST ISDN TRIALS



Source: USWest

Industrial

Forecast

Dataquest expects the industrial application market to grow by 7.9 percent in 1987. In the long term (1987 to 1991), we expect the industrial application market to grow at an 8.3 percent CAGR. The high growth segments include instrumentation and manufacturing systems with CAGRs of 8.3 percent and 8.7 percent, respectively, from 1987 to 1991. Other growth areas are power supplies, laser systems, and flight trainers and simulators. The fastest-growing equipment types in the manufacturing systems category are robot systems and automated material-handling equipment.

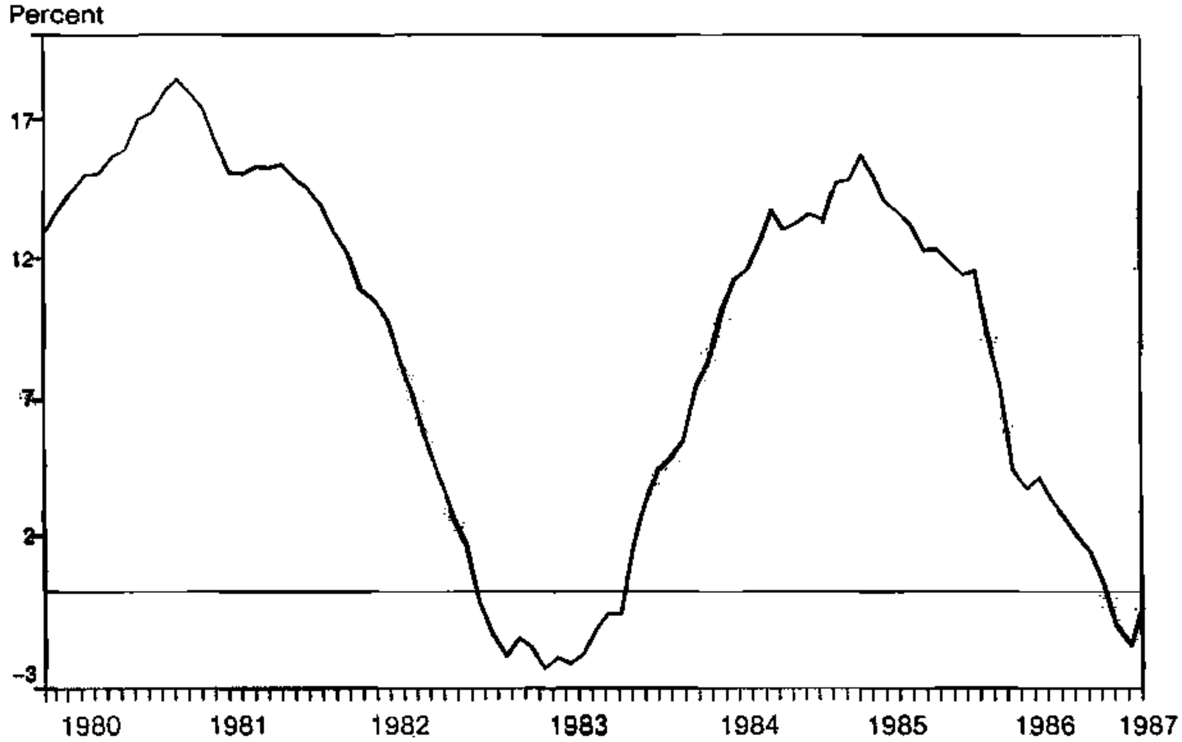
Dataquest expects the following products to experience strong growth through 1991:

- Robot systems
- Geophysical instruments
- Nuclear magnetic resonance equipment
- Semiconductor production equipment

The most recent monthly data from the DOC show that the rate of change of instrument shipments has increased since 1986, and we expect to see positive growth in 1987. Figure 5 shows the rate of change curve for the scientific and engineering instruments.

Figure 5

U.S. SCIENTIFIC AND ENGINEERING INSTRUMENT SHIPMENTS
(12/12 Rate of Change)



Source: U.S. Department of Commerce
Dataquest
May 1987

Industry Events and Trends

In the manufacturing systems category, the dominant issue is to focus on automating islands of equipment, rather than integrating islands of automation. The trend over the past few years has been toward large-scale integration and linking separate islands of automation under a single control scheme. Now--in a complete reversal of philosophy--the industry is encouraging users to start small, develop an automated work cell (the island), and work gradually toward expanding the automated parts into a larger whole.

The trend toward automated islands pushes users away from a central processing environment to a distributed computing environment. This will provide an opportunity for 32-bit microprocessor and workstation vendors to provide the computing power to run an automated work cell.

Consumer

Forecast

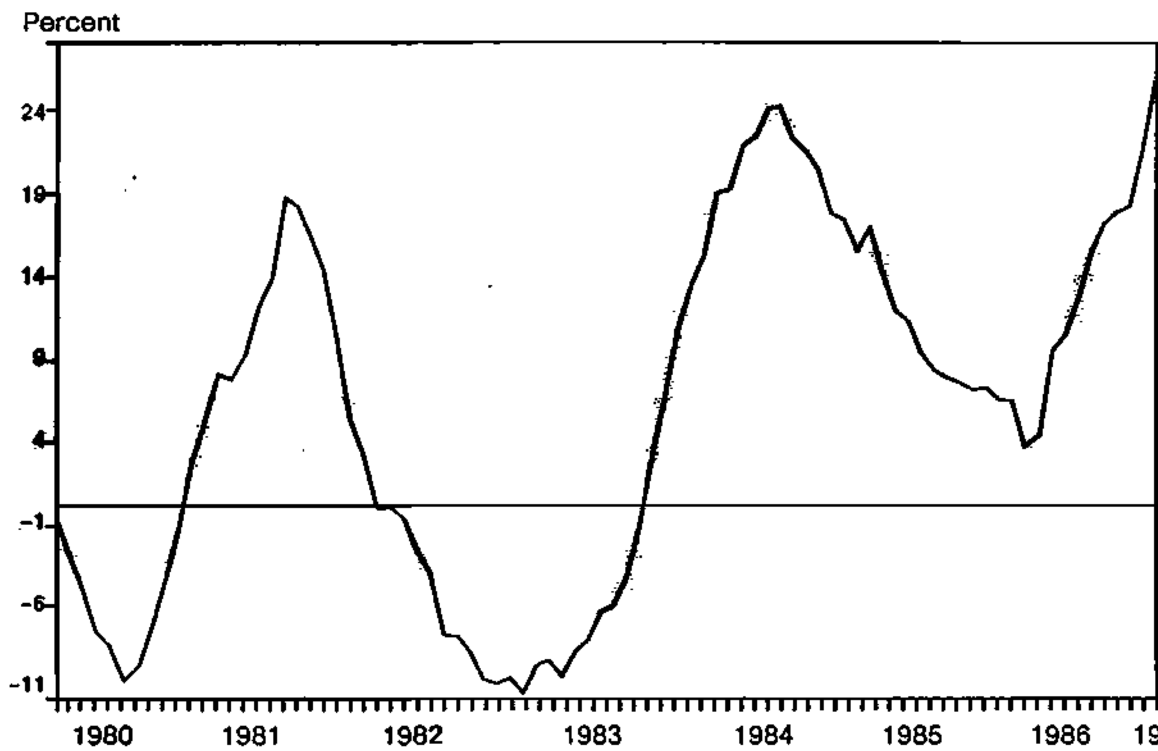
Dataquest expects the consumer application market to grow at a 5.6 percent CAGR from 1987 to 1991. The video segment is expected to grow the fastest, with a CAGR of 6.4 percent from 1987 to 1991. The fastest-growing equipment types in this application market include the following:

- VCRs
- Video cameras
- Stereo headphones
- Musical instruments

The most recent radio and television monthly shipment data (February 1987) from the DOC are displayed in Figure 6. It appears that shipments may be about to reach their peak. The recent tariffs imposed on certain Japanese TVs may push the growth up for a few more months, however.

Figure 6

RADIO AND TELEVISION SHIPMENTS
(12/12 Rate of Change)



Source: U.S. Department of Commerce
Dataquest
May 1987

Industry Events and Trends

Trade friction continues to be a major issue in the consumer electronics market. The trade problems between the United States and Japan may open the window of opportunity even wider for the Pacific Rim nations to take more market share from Japanese consumer electronics manufacturers. However, the Pacific Rim nations are more than wary of being the next target of trade friction with the U.S. government. Over the past years, many Japanese and Korean companies have moved their television assembly operations to the United States to try to avoid trade tension. This could turn into an opportunity for U.S. semiconductor vendors if other Japanese and Korean consumer electronics manufacturers follow suit by opening manufacturing sites in the United States, assuming that these factories do more than assemble "kits" of parts sent from the mother country.

On the upside, U.S. television manufacturers have not abandoned manufacturing television sets in the United States. For example, GE chose RCA over its previous OEM, Matsushita Electric, to manufacture GE's 19-inch color televisions at the RCA factory in Bloomington, Indiana. To win the contract, RCA employees at the Bloomington plant had to agree to work-rule changes. GE is planning to invest $20 million in the plant. According to Richard Miller, GE consumer electronics senior vice president, the investment along with the work-rule changes will make "the RCA facility the most cost-competitive television plant in the world." The first RCA-built GE television came off of the production line in early April of this year. It is only the first of 500,000 GE televisions expected to be built at the Bloomington facility in 1987.

Military

The 1987 defense budget was approved at $306 billion, down approximately 2 percent from the most recent executive and Department of Defense (DOD) requests. We expect this budget to result in continued streamlining across the various military programs.

In terms of military semiconductor consumption, Dataquest's most recent forecast shows military applications representing a decreasing share of North American IC consumption. As a percentage of total North American semiconductor consumption, military ICs will remain constant at 15 percent in 1987 (the same as in 1985 and 1986), falling to 12 percent in 1991. We believe that this falling market share is driven primarily by increased congressional pressure on military spending in general in an effort to reduce overall budget deficits.

Transportation

Forecast

Dataquest forecasts that transportation electronic equipment shipments will grow at a 12.8 percent CAGR from 1987 to 1991. The highest growth segment will be body controls and driver information, with CAGRs of 14.4 percent and 13.8 percent, respectively. Dataquest believes that the increasing pervasiveness of electronics in the automobile will drive the growth of automotive electronics despite the decline in automobile production.

Industry Events and Trends

The quarter ending March 31, 1987, was the first quarter since the Japanese auto manufacturers introduced their self-imposed quotas that they did not meet their import quota to the United States. The major reason cited was the effect of the strong yen on pricing of Japanese cars in the U.S. market.

This would be positive news for U.S. semiconductor vendors if U.S. automobile manufacturers were filling the void left by the Japanese manufacturers. It would mean an increase in U.S. auto production and higher semiconductor consumption by the U.S. auto industry. The converse is true, however. According to Automotive News, U.S. automobile production was down in the first quarter of 1987 compared to the first quarter of 1986. Table 3 displays North American automobile production by major manufacturer, indicating that first-quarter automobile production for Chrysler, GM, and AMC was well below first-quarter 1986 production. Ford was the only one of the major U.S. auto manufacturers to increase production in the first quarter of 1987, with an 11 percent increase over last year.

One reason that Japanese auto manufacturers may not be meeting their import quotas is that they are increasing U.S. production. Honda increased first-quarter U.S. production by 79 percent over last year, and Nissan increased its U.S. production by 82 percent during the same time period. Dataquest does not view the increased U.S. auto production by Japanese manufacturers as a major opportunity for U.S. semiconductor suppliers. We believe that, for the most part, Japanese manufacturers producing cars in the United States will continue to receive assemblies and subassemblies from their parent companies in Japan.

Table 3

NORTH AMERICAN AUTO PRODUCTION
(Units)

	January 1 to April 12, 1986	January 1 to April 11, 1987	% Change 1986-1987
American Motors Corp.	14,553	9,412	(35%)
Chrysler Motors	423,113	336,996	(20%)
Ford Motor Co.	521,693	577,926	11%
General Motors	1,329,072	1,101,661	(17%)
Honda	52,290	93,818	79%
Nissan	21,517	39,229	82%
Nummi	52,568	54,774	4%
Volkswagon	24,741	22,793	(8%)
Total U.S. Car	2,439,547	2,236,609	(8%)
Total Canadian Car	325,366	236,426	(27%)
North American Car	2,764,913	2,473,035	(11%)
North American Truck	1,302,292	1,293,756	(1%)
North American Car and Truck	4,067,205	3,766,791	(7%)

Source: Automotive News
Dataquest
May 1987

SUMMARY

Dataquest views 1987 with cautious optimism, expecting it to lead into a true growth year in 1988. The data processing, communications, and industrial application market growth rates, as viewed by other Dataquest technology research groups, will increase in 1987 over 1986. We expect a similar increase once again in 1988. Department of Commerce monthly shipment data also lead us to believe that growth rates will increase through the 1987 and 1988 time frame, thereby fostering a healthier environment in which semiconductor manufacturers can operate.

David G. Norman

Dataquest

Product Offerings

Industry Services

Asian Semiconductor and Electronics

Business Computer Systems

CAD/CAM

Computer Storage
- Flexible Disk
- Optical
- Rigid Disk
- Subsystems
- Tape Drives

Copying and Duplicating

Display Terminal

Electronic Printer

Electronic Publishing

Electronic Typewriter

Electronic Whiteboard

European Semiconductor

European Telecommunications

Gallium Arsenide

Graphics

Imaging Supplies

Japanese Semiconductor

Manufacturing Automation

Office Systems

Personal Computer

Personal Computer—Worldwide Shipments and Forecasts

Robotics

Semiconductor

Semiconductor Application Markets

Semiconductor Equipment and Materials

Semiconductor User Information

Software
- Artificial Intelligence
- Personal Computer
- UNIX

Technical Computer Systems

Technical Computer Systems—Minisupercomputers

Telecommunications

Western European Printer

Executive and Financial Programs

Corporate Technology Program

Financial Services Program

Strategic Executive Service

Newsletters

European PC Monitor

First Copy

Home Row

I.C. ASIA

I.C. USA

Focus Reports

The European PC Market 1985–1992

European PC Retail Pricing

PC Distribution in Europe

PC Software Markets in Europe

PC Local Area Networking Markets in Europe

The Education Market for PCs in Europe

Japanese Corporations in the European PC Markets

Home Markets for PCs in Europe

The IBM 3270 Market: 1986 and Beyond

Korean Semiconductor Industry Analysis

Diskettes—The Market and Its Requirements

Imaging Supplies Distribution Survey

Directory Products

I.C. Start-Ups—1987

SpecCheck—Competitive Copier Guide

SpecCheck—Competitive Electronic Typewriter Guide

SpecCheck—Competitive Electronic Whiteboard Guide

The DQ Monday Report

Future Products

- Industry Services
  - CIO Advisor
  - Semiconductor Application Markets—Military
  - Vertical Market Analysis
- Focus Reports
  - The IBM 3270 Market: 1987 and Beyond
- Directory Products
  - PurchaseTracker—Personal Computers
  - Purchase Tracker—Personal Computer Software
  - PurchaseTracker—Personal Computers Printers/Plotters
  - SpecCheck—Competitive Facsimile Guide
  - CAD/CAM Industry Directory—Second Edition

For further information about these products, please contact your Dataquest sales representative or the Direct Marketing Group at (408) 971-9661.

Dataquest

Conference Schedule

1987

Semiconductor Users/Semiconductor Application Markets	February 4-6	Saddlebrook Resort Tampa, Florida
Copying and Duplicating	February 23-25	San Diego Hilton Resort San Diego, California
Imaging Supplies	February 25-26	San Diego Hilton Resort San Diego, California
Electronic Printer	March 23-25	Silverado Country Club Napa, California
Imaging Supplies	March 25-26	Silverado Country Club Napa, California
Computer Storage	April 6-8	Red Lion Inn San Jose, California
Japanese Semiconductor	April 13-14	The Miyako Kyoto, Japan
Color Conference	April 24	Red Lion Inn San Jose, California
European Telecommunications	April 27-29	The Beach Plaza Hotel Monte Carlo, Monaco
CAD/CAM	May 14-15	Hyatt Regency Monterey Monterey, California
Graphics/Display Terminals	May 20-22	San Diego Hilton Resort San Diego, California
European Semiconductor	June 4-5	Palace Hotel Madrid, Spain
European Copying and Duplicating	June 25-26	The Ritz Hotel Lisbon, Portugal
Telecommunications	June 29-July 1	Silverado Country Club Napa, California
Financial Services	August 17-18	Silverado Country Club Napa, California
Western European Printer	September 9-11	Palace Hotel Madrid, Spain
Manufacturing Automation	September 14-15	San Diego Hilton Resort San Diego, California
Business/Office Systems and Software	September 21-22	Westford Regency Hotel Littleton, Massachusetts
Asian Peripherals and Office Equipment	October 5-8	Tokyo American Club Tokyo, Japan
Technical Computers	October 5-7	Hyatt Regency Monterey Monterey, California
Semiconductor	October 19-21	The Pointe Resort Phoenix, Arizona
Office Equipment Dealers	November 5-6	Hyatt Regency Monterey Monterey, California
Military IC	November 12	Hotel Meridien Newport Beach, California
Electronic Publishing	November 16-17	Stouffer Hotel Bedford, Massachusetts
Asian Information Systems	November 30-December 4	Tokyo, Japan
CAD/CAM Electronic Design Automation	December 10-11	Santa Clara Marriott Santa Clara, California

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Research Newsletter

SAM Code: 1987-1988 Newsletters: April-June
1987-13

DATAQUEST LOOKS INSIDE IBM'S NEW PCs

SUMMARY

On April 2, IBM announced its new line of personal computers called the Personal System/2. Dataquest was present at IBM's announcement in New York and has examined several of the new models.

While the true significance of IBM's new products will continue to unfold and evolve over the next few months, here are some of Dataquest's early observations:

- IBM has implemented a new architecture.
- IBM is using advanced technology--most of it--IBM's own.
- IBM has entered the PC systems solution business.
- IBM has reestablished itself as the leader in the PC arena.

Most of the models and features of the Personal System/2 have already been reviewed in a Dataquest newsletter entitled "IBM Raises the Bar--Dataquest Assesses the Impact." Figure 1 in this newsletter provides a quick look at the base system and configuration for each model type.

The most notable features include:

- IBM's built-in graphics, which is reportedly CGA/EGA-compatible (although a new graphics connector prevents use of standard monitors currently available)
- The use of 3.5-inch 1.44MB "floppy" drives (except the Model 30, which has 720KB capacity)

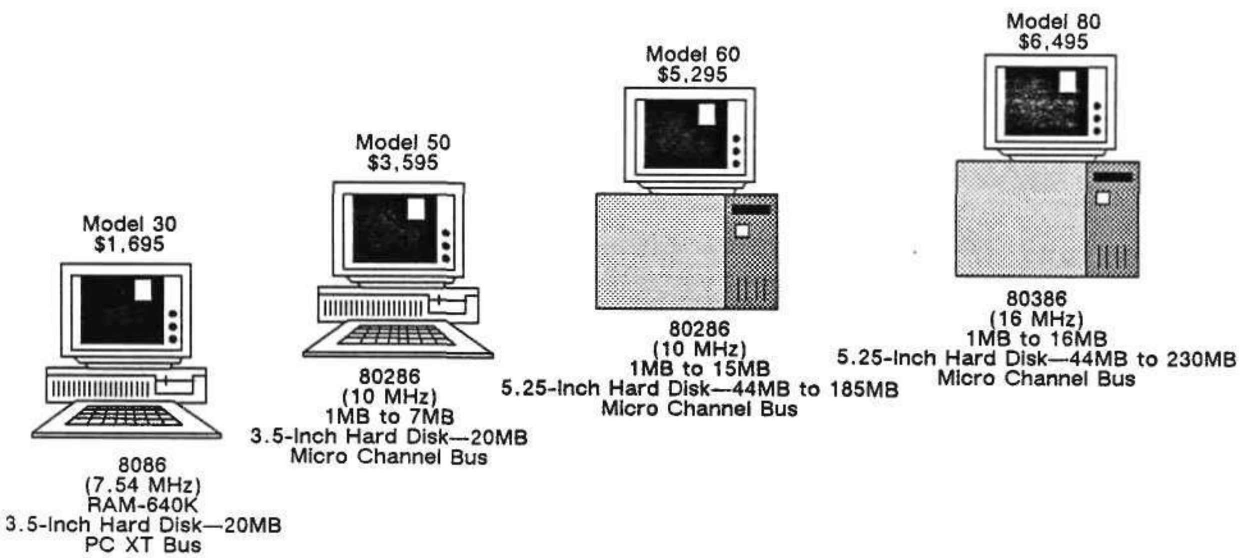
- IBM's own rigid disk drive interface controller (using a new 40-pin connector)

- A bidirectional parallel port to allow easy downloading from other PCs

Another interesting feature is the modular design approach taken by IBM. Virtually all internal screws and cables have been eliminated and replaced with plastic clips allowing complete system assembly in less than one minute. This is in keeping with IBM's overall strategy to design for automation.

Figure 1

**IBM PERSONAL SYSTEM/2
BASE PRODUCTS**



Source: Dataquest
April 1987

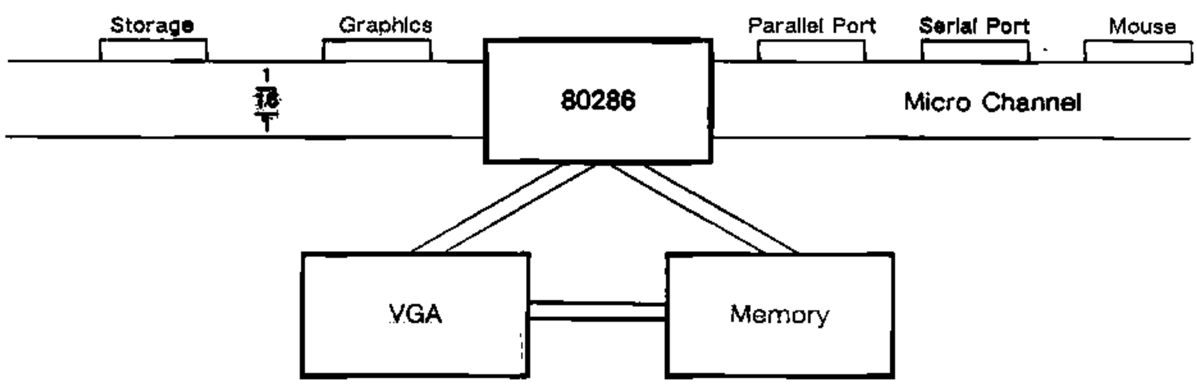
IBM'S NEW ARCHITECTURE

The most significant element of IBM's new product line to semiconductor, PC-clone, add-on board, and peripheral manufacturers alike is the proprietary architecture IBM has developed. Excepting the new low-end XT-compatible PC, the Personal System/2 is a completely new system that includes nearly 80 percent IBM developed technologies. Dataquest has heard, however, that IBM is releasing all specifications for its new bus, which, if true, will enable clone makers to quickly emulate the new IBM line.

At the heart of Personal System/2 is IBM's Micro Channel 16/32-bit bus architecture used in its 80286- and 80386-based products. Directly tied to Micro Channel are peripherals as well as built-in graphics support, and interface to both a serial and parallel port, as well as to the keyboard, graphics display, pointing device and storage subsystems (both the 3.5-inch floppies and rigid disk drives). Figure 2 illustrates the Micro Channel configuration.

Figure 2

IBM PERSONAL SYSTEM/2
MICRO CHANNEL CONFIGURATION



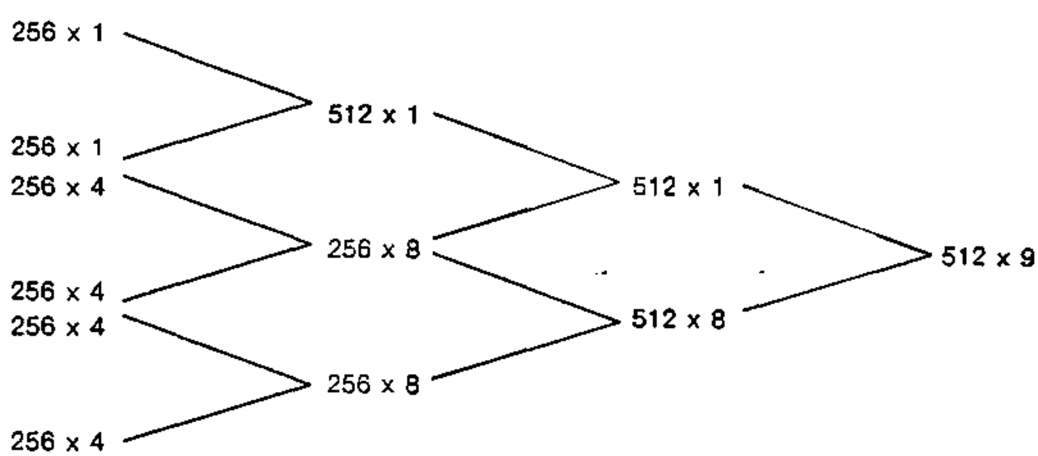
Source: Dataquest
April 1987

IBM USES ADVANCED ICs AND PACKAGING

IBM uses its own proprietary silicon and packaging as well. The Personal System/2 system board uses 16 IBM chips including 4 VLSI application-specific integrated circuits (ASICs) and, perhaps more surprisingly, its own leading-edge memory chips: 1 megabit, 80-nanosecond dynamic random access memories (DRAMs). The 80286-based desktop PC, called the Model 50, comes standard with 1MB of memory provided in two SIMs (single in-line modules), each arranged with 512 x 9 configurations, which plug into sockets on the mother-board. Dataquest believes that each memory SIM is configured as shown in Figure 3, resulting in some redundancy in two of the 1Mb chips.

Figure 3

IBM PERSONAL SYSTEM/2
ESTIMATED MEMORY MODULE CONFIGURATION



*Each module contains 6 chips configured 512 x 9.

Source: Dataquest
April 1987

By implementing much of the system logic in ASICs and using large memory chips in addition to the almost total use of surface-mount technology, IBM was able to significantly reduce board space resulting in a much smaller motherboard with on-board memory and graphics control. Table 1 provides a breakdown of the integrated circuits used in the Model 50's motherboard. To get a better idea of IBM's improved system integration, Figure 4 compares the IC count of IBM's PC AT (system logic and graphics control) with the new desktop Model 50. Except for eight NEC 64K DRAMs and NEC's industry-standard ST-412 floppy controller chip, all ICs are from U.S. manufacturers.

Table 1

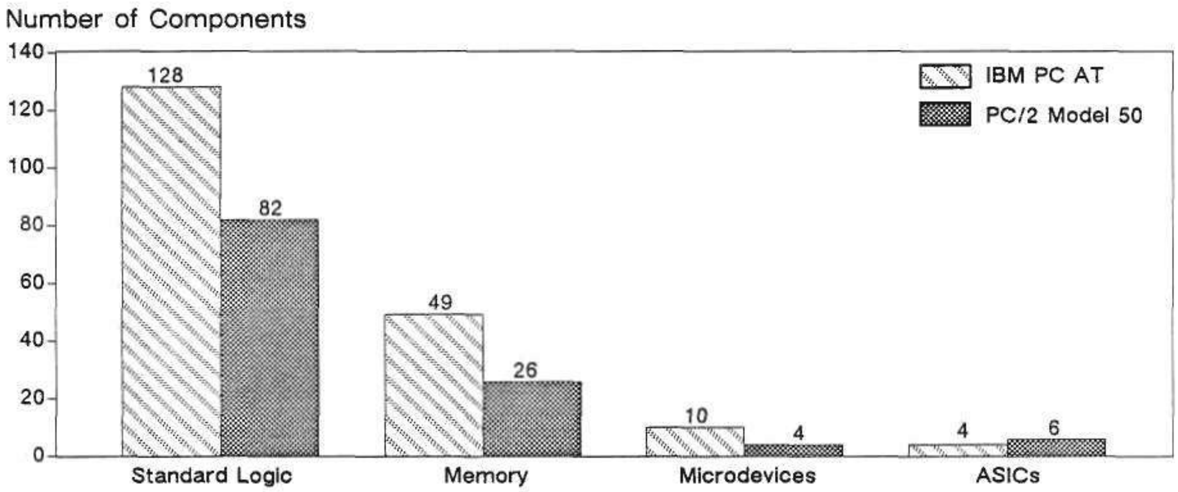
IBM PERSONAL SYSTEM/2 MODEL 50
ESTIMATED IC CONTENT

Description	Quantity	Major Suppliers
SSI/MSI Standard Logic	82	TI, National, Fairchild, Motorola
Memory Devices		
1Mb DRAMs (80ns)	12	IBM
256K EPROM (4-ROM BIOS)	5	Intel, AMD
64K DRAMs (120ns)	8	NEC
SRAM (35ns)	1	INMOS
	26	
ASICs		
Proprietary Custom VLSI	4	IBM
PAL	2	MMI
	6	
Microdevices		
80286 (10 MHz)	1	Intel
8259-A (Interrupt Control)	2	AMD
D765AC (Floppy Control)	1	NEC
	4	
Total IC Count	118	

Source: Dataquest
April 1987

Figure 4

IC CONTENT COMPARISON
IBM PC AT VERSUS IBM PERSONAL SYSTEM/2 MODEL 50



Source: Dataquest
April 1987

IBM used some of the most advanced design and manufacturing techniques available today in its new PCs. With few exceptions, the motherboard is packed with surface-mount components. While the use of surface-mount technology is relatively new to personal computers, IBM passed on using the most popular packages--leaded chip carriers (LCCs)--and opted instead for the gull-winged plastic quad flat packs. Dataquest believes that this move may have tremendous influence on the future of plastic leaded chip carriers (PLCCs). Exceptions to the surface-mount packaging include the Intel 80286 microprocessor (which is packaged in a 68-pin ceramic pin grid array (CPGA) and resides in a socket), five EEPROMs (including the four ROM BIOS chips), one Inmos and one NEC chip, and three of the four IBM ASICs--all of which are soldered to the motherboard. IBM's through-hole pin grid array packaging with flip chip bonded die is unique as well and is taken, in fact, directly from IBM's mainframe computers. Finally, there is also an open socket for addition of an Intel 80287 math coprocessor. Figure 5 is a photograph of the IBM Personal System/2 Model 50 cavity and motherboard. Figure 6 shows one of the two memory modules within the Model 50.

The Model 50 offers three 16-bit expansion slots. The Personal System/2 (excepting the XT model) uses new add-on board contactor spacing (50-mil centers) and thus requires newly developed boards. Unfortunately, no expansion boards are available yet including IBM's very-high-resolution graphics board, the 1024 x 768 advanced function analog (AFA). The AFA board, which will disable IBM's standard video graphics array (VGA) graphics (700 x 400), fits into the longer of the three expansion slots. The fourth slot seen on the motherboard houses casing to which the disk drives are attached. The controller card fits through a mounting bracket on this casing as well, and plugs into the slot seen standing alone in Figure 5.

While no system or IC cost analysis was done at this time, Dataquest believes that the PC/2, with its high level of chip integration and modular design methodology, is significantly less expensive to manufacture than IBM's old line of PCs. Thus, there appears to be plenty of margin for future price reductions.

Dataquest believes that as the PC/2 is validated in the marketplace, IBM may integrate some of the remaining standard system logic into ASICs, which will further reduce board space and system cost. IBM's recent announcement of a 4Mb DRAM with 65-nanosecond access time also conjures up ideas of things to come--particularly with the 80386-based systems. It is interesting to speculate as well on IBM's next generation of laptop computers, given IBM's new system approach and how it may affect future laptop designs.

Figure 5

IBM PERSONAL SYSTEM/2 MODEL 50
MAIN CPU BOARD AND POWER SUPPLY

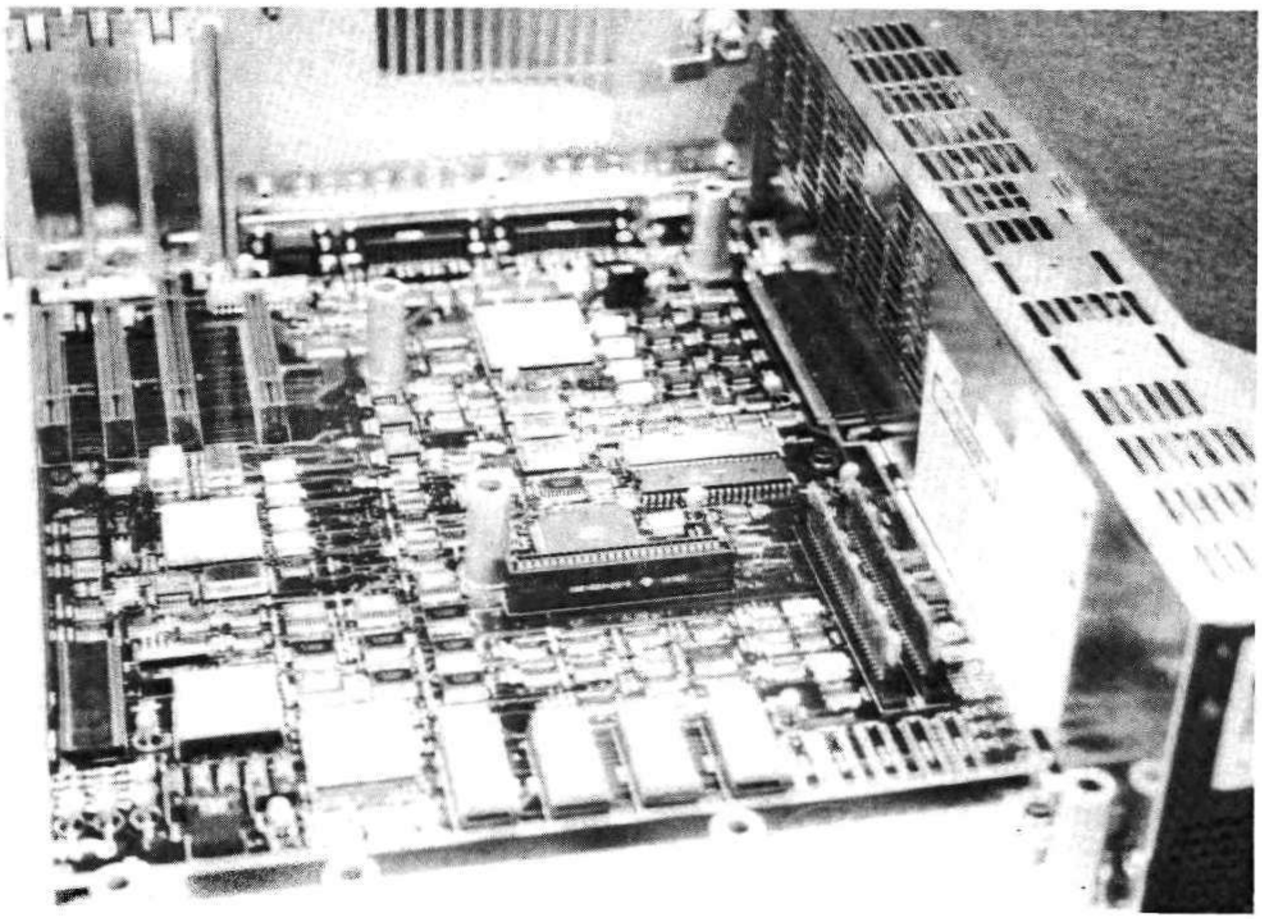
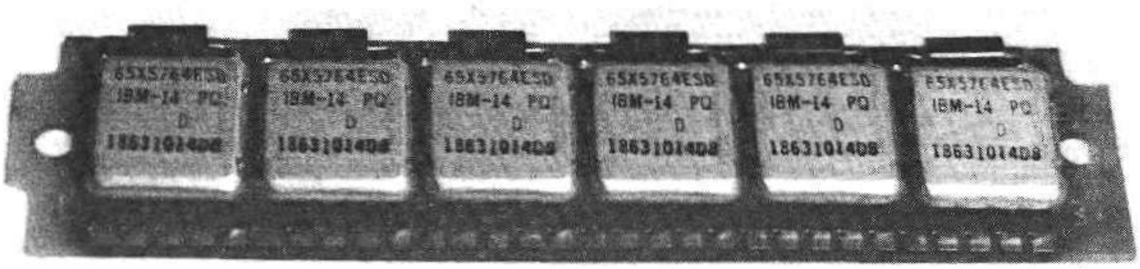


Figure 6

IBM PERSONAL SYSTEM/2 MODEL 50
SINGLE IN-LINE MEMORY MODULE



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DATAQUEST ANALYSIS

We believe that with this announcement, IBM has revolutionized the way personal computers will be built. With the concurrent introduction of two new operating systems from Microsoft (DOS 3.3 (available now) and Operating System/2 (available in early 1988), which reportedly will use the capabilities of the 80286 and 80386 processors), a number of IBM software solution packs, three new printers (including a laser printer for which IBM included a PostScript-driver coprocessor on the system motherboard), and a complete PC desktop publishing system, IBM has taken a new approach in PC marketing as well. With the Personal System/2 product introduction, IBM has acknowledged that the key to mass market penetration is through a systems solution sell. One can only hope that Operating System/2 is released on time and that it provides the true multitasking, memory addressability, and user-friendliness that will place PCs on top of the consumer's productivity tool shopping list.

Nanci J. Magoun

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LIGHTWAVE COMMUNICATIONS: REACHING ITS ZENITH OR RETRENCHING?

INTRODUCTION

Lightwave communications, as reported in our March 15, 1985 newsletter, is already searching for its next growth opportunity. At that time, we reported the bright future that existed for fiber optics, especially in the long haul, interexchange carrier business. Now, we believe that the long distance fiber market may have reached its zenith. As consolidation of the long distance carriers and business cooperation for facility utilization continue, the proliferation of network facilities is diminishing. The net effect is that the construction plans of many carriers are being revised and reduced.

This newsletter provides an updated overview of the fiber-optics market for telecommunications applications. The fiber-optics market described here includes the four primary telecommunication applications: long distance networks, exchange carrier networks, local loop applications, and other telecommunication applications.

A REVIEW OF THE FUNDAMENTALS

Fiber-optic systems transmit information by means of light over very tiny hair-like rods or strands of glass. The light is directed from a transmitter to a receiver by these glass fibers. This optical fiber only provides the transmission medium, and does not process or switch the signals. Switching and multiplexing are performed electronically, so therefore, an optical-to-electrical or electrical-to-optical signal conversion must take place at every repeater or terminal location.

The very low attenuation characteristics of optical fibers permit repeaters to be located very far apart, thus reducing the cost of system implementation and maintenance. The distance between repeaters varies with the attenuation of the fiber cable and system design parameters. Typical long distance carriers are placing repeaters at intervals of 7 to 25 miles or more.

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System Elements

The basic elements of a fiber optic system are:

- Fiber cable

- Fiber-optic terminals

The fiber-optic cable is made up of strands of fibers variously packaged into cable suitable for burying directly in the ground, inserting through duct work, or laying in the ocean. For long distance transmission, single-mode fiber is the medium of choice, with attenuations typically in the 0.4 to 0.7 dB/km. The actual number of fibers contained in each cable sheath may vary from as few as 4 to as many as 188.

There are approximately six basic cable designs with combinations of loose tube, gel-filled loose tube, and tight buffer designs, combined with metallic or dielectric cabling materials. Loose tube designs offer a high level of isolation from external forces, allowing more stable transmission under continuous mechanical stress. Loose tube construction permits high fiber count cables through the use of multiple fibers within a tube. Tight buffer designs provide a compact, lightweight cable, and are most often used indoors.

Fiber-optic terminals normally include the electrical-to-optical conversion equipment and driver circuitry. This equipment is frequently called the Light Termination Equipment (LTE). The transmitter consists of light emitting diodes (LEDs) or laser diodes, and the primary receiver element contains PIN or avalanche PIN diodes (APD). This type of equipment is normally classified by speed of operation ranging from 1.544 Mbps at the low end to the field-proven 565 Mbps for long distance networks.

The fundamental electronic subsystem for fiber-optic telecommunications is the transmission terminal equipment. It consists of receiver/ transmitter subassemblies and may include multiplexers/demultiplexers (MULDEMs). Transmitters/receivers are also used as repeaters or regenerators and are placed along the length of the fiber. The repeater spacings are determined by the system design characteristics of the cable, transmitter and receiver specifications, and the transmission speed.

Technology Evolution

Fiber-optic technology has undergone a number of changes since it was first introduced. These include:

- First generation: The first test installation by Bell Laboratories in Atlanta used multimode fiber-optic cable. Transmitters and receivers were based on gallium arsenide technology and intended to operate at about 135 Mbps. The repeater spacings for this early system were about five to seven miles.

- Second generation: An example of a second-generation system is the type that was actually initially installed by AT&T in the northeast corridor. This system also used multimode fiber cable and operated at 1300nm. Repeater spacings in this system were nominally eight miles, and the system went into operation at 45 Mbps. The cable was constructed of 12-fiber ribbons, with a total of 144 fibers in the cable.

- Third generation: Systems being installed today in the long distance network use single-mode fibers and operate at 1300nm. The losses are very low, and repeaters are located up to 20 or 30 miles apart. Line rates are routinely 565 Mbps. Future electronics will permit the line rates to be increased to 1.2, 1.6, and 2.4 gigabits per second (Gbps).

- Fourth generation: Undersea cable systems operate at the 1500nm wavelengths, where fiber losses are even lower. In addition, newer, single longitudinal mode lasers are becoming available for use at this higher wavelength.

Advantages of Fiber Optics

As pointed out in our earlier newsletter, fiber-optic systems offer many advantages over other forms of transmission media. These advantages include:

- Environmental robustness: Fiber is independent of temperature and humidity variations. The critical operating parameters of fiber--the index of refraction and the velocity of light--are not affected by these conditions.

- Interference resistance: Fiber is nonconductive and immune to electromagnetic, electrostatic, and radio frequency interference.

- Large bandwidth: Fiber provides bandwidths as high as 2.4 Gbps.

- Small size: A fiber pair transmitting at 565 Mbps provides 8,064 voice circuits. Cables with 12 fibers are less than one inch in diameter and can provide up to 48,384 equivalent voice circuits.

- Transmission capabilities: Repeater spacings are typically 7 to 25 miles apart compared with metallic media, which have repeater spacings of 1 to 2 miles.

- Low cost: Fiber-optic cable is less expensive than the equivalent coaxial cable.

- Error Performance: Error rates as low as 10^{-9}or one error per billion bits over long-haul networks are possible.

The Fiber-Optics Market

The fiber-optics market includes the following major segments:

- Telecommunications industry
- Military
- Other applications

Telecommunications

The telecommunications industry accounted for approximately 88 percent of the total fiber-optics market in 1986, and is expected to total approximately 90 percent by 1991. We believe that military applications for command, control, and communications systems and other special-purpose applications will represent the smallest share of the market for the foreseeable future.

The telecommunications area is segmented into four primary applications:

- Interexchange carrier networks
- Exchange carrier networks (distribution systems)
- Subscriber local-loop applications
- Data communication applications

Interexchange Carrier Networks

The interexchange carrier networks include the large interstate trunking requirements. Primary systems being fielded at this time are typically 565-Mbps systems. Cables with fiber counts ranging from 12 to 24 are generally used; although on some heavy routes, fiber counts as high as 50 may be used. Table 1 lists the miles of fiber-optic cable in place or planned by the major interexchange carriers.

Table 1

STATUS OF THE MAJOR INTEREXCHANGE CARRIER NETWORKS

Interexchange Carrier	Announced Network Miles	Estimated Completion Miles
AT&T	10,200	5,200
MCI Communications	7,000	2,500
US Sprint	20,000	13,000
National Telecommunications Network	11,941	8,604
Consolidated Network	731	300
LDX Net	2,161	2,076
Litel	1,363	971
Microtel	1,307	1,038
Southernnet	1,616	1,460
Southland Net	332	272
Williams Telecom.	4,431	1,727
Other Regionals/Distribution Companies	9,126	2,480

Source: Dataquest
April 1987

Exchange Carrier Networks

Both the exchange carrier networks of telephone companies and those being developed by competitive carriers tend to be intracity in nature, but often cover a greater metropolitan area spread over several counties. This is becoming a competitive area, with a number of independent carriers offering services in competition to the local telephone companies.

Transmission speeds range from 45 to 565 Mbps, and cables with 6 to 12 fibers are typically used. An example of a regional or local distribution company is Institutional Communications Co. (ICC) which has established its network in the greater Washington, D.C., area. ICC's fiber-optic network provides service to large businesses, long distance carriers, and government agencies.

Subscriber Local-Loop Applications

Subscriber local-loop usage of fiber optics is dominated by the local telephone companies. Primary candidates for fiber-optic applications appear to be subscriber local loops which--because of the economics involved--are at least in the 20,000-foot range. Southern Bell has been using fiber as the medium of choice for loops greater than 20,000 feet.

Data Communication Applications

Fiber-optic applications in data communication include:

- Point-to-point systems on user premises to eliminate multiple coaxial cable connections

- LANs (local area networks) offered by several vendors (these have found only limited market acceptance to date)

The RBOCs

The Regional Bell operating companies' usage of fiber optics is shown in Table 2.

Table 2

USE OF FIBER OPTICS BY THE RBOCs

Regional Company	Estimated Fiber Installations (km)
Southwestern Bell	110,700
BellSouth	92,000
Ameritech	83,025
Pacific Telesis	27,675
U.S. West	36,900
NYNEX	46,125
Bell Atlantic	64,575
Total RBOC Usage	461,000

Source: Dataquest
April 1987

Major Fiber-Optic Industry Participants

Telecommunications fiber-optic industry participants include:

- Fiber manufacturing: AT&T, Corning, ITT/EOPD

- Cable manufacturing: AT&T, Ericsson, ITT/Valtec, Northern Telecom, Siecor

- Transmission terminals: AT&T, Ericsson, Fujitsu, GT&E, NEC, Northern Telecom, Rockwell International, Stromberg Carlson, Telco Systems

- Connectors: AMP, Amphenol, AT&T, Dorran, Hewlett-Packard, IT&T Cannon, Optical Fiber Technologies Inc., Thomas & Betts, Photonics

FIBER OPTIC FORECASTS

Dataquest's forecast for the fiber-optics market for telecommunications is $500 million in 1986 and growing at a compound annual growth rate of 9.8 percent to $800 million in 1991. This forecast includes fiber cable, lightwave terminating equipment, and repeaters. Multiplex equipment is not included here but is covered in other segments of Dataquest's Telecommunications Industry Service.

The cable market growth is impacted by the slowdown in implementing long distance networks. Other sectors of the telecommunications market have not shown immediate promise to take up the slack and use the manufacturing capacity. We expect ordering rates to improve as the pace increases for implementing fiber optics in local distribution plants. This is not expected to occur in 1987.

We expect the fiber-optic cable market to be generally flat in 1987 and 1988. The market growth expected in 1989 and 1990 will be a result of applications in the feeder and local loop arena.

Key Factors to Industry Growth

Dataquest believes that the long distance telecommunications services market is incapable of absorbing all of the transmission capacity of the systems currently being implemented in the national networks. The capacity is a factor of two key elements: the cables being laid contain a large number of fibers, and manufacturers continue to offer terminal equipment with increasing bandwidths. Of the large number of fibers being laid, only a few pairs are being equipped for use. The balance are so-called "dark" fibers that will be put into service at a later date when traffic or services warrant. Therefore, cable additions along the routes are not likely in the forseeable future. Already, the carriers have been given the hope of not only adding equipment with gigabit-rate electronics, but also the possibility of using the technique of wavelength division multiplexing (WDM), a method whereby several light sources can operate over the same fiber pair. The net effect is that considerable growth in bandwidth demand can be accommodated without the necessity of installing more fiber-optic cable.

It can readily be seen that the fiber-optic cable manufacturers must look to areas other than long distance telecommunications to sustain their markets. One of the key factors for continued growth of the fiber-optic industry will be the growth of innovative services that require much greater bandwidths. These services are just starting to come into the marketplace and are related to the use of graphics, images, and other services requiring large bandwidths. For example, a 45-Mbps video signal uses the equivalent bandwidth of 672 digitized voice circuits or 28 T1 lines. Image transmission can also involve various graphic workstations or the high-resolution graphics used in conjunction with CAD/CAM terminals. These services require high-bandwidth facilities to be brought directly to the users' premises. This factor may be one of the major market forces to hasten the implementation of fiber optics in the local loop.

Dataquest also believes that a further influence on the fiber-optic industry trend over the next five years will be the gradual deployment of the integrated services digital network (ISDN). ISDN will provide voice, data, and video transmission from any workstation that incorporates the universally defined ISDN standards. ISDN will require extending digital channels to subscriber premises. Most of these connections will be at bit rates of 144 Kbps and 1.5 Mbps, and will use twisted-pair wires. However, we believe that reaching clusters of subscribers, such as in large office buildings or industrial parks, will represent an attractive application for fiber optics. The advent of ISDN, therefore, should be regarded as a potential boon to the fiber-optic market.

In the longer term, looking five to ten years into the future, we believe that broadband ISDN will become a market factor. The CCITT Study Group XVIII, which is responsible for ISDN standards, is starting to study broadband optical interface standards and it is likely to recommend several ranges of bit rates called bands. These will include a band from 30 to 50 Mbps, one from 60 to 90 Mbps, and one from 120 to 150 Mbps. Within the 30- to 50-Mbps band, two specific rates are being considered: 44.7 Mbps (U.S. DS-3 standard) and 30.72 Mbps (European standard). We anticipate that the CCITT will give final recommendations on broadband ISDN by 1988/89, with limited implementation starting in 1992. Therefore, we believe that broadband ISDN will not impact fiber-optic market growth through 1991, and will have only a minor effect by 1992. However, from now until broadband ISDN is more fully defined, and implementations proceed beyond the field trial stage, it will serve fiber-optic industry participants well to follow and understand these important standards activities. These ISDN services and standards will undoubtedly impact all fiber-optic industry participants in the future.

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David Norman
Victor Krueger

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IMAGE PROCESSING--FINALLY AN OVERNIGHT SENSATION

EXECUTIVE OVERVIEW

Image processing is undergoing a rebirth--and in some rather unexpected directions. Born in the laboratory, nurtured by academics and scientists, and funded by governments and universities, image processing's future belies its past and is destined, rather unexpectedly, for the office and the factory floor. This report examines the current state of image processing and presents a likely scenario for its immediate future. Included in the report is a structure of the overall image processing industry, major factors that will influence the growth of each segment, a discussion of the functionality inherent in image processing systems, and a look at the migration of image processing applications to PC AT platforms.

The digital image processing and display industry began in the early 1960s. Much of the early impetus was provided by NASA-directed programs such as the Manned Orbiting Laboratory (MOL) and the Earth Resources Technology Satellite (ERTS). Image processing systems were used to compensate for the distortion and image sensor characteristics inherent in these early satellites. Later, as random access memory (RAM) replaced rotating drums as the prevalent frame buffer technology, image processing began to address commercial applications.

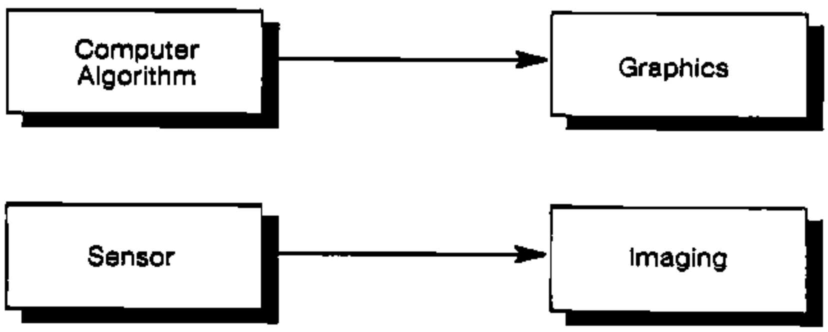
INDUSTRY STRUCTURE

Overview

Dataquest differentiates between graphics applications and imaging applications. Dataquest defines graphics as pictorial information that is computer generated under software control. This pictorial information generally takes the form of lines, symbols, text, and other algorithmically generated objects on a display screen. Dataquest further defines imaging to mean information captured by some form of sensor that measures parameters of real events. Images include photographic information, CAT-scan and ultrasound data, and digitized video, as shown in Figure 1.

Figure 1

GRAPHICS VERSUS IMAGING



Source: Dataquest
April 1987

Dataquest defines seven application areas that are imaging or image processing related:

- Medical imaging
- Industrial inspection/machine vision
- Remote sensing
- Geophysical and seismic imaging
- Graphic design arts
- Electronic publishing
- Other imaging

Medical Imaging

One of the earliest users of digital image processing technology was the medical industry. Led by such developments as computerized axial tomography (CAT) (1972) and nuclear magnetic resonance (NMR) (1974), scanners, technology, and the CRT promised to replace the old analog X-ray machine (1895) and the surgeon's scalpel as the primary diagnostic tools. Early participants included such companies as ADAC Laboratories, General Electric, and Hewlett-Packard. Pioneering display hardware companies included DeAnza, Lexidata, and Ramtek.

Today, medical imaging technology includes positron emission tomography (PET), digital subtraction angiography (DSA), sonography (SONO, also known as ultrasound), magnetic resonance imaging (MRI, formerly NMR), and single photon emission computed tomography (SPECT). Also emerging, although still in the research and development stage, are PACs, picture archiving, and communications systems. Led by university hospital researchers at Johns Hopkins and the University of Kansas, development continues on a system that will allow the different diagnostic modalities to be networked together. The goal is to eventually replace film as the primary storage and diagnostic media. Table 1 highlights the problems and the potential for PACs system designers.

Table 1

DIGITAL DATA GENERATED DAILY BY A RADIOLOGY DEPARTMENT
SERVING A 540-BED HOSPITAL POPULATION

Examinations	Patients	Display Images	Image Mbytes	Non-Image Kbytes	Total Mbytes
CT Body	16	26	67.30	80.70	67.38
CT Head	18	18	133.74	90.85	133.83
Nuclear Medicine (static)	24	4-8	3.34	121.13	3.46
Nuclear Medicine (dynamic)	8	15	0.61	40.38	0.65
Ultrasound	22	30-42	243.16	111.03	243.27
DSA	8	12-16	67.20	40.38	67.24
Digital Radiography*	20	2	41.98	100.94	42.08
MRI Head*	10	20	105.10	50.47	105.15
MRI Body*	10	50	262.66	50.47	262.71
Total*	136	177	925.09	686.35	925.77

*Estimated

Source: University of Kansas

To succeed, they must overcome formidable obstacles such as the data compression and data transmission problems inherent in large bit-mapped images. Slowing the whole process is the fact that to a large extent, hospital beds are going unused and budgets for medical imaging research in general are down. Present reimbursement policies have drawn many health-care procedures away from hospitals into outpatient clinical facilities. Many hospitals are seeing a 50 to 75 percent reduction in occupancy figures. Hard hit, and experiencing slow growth, these hospitals find it more difficult to plan or commit to the purchase of capital imaging equipment that does not produce revenue.

Industrial Inspection/Vision

The terms industrial inspection and machine vision refer to the use of display images that more accurately measure parts during the manufacturing process. Image processing techniques and algorithms, such as pattern matching and object recognition, are used to compare captured images and to perform tolerance measurements. Typical applications of industrial inspection and machine vision equipment involve a real-time image sample of an ongoing process or activity, such as a production line. Traditional vendors of industrial inspection hardware include Adage, Gould Imaging, International Imaging Systems, and Vicom. Newer entrants in this arena include Datacube and Matrox, which have PC-based product offerings.

Remote Sensing

The remote sensing industry has continued to mature since the early days of Sputnik and the pioneering space efforts at NASA. Through the use of satellite-born multispectral sensors that measured radiation in the different bands, earth-bound scientists found that they could detect macro changes on the earth from space much more readily than they could from the ground. Researchers quickly developed software and hardware techniques for improving the quality and quantity of data from these early primitive instruments. NASA greatly enhanced the availability of satellite imagery with programs such as the Earth Resources Technology Satellite (ERTS). Today, applications involving remote sensing include reconnaissance and surveillance for defense, weather imaging, earth resources management, and mapping. Companies involved in manufacturing image processing display hardware include Comtal, Gould Imaging, Imaging Technology Inc., International Imaging Systems, and Vicom. The Challenger disaster has had an adverse impact on commercial as well as noncommercial activities in remote sensing. Competition from the French Arianne unmanned launch system and from launch capabilities in other countries has moved much of the expertise in remote sensing away from the United States. Today, the French SPOT satellite has a camera resolution surpassed only by U.S. military spacecraft.

Geophysical and Seismic

Webster's dictionary defines geophysics as the physics of earth including the fields of meteorology, hydrology, oceanography, seismology, volcanology, magnetism, radioactivity, and geodesy or the measurement of the shape and size of the earth. Geophysical and seismic imaging has its principal use in the management of earth resources (including oil, mineral, and natural gas exploration) and earthquake monitoring. Geologists and seismologists gather subsurface data, principally through the use of sound waves induced by impact devices or explosives. These waves are deflected by varying material densities and are monitored by strings of sensors placed above ground. The resulting information is then modeled into a three-dimensional representation of a section of the earth's crust.

Falling oil prices have greatly reduced the exploration activities of the major oil companies, resulting in a contracting market for display hardware. On the other hand, attempts to increase the yield of existing wells have kept the processing side of the industry strong. Although shipments of new imaging displays will not be as robust as in the past, Dataquest estimates that shipments will exceed $60 million in 1987. Lower funding limits will cause many departments to choose PC-based solutions as alternatives to the more powerful and expensive systems.

Graphic Design Arts

Graphic design arts principally involve package design and poster art. Companies use digitizing cameras to transfer information from paper or other media to a digital electronic form for later incorporation in a product package design or poster. Image processing systems are used to enhance, colorize, size, and modify the scanned-in image. Graphic design arts traditionally combine image processing techniques with computer-generated graphics, producing attention-getting shapes, colors, light, shadows, and imaginative concepts. Typical images produced include package designs, camera-ready advertising art, textile and garment design, and fine art.

The development of more powerful, less expensive, and easier-to-use desktop publishing systems will have an adverse effect on the graphic arts service industry. Dataquest sees a lessening of the barriers to entry as more and more start-ups take advantage of lower-capital equipment expenditures and the lower skill levels required. The market for graphics and imaging displays in general, however, should experience accelerated growth as more companies absorb this as an in-house function. Dataquest estimates that the market for display hardware in the graphic design arts segment will top $20 million by the end of 1987.

Electronic Publishing

Closely related to graphic design arts is electronic publishing. Electronic publishing also uses digitizing image scanners to capture photographic images, text, or line drawings. Image processors can enhance, size, orient, and modify these images, as well as merge them with text files for inclusion in documents. Typical electronic publishing activities include pasteup, cropping, editing, page composition, airbrushing, screening, and related special effects.

The term desktop publishing has recently come into vogue, generating potentially as many start-ups as customers. Although these early products have little to do with imaging, traditional electronic publishing functionality will soon be incorporated. Dataquest predicts rapid growth in this application segment as the traditional word processing and electronic publishing activities merge.

Other Imaging Applications

There are numerous other specialty applications areas that offer few sales opportunities, but which make significant contributions collectively.

A recent write-up in the March issue of Byte, entitled "Digital Image Processing in Art Conservation," gives an interesting in-depth treatment of one such specialized application.

Other diverse areas in which image processing has found application are in archeological site discovery and mapping, ocean current and plantonic biomass monitoring, crime scene photography enhancement, disaster analysis of events such as Chernobyl and the space shuttle Challenger, and industrial siting and landscape architecture.

There are many agronomy and forestry applications including, but not limited to, fire control and damage assessment, crop harvest estimation, and irrigation monitoring.

One can also expect the news media to use remotely sensed imagery more frequently in the future.

ENVIRONMENTS

Scientific and Education

Image processing historically has been an academic discipline. With the advent of the civilian space program and the Freedom of Information Act of 1966, university researchers have been able to use the resources of the U.S. government for pure research projects. Satellite data have been used for such diverse activities as tracking the migration patterns of buffalo, identifying and classifying the signature of diseased crops, and tracing water pollution to its sources. University researchers have generally opted for low-cost image processing systems, partially as a result of budgetary constraints. Dataquest estimates that PC platforms will dominate this market in the latter 1980s, as shown in Table 2.

Table 2

IMAGE PROCESSING APPLICATIONS ON PC PLATFORMS

Application	CAGR Percent
Electronic Publishing	108.7%
Remote Sensing	66.1%
Medical Imaging	55.2%
Industrial Inspection	45.6%
Geophysical and Seismic	35.0%
Graphic Design Arts	32.9%

Source: Dataquest
April 1987

Government

The major user of image processing display systems within the U.S. government is the Department of Defense. Applications include:

- Simulation (aircraft, battlefield vehicles)
- Battlefield terrain analysis
- Target acquisition
- Weather imaging
- Cartography display

Government funding for image processing related applications comes primarily from the U.S. Department of Defense budget and is controlled in large part by the Defense Advanced Research Projects Agency (DARPA) and the Defense Mapping Agency (DMA). Other government agencies actively using image processing systems include the Central Intelligence Agency (photo interpretation, fingerprint analysis), the Department of Health, Education, and Welfare (medical imaging), and the Patent Office (document capture, storage, and retrieval).

Office

Office imaging promises to make image processing a growth industry in the last half of this decade. The barriers for growth in this arena have been reduced with the development of powerful 32-bit desktop computers (386-based machines), the advent of high-quality laser printers, and the market for electronic publishing.

Initial desktop publishing systems will be mostly graphics oriented with few shades of gray and little imaging processing capabilities. Requirements for photographic document capture, however, will drive the technological development of this application. Dataquest estimates that the market for imaging terminals and board-level products installed in electronic publishing systems with image processing capabilities will exceed $70 million by 1990.

Factory

Spurred by an increasing trade deficit and competitive pressure from offshore manufacturers, industry is beginning to examine the possibilities of the automated factory. In fact, revenue derived from manufacturing automation should exceed $35 billion by 1991. Although only a small part of the total, industrial inspection is an integral part of the automated factory concept. Dataquest estimates that the market for imaging display hardware for factory applications will reach $80 million by 1990.

USER REQUIREMENTS

Functionality

Image processing products have certain characteristics and functionality that differentiate them from computer graphics products. In general, these can be classified in three broad areas:

- Input
- Processing
- Output

Input

The major distinction between graphics and imaging is that imaging involves data that were detected or captured by an external device, such as a camera or sensor. Quite often the imaging that is done falls under the heading of postprocessing. Data are captured and stored on tape or disk for later processing by the image processor. Other systems process data in real time, taking input directly from a sensor. Because most sensors produce analog data, the latter type of image system must have analog-to-digital conversion, or digitizing capability.

One of the primary forms of input is the digitizing camera. These cameras fall into two groups: slow-scan and real-time, or frame grabbers. Frame grabbers are able to digitize a full-resolution (typically 640 x 512 pixels) image in one frame time or one-thirtieth of a second. Slow-scan cameras require several frame times to digitize the same image.

Processing

The volume of data associated with image processing imposes several conditions on the design of digital image processors. Single-image memory requirements of 1 to 4 megabytes are not unusual. Large disk drives or other high-capacity storage media are required. In addition, processing this much data requires a large, high-speed internal bus structure. While 16- and 32-bit wide data paths are generally thought to be sufficient for graphics applications, 32 bits is the minimum acceptable bus width for imaging. Other particulars of image processor design include datapath feedback loops for convolution algorithms, dedicated ALUs (arithmetic logic units), and array processors.

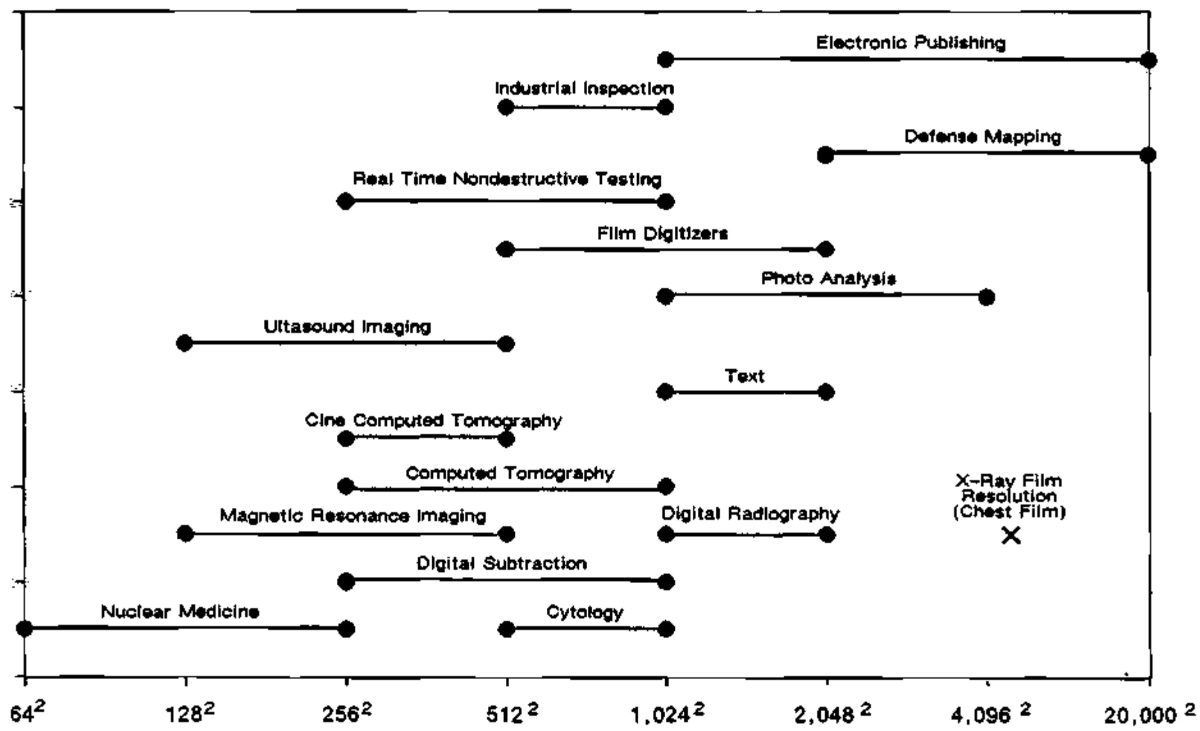
While much of the necessary processing can be accomplished in hardware, typical imaging systems have large associated software application packages that run on the host computers.

Output

Although most image processing applications can be accomplished with display resolutions of 640 x 512 or 512 x 512, the obvious trend in image processing is toward 1,280 x 1,024. Figure 2 illustrates the resolutions required by the various image processing applications.

Figure 2

MEMORY RESOLUTION REQUIREMENTS



Source: Virtual Imaging

__Color versus Monochrome__

While much has been written about the explosive growth in the use of color, many image processing disciplines prefer the added resolution and clarity of gray scale images. Radiologists, trained in the use of the X-ray image for diagnosis, have not readily accepted the expressed benefits of color as a diagnostic tool. New diagnostic modalities such as MRI and SPECT, however, have incorporated the use of color since their inceptions.

Industrial-inspection and machine-vision applications are more concerned with object recognition and pattern matching than with realism and aesthetics. The growth of color in electronic publishing is limited by the availability of adequate and cost-effective hardcopy solutions. Dataquest estimates that the CAGR for monochrome displays (47.4 percent) between 1986 and 1990 in imaging applications will exceed that of color (31.0 percent).

COMPARISON OF HIGH-END PRODUCTS

The high end of image processing is dominated by a handful of companies. Product offerings from these traditional image processing vendors typically have not been PC AT-based, but instead have incorporated processors or are based on minicomputers or mainframes. Table 3 compares some of these high-performance products.

COMPARISON OF PC-LEVEL PRODUCTS

Once consigned to video game status, the IBM PC AT has achieved acceptance as a platform for real image processing applications. Table 4 highlights some of the PC AT-based image processing systems on the market today.

Table 3

NON-PC-BASED IMAGING SYSTEMS

Company	Model	Resolution	Special Hardware	Software	Functions	Graphics	Price
Gould Imaging	IP9000	2K x 2K x 8 (times 16 per system, 1,024 x 1,024 viewable, 1 to 4 users)	Prog. resolution High-speed I/O (28 Mbytes/sec) Spatial xforms Real-time disk H/W histogrammer Image digitizer	LIPS 9000	Edge detection FFTs ROI proc. Convolutions Image merge Frame grab Warping	Conics Polygon fill Mesh Contour GKS compatibility	$74,000 to $120,000
Perceptics	9200	4K x 4K x 8/16 (512 x 512 or 1,024 x 1,024 viewable)	Image digitizer Xforms accelerator pipeline proc. Two ALUs Two multipliers	Resident firmware RIPS Subroutine library	Split screen FFTs ROI proc. Pan/zoom Edge detection Morph. xforms Dilation/Erosion Convolutions Frame grab	512 x 512 x 3-bit overlay 80 x 25 alpha-numerics Histograms	$30,000 to $150,000
Recognition Concepts Inc.	Trapix 5500	2K x 2K x 8 (1,024 x 1,024 viewable	Real-time disk Image digitizer H/W histogrammer Pipeline proc. Cursor/vector gen. High-speed I/O (25-Mbytes/sec) Video-rate networking	Subroutine library	Convolutions Warping ROI proc. FFTs Morph. xforms Dilation/erosion Pattern recognition Interpolated zoom Roam/scroll	Graphics and alphanumerics overlays	$25,000 to $75,000
Vicom	VICOM-VME	2K x 2K x 8 (1,280 x 1,024 viewable)	Sun-3 single bd embedded host Real-time convolver Image digitizer ALU H/W histogrammer Multiple LUTs Ethernet, DECnet, NFS Digital video disk	Subroutine library Cytology package Pattern recognition package	Pan/zoom Avg. ALU proc. Sun 3/160 functionality Networking Convolutions	CGI compatibility GKS compatibility Dual cursors Text w/prog. font Histograms Menu driven	$68,000

Notes:

ROI = Region of Interest	Avg. = Frame averaging	S/W = Software
Morph. = Morphological	Subr. = Frame subtraction	H/W = Hardware
Xforms = Transformations	Proc. = Processor	CGI = Computer graphics interface
ALU = Arithmetic logic unit	FFT = Fast Fourier Transforms	GKS = Graphical kernal system

Source: Dataquest
April 1987

Table 4

PC AT-BASED IMAGING SYSTEMS

Company	Model	Resolution	Special H/W	Software	Functions	Graphics	Price
Datacube	MaxVision	512 x 512 x 8 (times 3 per system)	ALU	Included: Source code Meta commands Filters	RS-170 input S/W based: Convolutions Erosion Dilation Pan/zoom	S/W based: Graphics Menus C routines	$ 9,500
Data Translation	DT2851	512 x 512 x 8 (times 2 per system)	Frame grabber Frame proc. Array proc.	Optional packages: IrisTutor DT-Iris PC-Semper	Hi/lo pass filters Laplacian filters Edge detect Avg., subr., div. Pan/zoom	Histograms Statistics Report generation	$ 9,685
Imaging Technology Inc.	Series 151	512 x 512 x 32 (times 4 per system)	ALU Real-time convolver Image digitizer	Optional packages: Toolbox 151 ITEX 151 Image Action 151	Real-time convolutions ROI proc. Pan/zoom		$12,275
Matrox	MVP-AT	512 x 512 x 32 or 1,024 x 1,024 x 8 (640 x 480 viewable)	EGA switch	Optional packages: Imager-AT Dr. Halo Image-pro	ROI proc. Real-time ALU proc. Pattern match Morph. xforms Avg., subr., div. Erosion Dilation Line thinning Pan/zoom	Histograms 4-bit overlay Lines, chars. Polygons Cursors	$ 8,995

Notes:
ROI = Region of Interest
Morph. = Morphological
Xforms = Transformations
ALU = Arithmetic logic unit
Avg. = Frame averaging
Subr. = Frame subtraction
Div. = Divide
Proc. = Processor
S/W = Software
H/W = Hardware
EGA = Enhanced graphics adapter

Source: Dataquest
April 1987

DATAQUEST ANALYSIS

An image processing system involves the integration of many different technologies. Cameras, analog-to-digital converters, large mass-storage devices, and other instruments often are required to operate together to process the image data. It is this operating mode that has resulted in the rack and stack nature of image processing systems and companies. The integration philosophy usually has extended to the application processor. Few image processing companies manufacture the host computer, choosing instead to integrate an off-the-shelf computer with their products. Typical solutions have involved Digital LSI-11 and MicroVax, VME board-based machines, and, at the low end, the IBM PC AT. However, the success of standalone graphics workstations has not gone unnoticed.

High-end image processing systems based on workstations, such as Sun Microsystems' Sun-3, are beginning to show up at major imaging trade shows. For example, the VICOM-VME image processor incorporates the Sun-3 single-board VME microcomputer as an embedded host. Ramtek Corporation is developing a UNIX-based standalone workstation, tentatively called the Pixel Processing Platform, for image processing. Dataquest expects more of the traditional imaging companies to follow suit as UNIX-based systems gain ground against the VAX/VMS machines that have thus far dominated the industry.

At the PC front, the new Intel 80386-based machines with their 32-bit wide bus appear to be ideal platforms for low-end image processing. Dataquest expects this device to make heavy inroads into the Macintosh's lead in desktop publishing as image processing functionality is mandated. We have yet to hear, however, from Apple, whose new UNIX-based offering could protect its lead. At the university level, where funding is tight, the 80386 machines should gain favor rapidly. Spurring their acceptance is the work now being done to port UNIX and X-Windows to the PC environment. Xenix, the UNIX look-alike from Santa Cruz Operations Inc., has already been demonstrated with X-Windows.

Plug-in boards for the PC are continuing to gain acceptance as an adequate component in image processing systems. One of the better price/performance offerings is the new MVP-AT from Matrox of Canada. While some of the traditional image processing companies have chosen not to enter this part of the market, others, like Comtal/3M, have introduced PC AT board-level products of their own. Bus-based PC devices, such as the single-board PC AT from Faraday, are also gaining acceptance as witnessed by a promising device from start-up Virtual Imaging.

While one can certainly argue that PC platforms are inadequate for the tremendous number crunching and high memory bandwidth required for many image processing applications, and that more powerful machines are needed, the gap is definitely closing. The ease of developing custom VLSI and the resulting shrinking of ever more powerful dedicated processors, combined with the increasing power and lower memory costs of the personal computer, have established a definite trend in the image processing industry. As was the case for the graphics industry, the PC will grow to meet the challenges of image processing.

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David Norman
Mike Tyler

July-September

The following is a list of the newsletters in this section:

(Continued)

July-September

Dataquest
DB a company of The Dun & Bradstreet Corporation

Research Bulletin

SAM Code: 1987-1988 Newsletters: July-September
1987-28

PERSONAL COMPUTERS TOP THE LIST OF LARGEST SEMICONDUCTOR APPLICATION MARKETS

Dataquest estimates that personal computers will consume the largest amount of semiconductors in North America this year, worth almost $1 billion. Following personal computers will be the automotive powertrain/ engine control, rigid disk drive, corporate resource computer, and large department computer markets.

HOW DOES DATAQUEST DEVELOP THE SEMICONDUCTOR TAM ESTIMATES?

We derive our semiconductor total available market (TAM) estimates from the Semiconductor Application Markets (SAM) data base of electronic equipment and semiconductor input/output (I/O) ratios. The semiconductor TAM numbers result from multiplying the estimated 1987 North American electronic equipment production by the I/O ratio for the specific equipment type. The I/O ratio is the dollar value of semiconductors used, divided by the total cost of the equipment. These ratios were developed from surveys of electronic equipment manufacturers and inputs from semiconductor vendors, and from physically analyzing the semiconductor content of selected equipment types.

Table 1 lists the top five semiconductor TAMs, and Table 2 lists the major manufacturers in each of the five markets.

Table 1

TOP FIVE NORTH AMERICAN SEMICONDUCTOR MARKETS IN 1987
(Millions of Dollars)

Rank	Market	Estimated Semiconductor TAM
1	Personal Computers	$990
2	Automotive Powertrain/Engine Control	$574
3	Rigid Disk Drives	$534
4	Corporate Resource Computers	$468
5	Large Department Computers	$438

Source: Dataquest
September 1987

Table 2

MAJOR NORTH AMERICAN MANUFACTURERS IN 1987

Market	Company
Personal Computers	IBM Apple Compaq Tandy Commodore
Automotive Powertrain and Engine Control	GM Ford Chrysler
Rigid Disk Drives	IBM Seagate Digital Equipment Data General Control Data
Corporate Resource Computers	IBM Unisys Amdahl Honeywell Cray
Large Department Computers	IBM Digital Equipment Data General Gould Unisys

Source: Dataquest
September 1987

WHAT DOES THIS MEAN TO SEMICONDUCTOR VENDORS?

Three of the top five semiconductor application markets are in the computer industry. This is good news for the computer manufacturers because their sales have turned around. However, Dataquest believes that semiconductor vendors should not focus on the computer industry exclusively because vendors that sold a large majority of their products to computer manufacturers in 1983 and 1984 were hit heavily by the industry downturn in 1985.

David G. Norman

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Research Newsletter

SAM Code: 1987-1988 Newsletters: July-September
1987-27

IC MEMORY CARDS--A REPLACEMENT FOR FLOPPY DISKS?

INTRODUCTION

One of the projected threats to the rotating magnetic storage market has been solid state memory. Until recently, the cost of IC memory chips has made commercial viability of high-capacity solid-state storage questionable. The current availability of 1MB RAM chips has caused the industry to look seriously at their use in mass storage applications once again.

Dataquest research indicates that the MS-DOS PC market may be the first to use removable IC memory modules as early as November 1987. Actual low-cost mass availability of these cards will be seen in 1989.

TECHNOLOGY

Three advancements in technology have provided a path to this new industry: high-capacity memory ICs, surface mounting, and tape-automated bonding of ICs. It is currently possible to mount 512 Kbytes of static RAM memory and a battery in a credit card-sized package. Toshiba and Panasonic demonstrated 256-Kbyte products at the Hannover Fair in March 1987. Mitsubishi has announced August 1987 shipments of 512-Kbyte memory cards.

The key to reliable and convenient use of this product is the package and its associated connector. DuPont has promoted its connector widely and is offering cards that package NEC memories. Figure 1 illustrates the DuPont memory card and its recessed connector.

Dataquest Incorporated, 1290 Ridder Park Drive, San Jose, CA 95131-2398, (408) 971-9000, Telex 171973

Figure 1

SRAM MEMORY CASSETTE CC-STYLE

S RAM MEMORY CASSETTE CC-STYLE

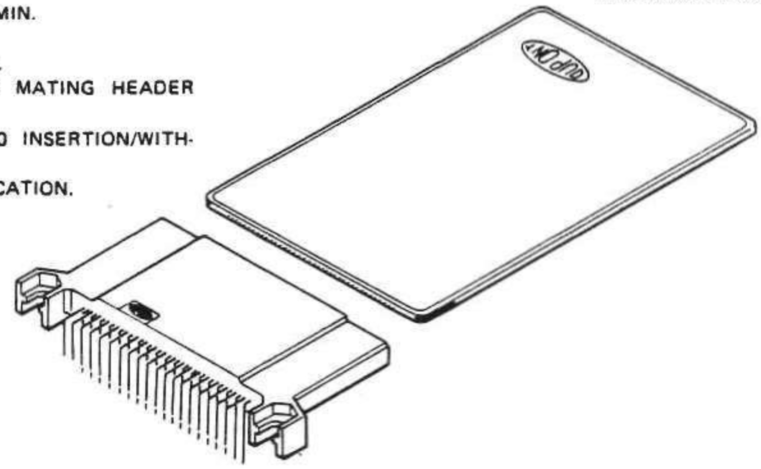
**THE MOST COMPACT HIGH MEMORY CASSETTE AVAILABLE ANYWHERE.
64K BYTE (0.5 MEGABIT) OR 128K BYTE (ONE MEGABIT)
S RAM CAPACITY IN CREDIT CARD PACKAGE SIZE.**

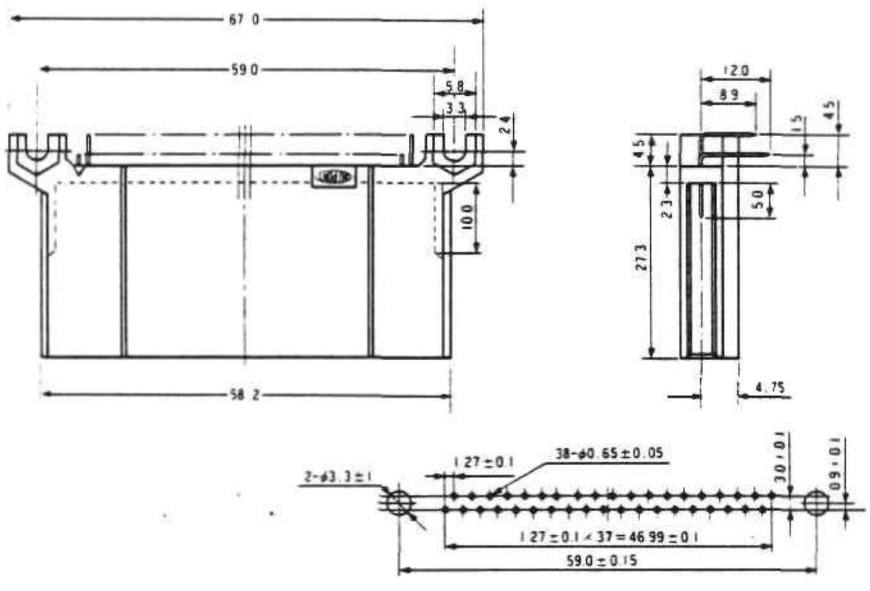
KEY PRODUCT FEATURES

- FULL CMOS S RAM 128K WORD X 8 BIT ORGANIZATION. (1 MEGABIT)
- LOW POWER DISSIPATION.
- BATTERY LIFE 2.5 YEARS MINIMUM.
- I.S.O. STANDARD CARD SIZE, 3.2MM THICKNESS.
- WRITE-PROTECTION SWITCH.
- E.M.I. & E.S.D. PROTECTION.
- READ/WRITE CYCLE TIME 350 N.S.MIN.
- WRITE PULSE WIDTH 200 N.S.MIN.
- 5V ± 0.25V SINGLE POWER SUPPLY.
- MICRO-TRI-BEAM CONNECTOR & MATING HEADER 1.27MM PITCH X 38 POSITIONS.
- DURABILITY MORE THAN 10,000 INSERTION/WITHDRAWAL CYCLES.
- POLARIZED FOR FAIL SAFE APPLICATION.

TYPICAL APPLICATIONS

FUNCTION	EQUIPMENT
•CONTROLLER	– L.A.N., FACSIMILE
•EXTERNAL STORAGE	– PERSONAL COMPUTER
•VIDEO/IMAGE MEMORY	– VIDEOTEX, CAD-CAM, TELEFAX
•PROGRAM SOFTWARE	– FLOPPY DISK BACK-UP, PROGRAM LIBRARY





RAM CASSETTE
PIN ASSIGNMENT

Pin No.	Signal
1	CA
2	GND
3	Vcc
4	BVC
5	CE
6	$\overline{WE}$
7	$\overline{OE}$
8	D0
:	:
15	D7
16	A0
:	:
32	A16
33	N.C.
34	N.C.
35	N.C.
36	Vcc
37	GND
38	CA

Note:
CA = Cassette acknowledge
BVC = Battery voltage check

Source: DuPont

APPLICATIONS

The proposed applications for such a product are:

- Software distribution
- Data interchange
- Temporary work storage
- Ruggedized factory data collection modules
- Disk backup

These applications sound as though they are well suited for floppy disks, but low-cost IC modules are smaller, faster, and more rugged.

Their use in software distribution is predicted on cost. Software vendors are very sensitive to the cost of media, and IC cards will be practical only when their capacity exceeds a megabyte and their cost approaches $10.

On first analysis, it would seem logical that memory cards would be memory mapped, addressed as additional memory for the host computer. This approach has been abandoned by all manufacturers, however, due to the complexity of variable-sized memory management. Instead, they are used as simulated disk drives and are formatted in much the same way floppy and rigid disks are prepared for use. This approach allows existing software to address files in a logical manner and provides for skipping of defective areas, just like on rotating mass storage, offering a "perfect" storage medium to the user. Memory chips that had been previously rejected as faulty can now be used at very low cost.

INTERFACING

Battery-backed static RAM memory is likely to be the most popular of the IC cards. Current specifications for battery life show a minimum usable period of 2.5 years. When the card is inserted in the home base, power is provided by the host computer. The battery is located so that it can be replaced while the card is inserted in the home base, and the memory is under external power. Battery failure is always a possibility, but a minimal risk. IC cards used for software distribution will likely use ROM memory and not require additional power.

Mishandling of IC cards will be a problem, but their rigidity exceeds that of the hard-shelled 3.5-inch floppy disks. Since the chips are mounted on flexible tape, it is unlikely that damage would result from even the roughest treatment. The connector is recessed and is the female side of the interconnect, so there are no pins to bend.

Also, it is unlikely that these cards would be susceptible to X-ray damage as floppy disks are, so the final judgment must be that they are truly a safer removable storage product than what we know today.

COSTS

Today, the cards with 256 Kbytes of memory cost $50. Another way of stating price is $200 per megabyte. High-capacity rigid drives are approaching $5 per megabyte. Retail price of a 360-Kbyte 5.25-inch floppy disk is less than $1. Leading Edge is selling the Iomega 20-Mbyte cartridge for less than $50.

It is estimated that 2-Mbyte IC cards can be produced for less than $10 per megabyte by 1989, and commercial popularity will reduce their cost to the $5 per megabyte range in 1992. These are felt to be conservative estimates. It is likely that these prices will propel IC memory cards into an industry standard within the next five years.

MARKETING PROJECTIONS

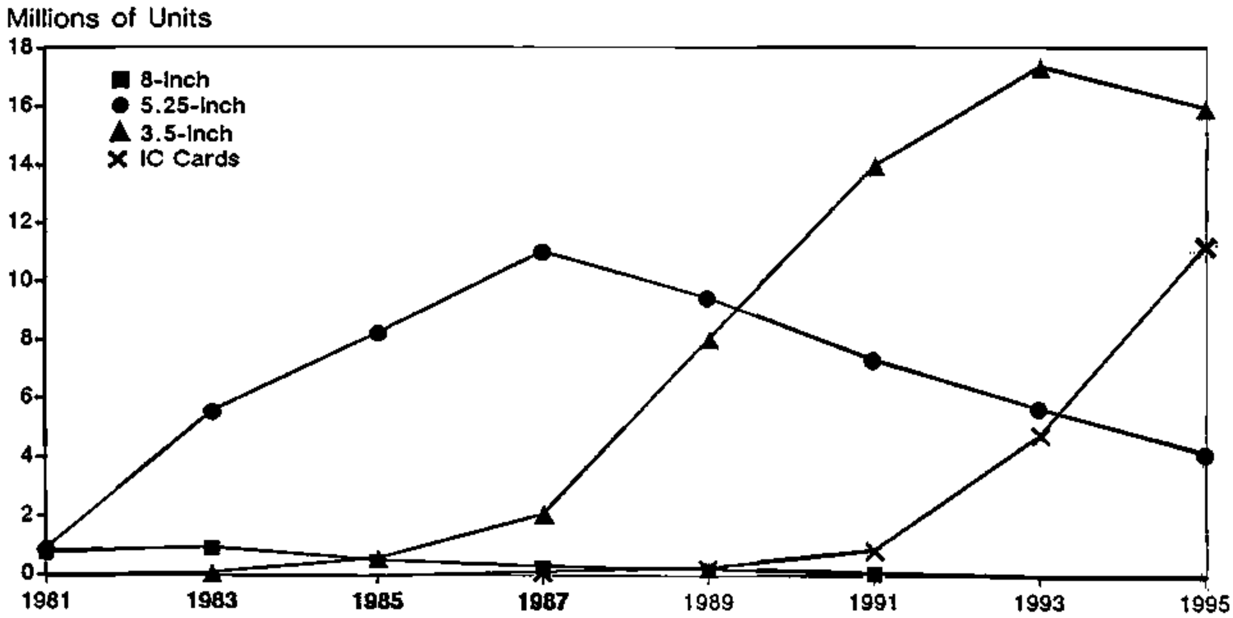
Historical evaluation of the floppy disk industry and its product life cycles makes it apparent that, in 1992, the 3.5-inch floppy drive will peak and begin a decline. This decline will result from the appearance of a replacement product such as the IC card. Figure 2 illustrates the life cycles of 8-, 5.25-, and 3.5-inch floppy drives and the emergence of a replacement product.

IC cards themselves will be the revenue-producing portion of this product, since the home base modules are likely to be manufactured by the computer vendors themselves. Floppy disk builders must prepare themselves for this eventuality, but they have five more prosperous growth years to plan for the future.

Since this report is based on the speculation of technological change, it is difficult to forecast shipments of IC memory cards. If 10 percent of the 21.5 million new PCs shipped in 1989, 20 percent of the 23.9 million in 1990, and 50 percent of the 26.4 million in 1991 incorporate home base modules, an installed base of 20 million users could be in place by 1992. If each system used 10 cards, this media market would exceed 200 million units over that period. At $10 per card, a new multibillion dollar market could emerge based only on the personal computer market. Their use in typewriters, games, calculators, and larger computers would increase the volumes substantially.

Figure 2

FLEXIBLE DISK DRIVE SALES--U.S. MARKET



Source: Dataquest
September 1987

DATAQUEST ANALYSIS

In order to look into the future of the computer storage industry, historical trends and new technology advances are the only guideposts along the way. The facts that led to the above conclusions are:

- Floppy disk product life cycles indicate a change is coming.
- IC memory cards are real today and are increasing in capacity on a regular, six-month cycle.
- Large sample orders have been placed for existing products by major computer vendors.
- IC technology predictability will drop chip prices to a practical range.

The answer to the question of what will replace floppy disks has to be a new technology, and Dataquest believes that IC memory cards will be that technology.

(This document is reprinted with the permission of Dataquest's Computer Storage Industry Service.)

David Norman
Phil Devin

Product Offerings

Industry Services

Asian Semiconductor and Electronics Technology

Business Computer Systems

CAD/CAM
- Electronic Design Automation Applications
- Facilities Design and Mapping Applications
- Mechanical Applications

CIO Adviser

Computer Storage
- Flexible Disk
- Optical
- Rigid Disk
- Subsystems
- Tape Drives

Copying and Duplicating

Display Terminal

Electronic Printer

Electronic Publishing

Electronic Typewriter

Electronic Whiteboard

European Semiconductor

European Telecommunications

Graphics and Imaging

Imaging Supplies

Japanese Semiconductor

Manufacturing Automation

Office Systems

Personal Computer

Personal Computer—Worldwide Shipments and Forecasts

Semiconductor
- Products, Markets, and Technology
- ASIC and Standard Logic
- Digital Signal Processing
- Gallium Arsenide
- Memory
- Microcomponents

Semiconductor Application Markets

Semiconductor Equipment and Materials

Semiconductor User Information

Software
- Artificial Intelligence
- Personal Computer
- UNIX

Technical Computer Systems

Technical Computer Systems—Minisupercomputers

Telecommunications

Western European Printer

Executive and Financial Programs

Corporate Technology Program

Financial Services Program

Strategic Executive Service

Newsletters

European Monitor

First Copy

Home Row

I.C. ASIA

I.C. USA

Focus Reports

PC Home Survey—1987

The European PC Market 1987-1993

PC Software Markets in Europe

PC Local Area Networking Markets in Europe

Japanese Corporations in the European PC Markets

The IBM 3270 Market: 1987 and Beyond

Imaging Supplies Distribution Survey

Competitive Guides

SpecCheck—Competitive Copier Guide

SpecCheck—Competitive Electronic Typewriter Guide

SpecCheck—Competitive Electronic Whiteboard Guide

SpecCheck—Competitive Facsimile Guide

Other Products

I.C. Start-Ups—1987

The DQ Monday Report

CAD/CAM Industry Directory—1987

For further information about these products, please contact your Dataquest sales representative or the Direct Marketing Group at (408) 971-9661.

Dataquest

Conference Schedule

1987

Western European Printer	September 9-11	Palace Hotel Madrid, Spain
Computer Products	September 21-22	The Westford Regency Inn Westford, Massachusetts
Asian Information Systems	October 5-9	Tokyo American Club Tokyo, Japan
Technical Computers	October 5-7	Hyatt Regency Monterey Monterey, California
Semiconductor	October 19-21	The Pointe at Squaw Peak Phoenix, Arizona
Office Equipment Dealers	November 5-6	Hyatt Regency Monterey Monterey, California
Electronic Typewriter	November 6	Hyatt Regency Monterey Monterey, California
Electronic Publishing	November 16-17	Stouffer Hotel Bedford, Massachusetts
Asian Semiconductor and Electronics Technology	December 7	Asiaworld Hotel Taipei, Taiwan, ROC

1988

Semiconductor Users/ Semiconductor Application Markets	February 22-24	Westin St. Francis Hotel San Francisco, California
Copying and Duplicating	March 7-9	The Pointe at Squaw Peak Phoenix, Arizona
Imaging Supplies	March 9-10	The Pointe at Squaw Peak Phoenix, Arizona
Telecommunications	March 16-18	Pier 66 Hotel and Marina Fort Lauderdale, Florida
Electronic Printer	April 5-7	Hyatt Regency Monterey Monterey, California
Imaging Supplies	April 7-8	Hyatt Regency Monterey Monterey, California
Japanese Semiconductor	April 11-12	Tokyo, Japan
Computer Storage	April 18-20	Silverado Country Club Napa, California
European Semiconductor	June 8-10	Gleneagles Hotel Auchterarder, Scotland
Display Terminals/Graphics and Imaging	June 13-15	Hyatt Regency Monterey Monterey, California

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Research Bulletin

SAM Code: 1987-1988 Newsletters: July-September
1987-26

SEPTEMBER PROCUREMENT SURVEY: MODEST GROWTH CONTINUES

A mixed bag of results was reported in this month's semiconductor procurement survey; however, users in general reported a slight increase in their expectations for September orders. September billings were also increasing, with users citing anywhere between 2 and 75 percent over August billings. It is interesting to note that distribution purchases are expected to slow a bit in September, while prices are expected to remain the same.

Of most significance was that lead time reduction was less frequently mentioned as a major issue and that average lead times decreased from 13 weeks in August to 11 weeks in this month's results. Also important to watch is a reported increase in inventory levels. Table 1 reflects the pattern in current actual versus target inventories since the survey began. While inventories popped in July and slowed in August, the actuals versus targets have increased once again. In all, for the last three months users have indicated that they are allowing increases in their semiconductor inventories. Target levels have also increased from an average of 29 to 31 days.

Table 1

CURRENT ACTUAL VERSUS TARGET SEMICONDUCTOR LEVELS

May	Down 1.0%
June	Down 1.1%
July	Up 24.7%
August	Up 7.9%
September	Up 16.0%

Source: Dataquest
September 1987

Dataquest, 1290 Ridder Park Drive, San Jose, CA 95131-2398, (408) 971-9000, Telex 171973

No single product area was cited as being difficult to obtain in required quantities. Just about all users were having difficulty obtaining something, but no trend emerged this month. Electronic equipment manufacturers mentioned continued increases in the health of their businesses, indicating that on a scale of 1 to 10, with 1 being lower, 5 being the same, and 10 being higher, their aggregate response climbed from 7.5 in August to 8.1 in September--another reinforcement that the upturn is continuing.

An interesting combination of issues emerged as the main concerns for this month, as follows:

- Lead time reduction and lead times on FMV parts
- Delivery of new technology and product quality to sustain that delivery
- Surface-mount discretes
- Product discontinuance
- DRAMs
- Government intervention
- Standard versus custom components

Anthea C. Stratigos

Dataquest
a company of The Dun & Bradstreet Corporation

Research Newsletter

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1987-25

CHIP MAKERS SHOW OFF GRAPHICS PROCESSOR APPLICATIONS AT SIGGRAPH

SUMMARY

AMD, Intel, National, and Texas Instruments--four of the major graphics processor makers--were on hand at Siggraph '87, the industry's premier graphics show, directing attendees to on-site OEMs that were displaying various products that used their respective parts.

The show, which ran from July 26 through July 31, included hundreds of exhibits as well as a full technical program that offered courses, papers, and panel discussions. For the chip makers, Siggraph culminated on the last day with a panel discussion among the four companies on the topic: "A Comparison of VLSI Graphics Solutions." Before an audience of more than 100 graphics system users, the participants concluded that:

- A number of approaches are now being taken to define ultimate graphics processors.
- To date, no one approach is necessarily better than another.
- A number of features remain to be incorporated in next-generation chips.
- The graphics community is eager to implement state-of-the-art ICs in their systems.

APPLICATIONS FOR GRAPHICS PROCESSORS

Graphics processors are showing up in hundreds of products, including high-resolution graphics add-on boards for PCs and terminals for workstations; laser printers; imaging systems for scientific, medical, military, and industrial use; fax machines; color copiers; and optical scanners.

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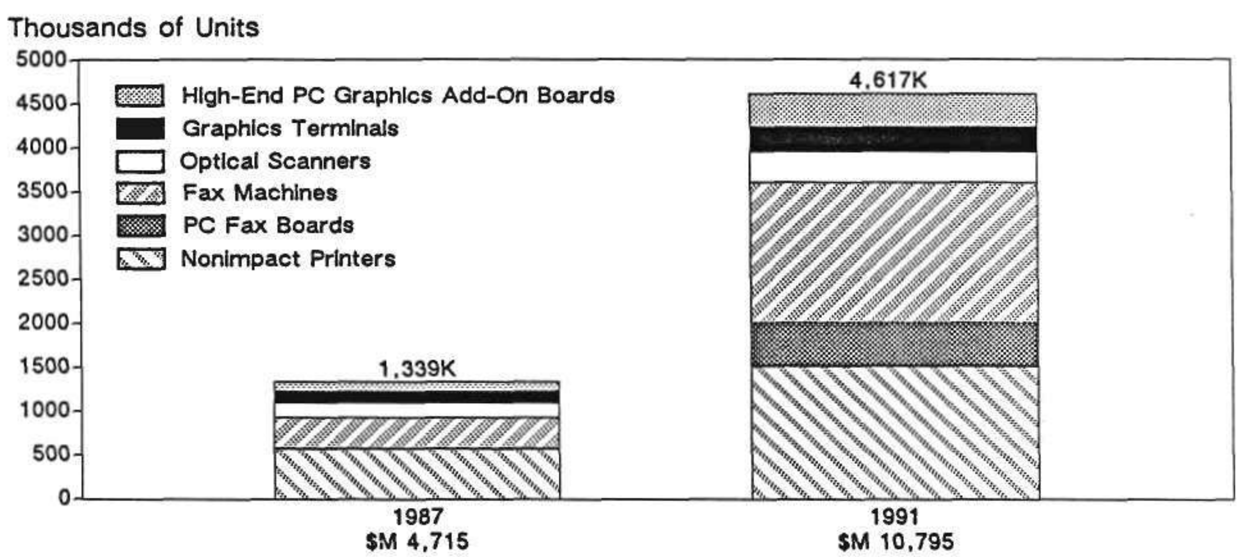
At Siggraph, examples of each of these uses were easily found. Systems incorporating TI's processor, the 34010, included the AST Turbo Vision PC WYSIWYG (What You Set Is What You Get) board and monitor, AT&T's Vista Imaging Board, the Motorola MVME397 VME Graphics Display Controller, a color thermal printer made by QMS, Inc., and nine others. To date, TI claims more than 200 design wins. Its shipments are running one year behind the Intel 80386 general-purpose microprocessor in volume.

Both AMD- and National-based systems number far fewer than the more mature Intel- and TI-based systems. A number of graphics systems continue to use general-purpose CPUs such as Intel's 80286 or Motorola's 68020 as well. In some cases, the processing is done in a nondedicated mode; in others, an additional part is used as a coprocessor.

About 12 users of Intel's 82786 processor displayed their products in a single booth. Most of the applications were video graphics boards in PCs. A more interesting product was a 35mm film digitizer, editor, and transmitter called the Portable Transfax. The compact carry-along system, made by Leaf Systems, Inc., of Massachusetts, allows users (such as field reporters) to digitize a 35mm film negative when it appears on a miniature color or black-and-white display that can then be electronically cropped, positioned, enlarged, or adjusted for color, brightness, and contrast. Prior to electronically mailing the final image by telephone (via built-in communications) to a final destination such as a newspaper production facility, a caption can be added. Figure 1 provides Dataquest forecasts for some of the high-volume target markets for graphics processors.

Figure 1

**HIGH-VOLUME SYSTEM TOTAL UNIT SHIPMENTS--
CANDIDATES FOR GRAPHICS PROCESSORS**



Source: Dataquest
September 1987

Although these figures do not necessarily correlate to current or future placements of graphics processors, it does imply that the bulk of the shipments will probably not be in what is currently the most obvious application, PC graphics boards. There is, however, the strong possibility that new higher-performance PCs may be shipped with dedicated graphics processors embedded on the motherboard. Should this happen, the chip volume for PCs could easily exceed all other applications combined. A host of other potential applications prepared by Intel is provided in Table 1.

Table 1

POTENTIAL APPLICATIONS FOR GRAPHICS PROCESSORS

Aerospace	Mainframe terminals
Airport displays	Medical monitors
Answering machines	Microwave ovens
Art	Military equipment
Automated materials handling	Mobile navigation (maps)
Automated tellers	Paint stores
Automated warehouses	Pay TV equipment
Automatic ID systems	Photography
Automobile dashboards	Point-of-sales
Auto repair diagnostics	Preschool education
Banking terminals	Process control
Blood analysis	Proximity systems
Cash registers	Quality control
Catalog terminals	Real estate listings
Computer-integrated manufacturing	Repair manuals
Control systems	Restaurant menus
Copiers	Security monitors
Dryers	Self-teaching instructions
Electronic publishing	Sentry alarms
Elevator displays	Sewing machines
Emergency exit signs	Sonar displays
Factory automation	Sprinkler systems
Factory floor equipment	Stereo systems
Financial listings	Stock exchanges
Financial terminals	Stock exchange quotes
Fire alarms	Telephone directories
Fire escape/alarms	Televisions
Graphics terminals	Testing
Grocery checkout	Touch screens
Industrial looms	Toxic system monitors
Industrial ovens	Toys
Information displays	Tract home floor plans
Inspection stations	Training
Intensive care units	Vending machines
Inventory control	Video editing
Library directories	Video games
Low-cost studio equipment	Voice/data telephones
Mainframe diagnostics	Washing machines

Source: Intel Corporation

INFORMATION AVAILABLE ON GRAPHICS PROCESSORS

Given the current popularity of and opportunities in the graphics marketplace, it is not surprising that a variety of articles on graphics processors have begun to appear. Dataquest has published several newsletters on related topics, including one entitled "Graphics-Specific ICs--Revolution in the Graphics Industry." Some other excellent articles on graphics processors include the following:

- "Diversity the Watchword for Graphics Processor ICs," Electronic Products, (July 15, 1987), pp. 24-30.

- "Graphics Developments Geared Toward Speed and Capacity," Computer Design, (December 1986), pp. 127-140

- "PC Graphics Hardware Dictates Standards at High End," Electronic Systems Design (ESD) Magazine, (February 1987) pp. 37-42

- "Squeeze Your Image on the PC," ESD, (February 1987), pp 66-67

- "Array Processor Spurs Faster Imaging," ESD, (February 1987), pp. 70-75

- "A Versatile Architecture for Imaging," ESD, (February 1987), pp. 81-84

- "Image Processing Migrates to the PC," The S. Klein Computer Graphics Review, (Summer 1987), pp. 51-68

Dataquest continues to be optimistic about opportunities in the graphics areas. As evidenced by Siggraph '87, there continues to be growing interest among users and suppliers of graphics ICs.

Nanci J. Magoun

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SALES ARE UP, BUT SO IS COMPETITION: THE PRIVATE PACKET NETWORK MARKET IN 1986

INTRODUCTION

The private packet market showed slow growth in 1986. Sales of packet nodes, switches, packet assembler and disassemblers (PADs), and complete private packet network systems reached $262.2 million, up 8.5 percent from the previous year's revenue. The reasons for this disappointing rate of increase include price erosion for existing hardware and a delayed introduction of new products, as well as competition for existing telecommunications budgets from other technologies.

In addition to presenting a scorecard of the market's performance, this newsletter will analyze a shift in the way that the leading vendors are positioning their new and existing products in response to the sluggish domestic economy. This market shift is reflected in the new way that Dataquest is presenting the 1986 revenue and market share data. In addition to analyzing the new structure of the industry, this newsletter will examine the products and strategic directions of two new private packet network vendors.

MARKET STRUCTURE

Through the first half of the 1980s, vendors produced products that fit easily and naturally into three categories:

- PADs, comprising standalone boxes, generally adhering to the X.3 Packet Assembler and Disassembler standard

- Switch/concentrators, comprising standalone boxes with either a packet switching, combined packet switching and PAD, or concentration function (The concentration function could also be combined with switching and/or packet assembly and disassembly.)

- Nodes, comprising standalone boxes with on-board network management as well as switching functionality (These nodes generally formed a private network's backbone structure.)

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This earlier market classification is no longer best suited for the analysis of this marketplace, and Dataquest has restructured its own reporting to better align the analysis with purchase and applications trends in the market.

The market changes that have prompted the new reporting structure include changes in all three product areas. PADs are now found as board-level products and plug-in modules added to local area network (LAN) servers and gateways, as well as to T-1 and statistical multiplexers and other data communications products. Switches now routinely include PAD functionality, and their sophistication is improving to the point where it is becoming difficult to securely define the boundary between a switch and a small node. More small nodes have appeared on the marketplace, and they are becoming smaller--in footprint as well as functionality and price.

To provide a more valuable understanding of the emerging new marketplace, Dataquest has redefined the three categories, as follows:

- PADs, now comprising standalone single-function boxes, board-level products, and modules that plug into other data communications equipment

- Packet switches, concentrators, and small packet nodes, comprising products whose primary function is switching

  - The small packet nodes are distinguished from the system nodes of the final category in that their throughput is too low to allow them to be used to create a network backbone.

- Packet nodes, comprising only the medium and large network systems nodes and directly associated software revenue

  - The domestic revenue generated by the vendors that sell systems composed exclusively of hardware they have purchased as OEMs and the revenue they may earn from sales of software they develop are reported separately

  - International sales revenue, revenue derived from lease options, and all other revenue not directly attributable to new domestic sales of packet nodes are also not reported in this category.

The significant difference in this new classification is in the second category. The migration of node functionality (that is, routing and traffic control in addition to simple switching) into smaller and less-intelligent packages is producing new products that more closely resemble switches than they do their mammoth backbone cousins. These new small nodes may include built-in PADs, so they may packetize data from synchronous and asynchronous sources. The new switches generally concentrate as well as switch.

In one of the significant movements this marketplace saw in 1986, vendors unleashed a torrent of new products in the last quarter of the year. Dataquest believes that the savviest vendors are broadening their product lines in an attempt to increase their market share in 1987 and early 1988. These vendors clearly expect, as Dataquest does, that the Regional Bell Holding Companies (RBHCs) will be allowed to enter the private packet network marketplace sometime during 1988 or early 1989. The introduction of RBHC contenders into an already competitive market will have serious consequences for those vendors least able to compete. Dataquest expects the upsurge in new product announcements, coupled with additional alliances and joint-marketing agreements, to continue through 1987.

The following sections profile the revenue and market shares of the leading companies in these three product areas.

VENDOR PERFORMANCE

PADs

Eleven vendors earned $1 million or more in the PAD marketplace in 1986. Dynapac was the market leader with 21.2 percent of the market, followed by Amdahl, Memotec, Atlantic Research Corporation, Micom, Timeplex, M/A-Com, Protocom, Gandalf Data, Paradyne, and others. These vendors are listed in order of rank, with market shares and revenue, in Table 1.

Table 1

U.S. PADs
END-USER, IF-SOLD REVENUE
(Millions of Dollars)
1986

Vendor	Market Share	Revenue
Dynapac	21.2%	$ 9.0
Memotec	13.7	7.0
Atlantic Research	10.9	4.5
Micom	5.9	3.0
Timeplex	5.8	3.0
Amdahl	5.8	3.0
M/A-Com	5.3	2.8
Protocom	4.1	2.2
Gandalf Data	4.0	2.0
Paradyne	4.0	2.0
Others	5.5	3.9
Total	100.0%	$42.4

Source: Dataquest
August 1987

Dynapac is the market leader in the asynchronous traffic submarket, which accounts for less than 25 percent of PAD revenue. Most of the revenue in this marketplace is earned from sales of synchronous or multifunction PADs.

An upcoming newsletter will analyze the PAD market in detail and will present a strategic view of the companies and their products, as well as new directions for PAD manufacturers in this increasingly competitive marketplace.

Packet Switches, Concentrators, and Small Nodes

Four major vendors earned more than $1 million from packet switches and small nodes in 1986. Amdahl held the lead with 39.5 percent of the market, closely followed by Dynapac with 17.0 percent and Protocom with 16.9 percent. Paradyne earned 11.8 percent and Memotec half that amount, as shown in Table 2. Additional vendors, constituting less than 13.8 percent of the market, included AMNET, ITT, and Micom.

Table 2

U.S. PACKET SWITCHES AND SMALL PACKET NODES
END-USER, IF-SOLD REVENUE
(Millions of Dollars)
1986

Vendor	Market Share	Revenue
Amdahl	39.5%	$ 7.0
Dynapac	17.0	3.1
Protocom	16.9	3.0
Paradyne	11.8	2.1
Memotec	5.4	1.0
Others	13.8	2.6
Total	100.0%	$18.8

Source: Dataquest
August 1987

Packet Nodes

BBN Communications retained its leadership position, as shown in Table 3, with sales of $44 million from domestic packet nodes, followed by Telenet with $36 million, Siemens with $35 million, and Tymnet with almost $25 million. BBN's sales showed an increase from 1985, while Telenet showed an essentially flat revenue trend and Tymnet posted a decline. Dataquest believes that Tymnet's lackluster performance reflects obsolescence in the product line. Since Tymnet expects to have new products, with smaller footprints and higher throughput, available in the second quarter of 1988, the company may be able to halt the revenue slide in 1988. Sales are not expected to rebound with the present product line.

Table 3

PACKET NODES AND NETWORK SYSTEMS
END-USER, IF-SOLD REVENUE
(Millions of Dollars)
1986

Vendor	Market Share	Revenue
BBN Communications	21.9%	$ 44
Telenet (U.S. Sprint)	17.9	36
Siemens	17.4	35
Tymnet McDonnell Douglas Network Systems	12.4	25
Telematics	8.9	18
Northern Telecom	7.5	15
M/A-Com	3.5	7
Dynapac	2.0	4
Memotec	1.5	3
Others	7.0	14
Total	100.0%	$201

Source: Dataquest
August 1987

Telenet took steps to try to boost its market performance by increasing the size of its sales force. It also signed an important OEM agreement with Timeplex, a move that will be discussed in detail in the T-1 Alliances section of this newsletter.

Siemens has had a long history of sales to U.S. telephone companies. In 1986, Siemens sold approximately $35 million of packet switching equipment to the Bell Operating Companies (BOCs) and RBHCs. Since the BOCs and RBHCs have been setting up private packet networks for their internal use, this rapid deployment and the associated sales revenue have been legitimately counted as part of the private network marketplace. However, the RBHCs have been requesting tariffs to offer expanded packet-switching services in their areas. If these new tariffs are approved and the RBHCs begin offering their private wide-area networks for public use, the service revenue they generate and the nodes and switches they purchase to expand, maintain, and develop their packet networks will be followed in the Public Data Networks service section. They will no longer be followed in the Private Packet Networks service section.

Complete Private Networks

Most vendors in the packet node market did more than sell nodes. They also provided design, configuration, and installation of complete network systems. Table 4 lists the number of private packet network installations completed in 1986. Vendors that primarily install private networks costing less than $250,000 were not included in this analysis.

Table 4

NEW COMPLETE NETWORK INSTALLATIONS COMPLETED IN 1986
(In Dollar Value Order)

Vendor	Installations
BBN Communications	4
Telenet	3
GEISCO	3
Siemens	2
Tymnet	2
Paradyne	2
Hewlett-Packard	2
Total	18

Source: Dataquest
August 1987

Two vendors entered the private packet network marketplace in 1986, representing a new trend in packet networking--the network supplier that manufactures none of what it sells. Although the value-added reseller is nothing new in the computer marketplace, the packet-switching market has traditionally been fueled by innovations in hardware. This situation is changing.

Armed with a 16 percent share of the public packet network market, GEISCO decided to throw its corporate hat into the private network ring in 1986, reasoning that its expertise in the public arena would allow it to compete in this crowded marketplace. Buying nodes, PADs, and switches primarily from Dynapac and Telematics, GEISCO grossed $3 million from sales of private networks. The median size of a GEISCO private network was three nodes. These networks, although quite small by other standards, are appropriate for the midsize corporations to which GEISCO is already marketing its public data network service.

An even more interesting new entrant was a computer manufacturer with no particular expertise in wide-area packet networks.

HEWLETT-PACKARD JOINS THE FRAY

In a significant move that other computer equipment manufacturers may decide to emulate, Hewlett-Packard became a packet network supplier in 1986. Hewlett-Packard private networks generated about $2 million in this first half-year of operation.

Hewlett-Packard's private networks are relatively small, as befits a fledgling vendor, with an average of three to four nodes per network.

To help design and install its private networks, Hewlett-Packard has hired 39 network consultants to support its worldwide sales force. The hardware is provided by XMIT, a Swiss PAD vendor, and M/A-Com, a packet node vendor. The new AdvanceNet nodes are a codevelopment project, with Hewlett-Packard primarily active in communications software development and M/A-Com providing hardware expertise.

Hewlett-Packard is aiming its X.25 Packet AdvanceNet at its installed base of computer customers. With its entrance into the private network market, this computer vendor has made a solid move to add wide-area networking to its total solution matrix.

Dataquest believes that Hewlett-Packard's choice of packet switching over another wide-area proprietary architecture was a result of several factors:

- Proprietary communications architectures are extremely expensive to develop.
- A proprietary solution might not allow multivendor connectivity, a strategic imperative in today's business environment.
- X.25 is a CCITT (Comitee Consultative International de Telephonique et Telegraphique) international standard for the Network Layer of the Open Systems Interconnection (OSI) model.
- The X.25 standard is well understood in the U.S. market and nearly universally present in foreign markets. Using this international standard will enhance export sales.
- If the Hewlett-Packard private network is an X.25 backbone, customers will still be able to buy equipment from multiple manufacturers. This situation should ease a major customer fear--obsolescence.
- Network interface development for peripherals that connect to an X.25 packet network is done by the peripheral's manufacturer, shifting research and development costs away from the network vendor.

International Sales Trends

Private packet network vendors did not find Japan a hospitable environment for their sales forces. The formidable Japanese barriers to telecommunications sales prevented significant market share from developing.

In Europe, West Germany's market is almost as closed as Japan's, but European sales were generally strong in 1986. Australia and New Zealand are fast-growing Pacific Basin markets.

Sales to the remainder of the third world nations were slow in 1986. The debt crisis in the undeveloped nations has been of increasing concern at major European and U.S. banks, whose fiscal stability may be imperiled by the huge amounts of possibly unsecured debts they hold. In addition, growing political instability in key areas of the world has led to caution among vendors.

STRATEGY AND TACTICS: THE YEAR IN FOCUS

Although it is always useful to segment sales and market shares by product type, it is even more important to look at this marketplace in terms of the strategic foci of the various vendors.

Vendor Strategic Focus

The private packet network market can be imagined as a continuum, along which vendors segregate themselves. At one extreme is the manufacturer. These vendors produce products whose buyers either are in the system integrator business or are users with existing networks that need expanding. Telematics and Siemens fit into this slot in 1986. At the opposite extreme is the system supplier, a vendor that manufactures very little of the final customer's product. Instead, this vendor buys the best existing hardware it can, codevelops software as appropriate, and focuses its energies on the first-time private packet network buyer. Hewlett-Packard would be the archetype of the system supplier. Because the company manufactures none of the hardware it sells, to prevent double-counting of nodes, its revenue from private network sales is not reported under packet nodes in the sales matrix.

Every other vendor in the formidable list of companies competing in this marketplace falls somewhere between these two poles. As a vendor moves away from the manufacturer end of the continuum, it concentrates less on technical innovation and product features and more on the business problem that the technology is solving.

Clearly, the vendors moving in the system supplier direction outnumber those moving toward the manufacturer's end. Yet, the vendors concerned with technology innovations are providing the raw material transmuted by the rest of the marketplace. Vendors are expected to continue generating important revenue from all points on the continuum through the remainder of the 1980s. By 1991, the number of vendors will be substantially reduced, as a small number of innovative technology-intensive companies will be able to generate the products for a generally mature market.

T-1 Alliances

The top revenue generators in this marketplace positioned themselves for future growth by betting on the future of packet/T-1 hybrid networks.

In the case of BBN Communications, it was outright purchase. For $18 million, BBN purchased the fledgling Network Switching Systems, Inc. (NSS), a T-1 systems house that has the wideband circuit-switching expertise that BBN lacked. BBN's eventual goal is to offer integrated voice/data/image networks with nodes that can multiplex packet-switching and circuit-switching with fully allocatable bandwidth. In the short term, BBN can now sell the N16 wideband circuit switches, which should find a healthy niche in the market.

Telenet Communications, a subsidiary of U.S. Sprint, chose the OEM route. In March 1987, Telenet announced what it called Integrated Data Network (IDN) service, its own version of multiplexed circuit and packet switching. To offer IDN, Telenet is buying Timeplex's Link series of T-1 nodes in a multiyear OEM agreement. The Link/100 digital switch offers up to 144 T-1 circuits and 15,000 input/output channels. The user also has the power to determine the endpoint of each transaction, as the call is set up. This is a significant breakthrough in the T-1 switching market, in which fixed senders and receivers have been the rule. With control of the switching in the user's hands, the Link family fits more easily into Telenet's networks and into its private network strategy. Dataquest estimates that Telenet will spend $7 million on Timeplex T-1 products in 1987.

These two solutions have a common element. By short-circuiting the in-house development process, with its huge time and dollar costs, BBN and Telenet have moved quickly into the hybrid network business.

Dataquest believes that the marketplace is moving to hybrid networks. The alliances and purchases of 1986 are only the beginning of the shift in the technology and applications focus that will propel successful vendors into the 1990s.

FUTURE TRENDS IN PRIVATE PACKET NETWORKING

As expected, revenue growth in this market area is slowing. The successful vendors used various techniques to either differentiate themselves from their competitors or develop new sources of revenue.

Smaller and broader were the watchwords for successful products and product lines, respectively, in 1986.

Four market movements were evident:

- Prices eroded, especially in the PAD market.
- New products moved into smaller packages.

- Hardware revenue declined relative to functionality.

- The broadest product lines captured the competitive high ground.

Price erosion has been a continuing problem for packet manufacturers. Because of this erosion, most vendors experienced flat or falling revenue from their product lines, even while shipments remained steady. Dataquest expects this trend to continue and intensify, leading to the overall downturn in revenue for this marketplace in the 1989 to 1990 time frame.

Successful products are increasingly those found in the smallest packages. In the connectivity battle, the winning combination is the smallest footprint combined with the highest amount of modularity and/or broadest functionality. PADs and switches are migrating to board-level and modular plug-in products. Asynchronous PADs are moving into smaller packages even more quickly than synchronous PADs. Although the market for board-level products was only $8 million in 1986, Dataquest expects this trend to accelerate.

Vertical product integration is clearly the order of the day. The small box and the multifunction box have a fundamental packaging characteristic in common: hardware revenue is declining relative to functionality. This is welcome news for buyers but a challenge for vendors, which need to develop new revenue sources.

The most successful vendors in 1986, in general, were those with the broadest product lines, whose customers could one-stop shop. Vendors accomplished this through OEM agreements with other manufacturers, through purchase of companies with complementary product lines, and through new product development.

The other characteristic of the successful vendor in 1986 was a clear strategic direction combined with a thorough understanding of all actual and potential competitors. This understanding of the competition transcends knowledge of other product lines and extends to a thorough understanding of the specific reasons why customers buy from a competitor. As competition in the private packet network market intensifies, this detailed competitive analysis will become critical to survival.

Although overall sales levels climbed in 1986, and will continue to climb in 1987, increased competition partially nullified these gains. Consequently, vendors did not experience a banner year for net profits. Through the remainder of the 1980s, successful vendors will be those that learned the lessons of 1986 and are looking ahead to the marketplace of 1991.

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AUGUST PROCUREMENT SURVEY: THE UPTICK RESUMES

The pause reflected in last month's flash report may have been short-lived as users once again state that they expect August billings for semiconductors to increase slightly. Many of our respondents also reported that their August orders will increase, with two major manufacturers in the data processing area reporting that their August semiconductor orders will be double those of July. Another major computer manufacturer stated orders would increase by 10 percent. These responses confirm that the data processing application market is driving 1987's market growth.

Our respondents also told us that the combined amount they will order from distribution in August will be 4 percent higher than the portion ordered from distribution in July. Interestingly enough, however, prices still continue to remain relatively stable, with few respondents seeing any movement one way or another.

After four months of surveys, Dataquest can now plot monthly results in order to assess trends in semiconductor inventories and lead times. Table 1 shows the relationship between current actual and target inventories. It is interesting to note that the two were in parity the first two months, surged in July, and have calmed in August, but that they are higher than when the survey began, confirming that OEMs are allowing inventories to increase slightly. Target inventory levels for all of the respondents have remained the same since May.

Also, since the survey began, lead times have stretched from 11 to 13 weeks and users are stating that their electronic equipment sales are stronger than at this same time last year. In May, they indicated that sales were the same as in May of last year. Now in August, on a scale of 1 to 10, with 1 being lower, 5 being the same, and 10 being higher, their aggregate response is 7.5.

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Memory components are still being cited as the components most difficult to purchase in required quantities, and users are telling us resoundingly that lead times, obtaining memories (especially DRAMs and EPROMs), on-time delivery, government intervention, and the FMVs are the hottest issues that they are facing. Interestingly, in this month's survey, ASICs were less frequently cited as difficult to obtain.

Anthea C. Stratigos

Table 1

CURRENT ACTUAL VERSUS TARGET SEMICONDUCTOR LEVELS

May	Down 1.0%
June	Down 1.1%
July	Up 24.7%
August	Up 7.9%

Source: Dataquest
August 1987

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Research Newsletter

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1987, THE YEAR OF THE TURNAROUND: SECOND QUARTER ELECTRONIC EQUIPMENT UPDATE

SUMMARY

Dataquest continues to see 1987 as a turnaround year for the electronics industry, leading into higher growth in 1988. This newsletter outlines our forecast for various equipment markets. We believe that the following observations are important to semiconductor suppliers:

- As in the past, the computer segment is driving the current upturn in semiconductor industry sales. Dataquest estimates that semiconductor consumption by computers will grow 14 percent this year.

- Data communications is the area of greatest opportunity for semiconductor manufacturers in the communications application market. These opportunities are fostered by increasing use of digital technology, reduced costs, and higher bandwidths.

- The growth resurgence in electronics markets has prompted manufacturers to expand capacity. This has had a positive effect on the industrial application market.

- The large amount of consumer debt accumulated in 1986 will have a moderating effect on the growth of the consumer electronics market.

- Limited congressional spending will cause the military electronics market to decline; however, the need for state-of-the-art technology will allow the military semiconductor market to grow.

- Automotive production is expected to decline 9 percent this year. However, Dataquest expects the automotive electronics market to grow 13 percent due to the increasing pervasiveness of electronics in the automobile.

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OUTLOOK FOR APPLICATION MARKETS

Table 1 displays Dataquest's latest electronic equipment forecast. We expect the industry as a whole to grow 4.8 percent in 1987, a small increase over the 4.3 percent growth of 1986. However, if we extract the military market from the total, the growth increases are a little more dramatic--7.5 percent in 1987 versus 5.3 percent in 1986. We forecast the market, excluding the military, to grow 8.3 percent in 1988 and, in the long term (1987 through 1991), to grow at a 7.4 percent CAGR.

Table 1

SEGMENT OVERVIEW
NORTH AMERICAN ELECTRONIC EQUIPMENT FORECAST
(Millions of Dollars)

Segment	1987	1988	1989	1990	1991	CAGR 1987-1991
Data Processing						
Computers	$ 61,397	$ 67,327	$ 72,262	$ 78,284	$ 83,445	8.0%
Data Storage Subsystems	18,177	19,466	21,174	22,122	22,691	5.7%
Terminals	3,588	3,916	4,274	4,494	4,640	6.6%
Input/Output	8,236	8,468	8,514	8,688	8,781	1.6%
Dedicated Systems	3,821	3,473	3,315	3,392	3,451	(2.5%)
Subtotal	$ 95,219	$102,650	$109,539	$116,980	$123,008	6.6%
Communications						
Customer Premises	$ 10,170	$ 11,117	$ 12,142	$ 13,021	$ 14,029	8.4%
Public Telecom-munications	6,834	7,080	7,516	7,881	8,297	5.0%
Radio	6,513	7,608	8,654	9,785	10,556	12.8%
Broadcast and Studio	1,582	1,767	1,892	2,100	2,331	10.2%
Other	1,958	2,010	2,144	2,346	2,575	7.1%
Subtotal	$ 27,058	$ 29,581	$ 32,348	$ 35,133	$ 37,788	8.7%
Industrial						
Security/Energy Mgmt.	$ 2,211	$ 2,388	$ 2,483	$ 2,678	$ 2,905	7.1%
Manufacturing Systems	12,772	14,348	15,021	16,213	17,840	8.7%
Instrumentation	7,235	8,167	8,589	9,197	9,938	8.3%
Medical Equipment	5,345	5,757	6,072	6,432	6,858	6.4%
Commercial Aviation	2,216	2,394	2,582	2,657	2,838	6.4%
Other	5,669	6,291	6,964	7,671	8,466	10.5%
Subtotal	$ 35,447	$ 39,345	$ 41,711	$ 44,848	$ 48,845	8.3%
Consumer						
Audio	$ 324	$ 332	$ 357	$ 395	$ 407	5.9%
Video	5,127	5,291	5,647	6,254	6,577	6.4%
Personal Electronics	720	756	794	801	816	3.2%
Appliances	11,068	11,522	12,098	12,891	13,691	5.5%
Other	1,116	1,167	1,218	1,270	1,325	4.4%
Subtotal	$ 18,355	$ 19,067	$ 20,114	$ 21,611	$ 22,816	5.6%
Military	$ 47,500	$ 46,900	$ 46,400	$ 46,300	$ 46,700	(0.4%)
Transportation	$ 10,809	$ 11,799	$ 13,812	$ 15,050	$ 16,209	10.7%
Total Equipment	$234,388	$249,342	$263,924	$279,922	$295,365	6.0%

Source: Dataquest
August 1987

The following pages discuss each application market forecast, highlighting the most recent events that we expect to affect the semiconductor market in the near future.

Data Processing

Resurgence in the computer and peripherals markets is the source of accelerating growth in the data processing application market. Dataquest expects this market to grow 6.4 percent this year and accelerate to 7.8 percent in 1988. Growth in the computer segment will be 6.6 percent for 1987, climbing to 9.7 percent in 1988. The computer storage segment will finish 1987 with 12.8 percent growth, the highest in the data processing application market this year. Growth in the terminals and input/output segments is expected to be lackluster at best in 1987--1.9 and 3.4 percent--respectively. We expect the dedicated systems segment to decline by 10 percent in 1987.

As in the past, the computer segment continues to drive the current upturn in semiconductor industry sales. Dataquest estimates that the computer industry will consume 26 percent of total North American semiconductor sales in 1987.

Computer manufacturers' recently reported financial results show that the computer industry is doing more than replenishing inventory. Many of the major computer manufacturers' revenue and profits jumped in the first two quarters of 1987 compared with the same period in 1986. Computer manufacturers <u>are</u> selling equipment. Table 2 displays first quarter financial results for selected data processing companies.

New products replacing old technology is the impetus for new computer sales. Almost 50 percent of Apple's second quarter revenue came from the Macintosh SE, Apple IIgs, and Macintosh II. IBM has shipped more than 250,000 units of its new PS/2 family and has booked orders for at least 500,000 more units to be shipped this year. Compaq's Deskpro 386 is continuing to sell well. In the mainframe arena, new products are cited as the reason for Amdahl's recent jumps in revenue and profit.

The pick up in new computer sales has had a positive effect on computer storage shipments. Storage sales of companies such as Seagate, Micropolis, and National Advanced Systems have soared this year compared with the same time last year. The demand is not only for storage in new computer products but for increasing the storage capacity of the installed base of computers as well.

At first glance, the terminals segment looks mundane. However, graphics and imaging terminals, which constitute one of the fastest-growing types of electronic equipment, is included in this segment. Dataquest expects graphics and imaging terminals to grow 21.4 percent in 1987 and to continue at a 16.2 percent CAGR from 1987 through 1991. Growth in the graphics industry has been driven by new semiconductor technology and new software applications like electronic publishing and computer-aided design (CAD).

Table 2

QUARTERLY REVENUE OF SELECTED DATA PROCESSING COMPANIES
(Millions of Dollars)

	First Quarter 1987				First Quarter 1986	
	Sales	% Change 1986-1987	Earnings	% Change 1986-1987	Sales	Earnings
Altos Computer Systems	$ 40.4	7.2%	$ 2.8	(9.7%)	$ 37.7	$ 3.1
Amdahl	318.5	59.1%	23.2	866.7%	200.2	2.4
Apollo Computer	123.4	50.5%	6.4	1,180.0%	82.0	0.5
Apple	575.3	40.7%	33.9	6.6%	408.9	31.8
Commodore International	169.5	(7.0%)	0.0	100.1%	182.3	(36.7)
Compaq Computer	211.0	46.5%	20.2	143.4%	144.0	8.3
Convergent Technologies	73.6	(17.8%)	11.0	423.8%	89.5	2.1
Data General Corp.	315.2	(1.1%)	(42.6)	2,266.7%	318.8	(1.8)
Digital Equipment	2,410.1	25.0%	307.6	80.6%	1,928.3	170.3
Gould Inc.	227.6	(0.3%)	7.6	106.6%	228.3	(115.1)
Harris Corp.	522.3	1.0%	21.9	43.1%	517.3	15.3
Hewlett-Packard	1,740.0	9.0%	116.0	6.4%	1,597.0	109.0
Honeywell Inc.	1,482.5	28.8%	43.7	66.8%	1,150.8	26.2
IBM Corp.	10,681.0	5.5%	785.0	(22.8%)	10,127.0	1,017.0
Micropolis	61.8	21.9%	6.2	67.6%	50.7	3.7
NCR Corp.	1,121.5	16.7%	61.5	22.5%	960.8	50.2
Perkin-Elmer Corp.	337.0	5.1%	18.2	(1.6%)	320.7	18.5
Prime Computer Inc.	221.7	12.7%	11.9	28.0%	196.8	9.3
Seagate	267.1	110.3%	40.5	243.2%	127.0	11.8
Tandy Corp.	776.9	12.0%	50.4	20.0%	693.4	42.0
Texas Instruments	1,271.9	11.1%	83.8	452.1%	1,145.2	(23.8)
Unisys	2,415.8	112.7%	110.2	588.8%	1,136.0	16.0
Wang Laboratories	745.9	8.8%	5.9	(72.4%)	685.3	21.4
Xerox	2,318.0	15.0%	137.8	34.4%	2,016.0	102.5
Total	$28,428.0	16.8%	$1,863.1	25.5%	$24,344.0	$1,484.0

Source: Dataquest
August 1987

A number of semiconductor manufacturers have recently jumped into the graphics processor market. AMD, Intel, and Texas Instruments displayed their chips at the SIGGRAPH show in Anaheim, California, this July, along with the OEMs who have put their hardware to use.

In the input/output segment, the most attractive equipment continues to be the page printer. The move to decentralized computing has led to decentralized printing. The desire for letter-quality printing and desktop publishing capabilities has opened up an area of opportunity for page printer vendors. Dataquest expects page printer shipments to grow 28.9 percent this year and then to taper off to a 9.9 percent CAGR in the long term (1987 through 1991).

As the functions that page printers are required to perform become more complex, the need for sophisticated semiconductor technology in these products increases. This market is evolving as an area of opportunity for graphics processor and microprocessor manufacturers.

We expect the dedicated systems segment to decline 9.9 percent in 1987 and to continue to decline at a 2.5 percent CAGR through 1991. Dataquest believes that U.S. manufacturers' dedicated systems segment shipments will shrink for a number of reasons, including the following:

- Very high market penetration (mature market)
- Technology obsolescence
- International competition

The following descriptions of the three major dedicated systems markets illustrate the points we mentioned earlier:

- Copiers--The growth rate of new sales is slowing as market penetration increases. Japanese suppliers own the low-end, high-growth personal copier market and have the majority of market share in all other segments.
- Electronic typewriters--Japanese typewriter manufacturers have been very aggressive and are determined to take market share away from U.S. manufacturers.
- Word processors--PCs have practically made these products obsolete. Word processor sales are forecast to drop at a 25 percent CAGR over the next four years.

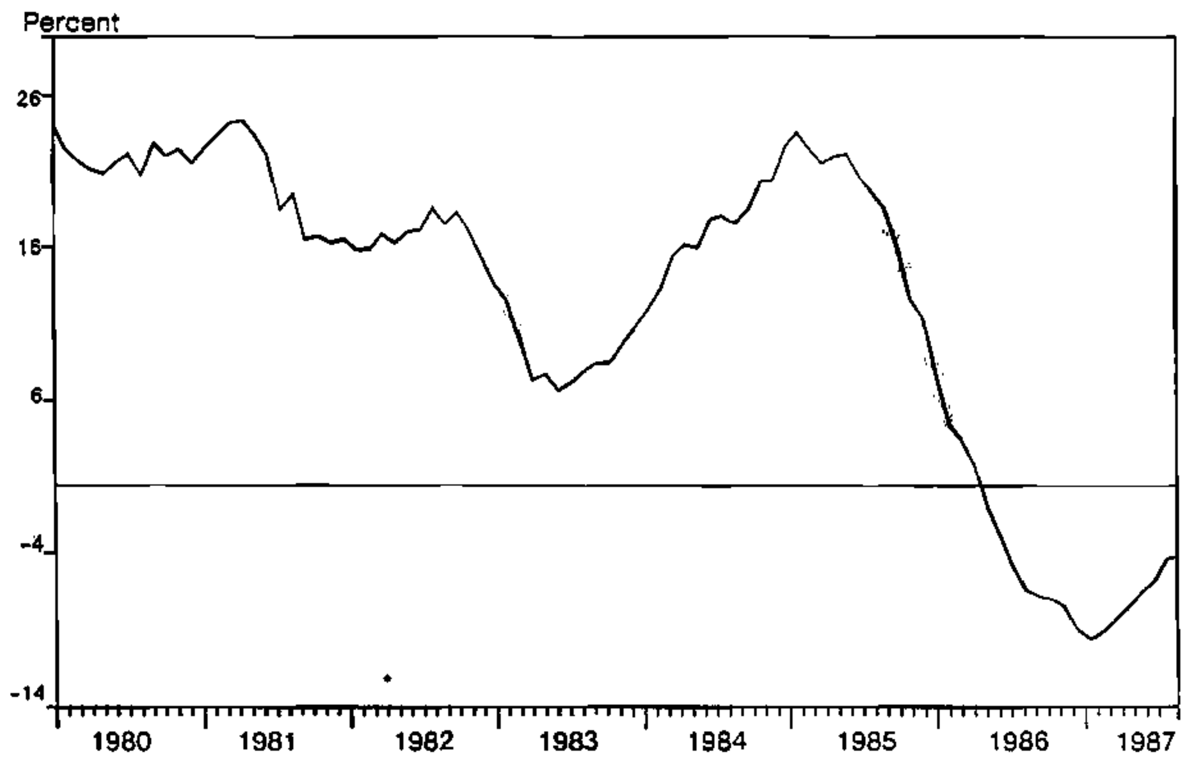
U.S. manufacturing in the dedicated systems segment could grow in the near future for one reason: U.S./Japan trade friction. The U.S. manufacturers' equipment is more competitive now because the yen has strengthened against the dollar. This currency situation also provides an incentive for Japanese manufacturers to move manufacturing to the United States.

In fact, one Japanese electronic typewriter manufacturer has already started manufacturing in the United States. Brother Industries has moved a portion of its electronic typewriter manufacturing to Bartlett, Tennessee. More than 50 percent of the typewriter components are locally sourced. Brother expects to produce 300,000 typewriters per year at the Tennessee plant.

Although there are definitional differences between Department of Commerce (DOC) data and Dataquest methodology, we believe that the DOC monthly data are a good source for aggregate top-level monthly data. The June 1987 DOC data shown in Figure 1 indicate that computer and office machine shipments are recovering. A 12/12 rate-of-change curve shows that bookings are now showing positive growth. The rate of decline of shipments has turned and is heading for positive growth.

Figure 1

COMPUTER AND OFFICE EQUIPMENT SHIPMENTS
(12/12 Rate of Change)



Source: U.S. Department of Commerce
Dataquest
August 1987

Communications

Our forecast for the communications market as a whole continues to be 8.2 percent in 1987, with long-term growth of 8.7 percent from 1987 to 1991.

In the customer premises segment, data communications equipment continues to be the focus of the industry, specifically the following equipment types:

- Statistical multiplexers
- Local area networks
- Data PBXs
- Modems

One area of interest to data communications equipment suppliers has been which company is winning "the battle to connect the desk." Table 3 displays Dataquest's estimates of the number of connections in the office by equipment type by method of connection. We believe that LAN and PBX connections will grow the most rapidly over the next four years.

Table 3

DATAQUEST CONNECTION MATRIX
(U.S. Business Environment)

Year	Type of Desktop Device	Estimated Installed Base at Year End (Units, Thousands)	Estimated Percentage Connected Via: LAN	PBX	Data PBX	Hard-Wired	Remote	Not Connected	Total
1986	Display Terminal	11,722	9.5%	0.8%	12.0%	52.0%	25.7%	0.0%	100.0%
	Personal Computer	12,225	6.5%	0.2%	3.0%	12.5%	16.8%	61.0%	100.0%
	Word Processor	1,040	11.4%	0.8%	2.4%	29.0%	9.0%	47.4%	100.0%
	Integrated Voice/Data Workstation	300	2.6%	68.0%	0.0%	6.0%	17.0%	6.4%	100.0%
	Technical Workstation	100	98.1%	0.0%	0.0%	0.0%	0.4%	1.5%	100.0%
	Electronic Typewriter	4,317	0.0%	0.0%	0.0%	0.5%	1.5%	98.0%	100.0%
	Total	29,704	7.2%	1.1%	6.1%	26.8%	17.8%	41.1%	100.0%
1987	Display Terminal	13,051	12.5%	1.3%	11.5%	49.0%	25.7%	0.0%	100.0%
	Personal Computer	15,672	8.6%	0.3%	3.5%	12.0%	16.0%	59.6%	100.0%
	Word Processor	1,024	12.0%	1.2%	3.0%	29.0%	11.0%	43.8%	100.0%
	Integrated Voice/Data Workstation	500	3.0%	70.0%	0.0%	5.0%	14.3%	7.7%	100.0%
	Technical Workstation	200	96.3%	0.0%	0.0%	0.2%	0.5%	3.0%	100.0%
	Electronic Typewriter	5,240	0.1%	0.3%	0.0%	1.0%	2.1%	96.5%	100.0%
	Total	35,687	9.3%	1.7%	5.8%	24.2%	17.3%	41.7%	100.0%
1991	Display Terminal	16,586	22.0%	7.5%	6.5%	40.0%	24.0%	0.0%	100.0%
	Personal Computer	30,567	23.5%	1.0%	3.5%	10.0%	14.0%	48.0%	100.0%
	Word Processor	691	13.5%	2.0%	3.5%	30.0%	13.0%	38.0%	100.0%
	Integrated Voice/Data Workstation	2,000	9.5%	75.0%	0.0%	3.0%	10.0%	2.5%	100.0%
	Technical Workstation	1,800	94.0%	0.0%	0.0%	0.5%	0.5%	5.0%	200.0%
	Electronic Typewriter	6,794	0.1%	0.5%	0.0%	2.5%	3.5%	93.4%	100.0%
	Total	58,438	21.9%	5.3%	3.7%	17.3%	15.1%	36.7%	100.0%

Source: Dataquest
August 1987

Data communications is opening an area of opportunity for digital IC suppliers as more analog functions are upgraded to digital technology to transmit both voice and data.

In the public telecommunications segment, declining growth in central office switching equipment continues to moderate the overall growth (5 percent CAGR from 1987 to 1991). Dataquest forecasts that central office switching equipment revenue will drop 2 percent this year and decline at a 4.5 percent CAGR from 1987 to 1991. However, Dataquest expects packet switching equipment to pick up the slack in this segment. We forecast packet switching equipment revenue to grow at a 21.7 percent CAGR from 1987 to 1991.

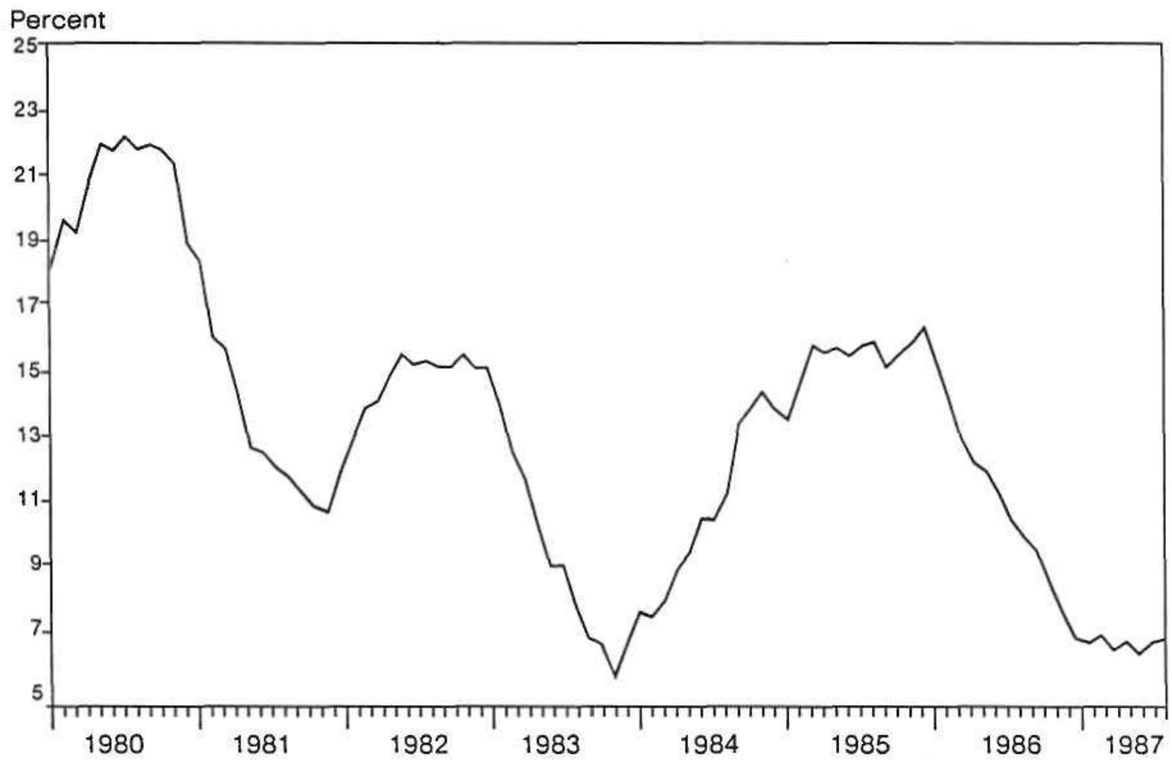
The 17.8 percent growth in the radio segment is due in large part to the success of cellular mobile radio. We expect CMR base stations to grow 71.8 percent this year and to grow at a 28.3 percent CAGR from 1987 to 1991.

Broadcast and studio equipment are expected to grow 5.9 percent in 1987 and to reflect a 10.5 percent CAGR from 1987 through 1991. Most of this growth will be in transmitters, cable television equipment, and video equipment, due to technology replacement.

Figure 2 shows a 12/12 rate-of-change curve for communications equipment shipments. The rate of change appears to be moving toward the 8 to 9 percent trend line.

Figure 2

COMMUNICATIONS EQUIPMENT SHIPMENTS
(12/12 Rate of Change)



Source: U.S. Department of Commerce
Dataquest
August 1987

Dataquest believes that the communications application market will be a consistent growth opportunity for semiconductor suppliers through 1991. We estimate that semiconductor consumption by the communications application market will grow at a 13.9 percent CAGR from 1987 through 1991.

Data communications is the area of greatest opportunity for semiconductor manufacturers due to increasing use of digital technology, cost reductions, and higher bandwidths.

Industrial

The turnaround in other electronics industries has had a positive effect on the industrial market because electronics manufacturers are slowly expanding capacity to keep up with the new growth. Dataquest expects the industrial segment growth to jump 5.6 percentage points this year to reach 7.9 percent market share. We expect growth to accelerate to 11.6 percent in 1988, then taper off to an 8.3 percent CAGR for the long term (1987 through 1991).

The recovery in the computer industry has had a positive effect on the manufacturing systems segment. However, the current decline in automotive production could moderate growth this year. U.S. manufacturers are upgrading old manufacturing technology to compete in international markets.

The instrumentation market is also positively affected by the upturn in other electronic markets. We expect this segment to grow 9.9 percent this year versus no growth in 1986. We forecast growth in this segment to accelerate to 10.9 percent in 1988. We believe that in the long run (1987 through 1991) the segment will grow at a 10.5 percent CAGR.

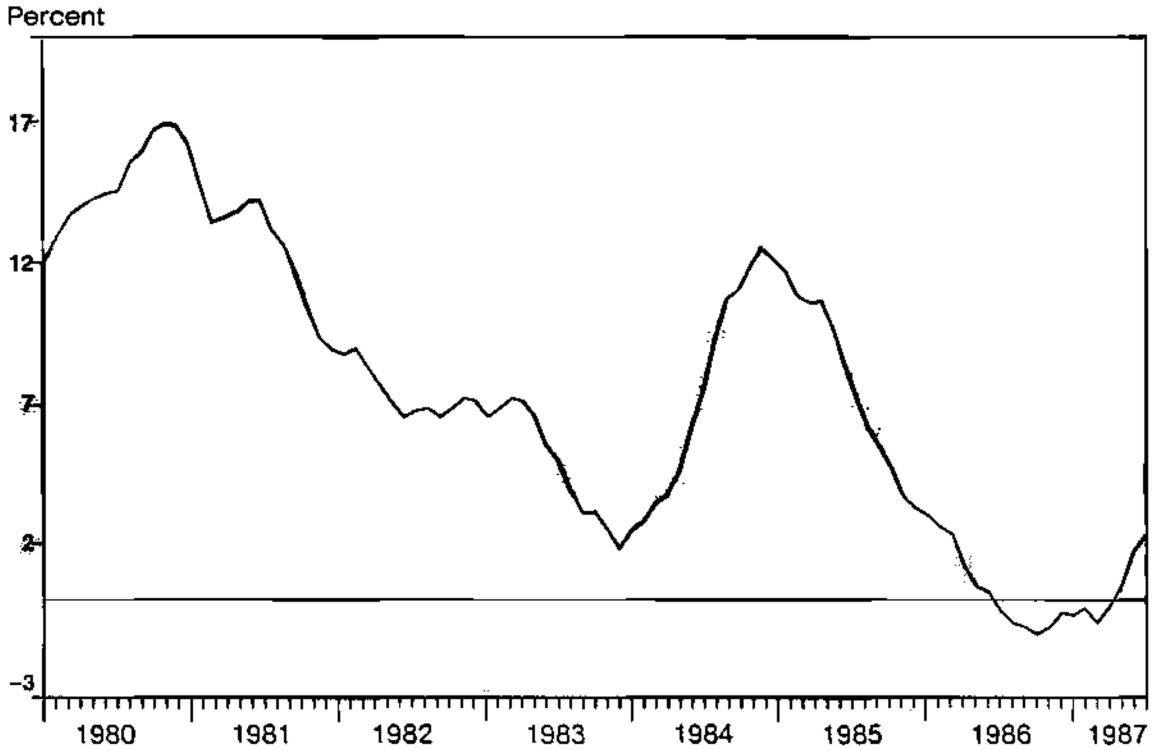
The latest DOC electronic instruments shipment data is displayed in Figure 3. The rate-of-change curve shows that instrument shipments have started to pick up, reaching 2.4 percent.

We expect the medical electronics segment to continue its recovery from the downturn in 1984 and 1985. We believe that this segment will grow 6.9 percent this year and continue to grow at a 6.4 percent CAGR from 1987 through 1991.

New technology continues to be the impetus for growth in the medical electronics segment. Production of new products such as smaller magnetic resonance imaging equipment and implantable defibrillators is expected to grow through the forecast period.

Figure 3

U.S. SCIENTIFIC AND ENGINEERING INSTRUMENT SHIPMENTS
(12/12 Rate of Change)



Source: U.S. Department of Commerce
Dataquest
August 1987

Consumer

Overall, we expect the consumer application market to grow 7.9 percent in 1987 and level off to a 5.6 percent CAGR from 1987 through 1991.

In the audio segment, portable systems and high-end audio systems are the key to new sales today. According to the Electronics Industry Association, 1987 sales of "boom boxes" and portable CDs have increased over last year's sales.

The video segment is expected to grow 10.1 percent this year and continue to grow at a 6.4 percent CAGR from 1987 through 1991. The fast-growing areas in this segment are VCRs and color televisions with stereo sound. Although VCR sales to dealers are virtually flat, Dataquest believes that there is growth in U.S. manufacturing as Japanese manufacturers move more VCR production to the United States to benefit from the strong yen.

Japan's Ministry of International Trade and Industry (MITI) recently directed Japanese VCR manufacturers to move more production to the United States. These manufacturers claimed that this was too difficult because components could not be obtained in the United States, so MITI directed the companies to produce VCR components in the United States. As a result, Mitsubishi has announced that it will produce VCR components in the United States, as have a few other manufacturers.

In the personal electronics segment, offshore manufacturing and a lack of new products from U.S. suppliers caused this market to decline in past years. However, Dataquest believes that trade friction and new American participants will promote growth in the near future. We expect the personal electronics segment to grow 12.3 percent this year and continue to grow at a 3.2 percent CAGR from 1987 through 1991.

Because of the fickle nature of the American consumer, the personal electronics segment is highly dependent upon new product introductions for growth. One such product was announced last quarter by Worlds of Wonder (WOW), a Fremont, California, toy company. Its new toy, a doll named Julie, could mark the opening of a completely new market for semiconductor vendors.

What makes Julie significant to semiconductor manufacturers is her speech recognition capabilities by way of a Texas Instruments' digital signal processing (DSP) chip built especially for WOW.

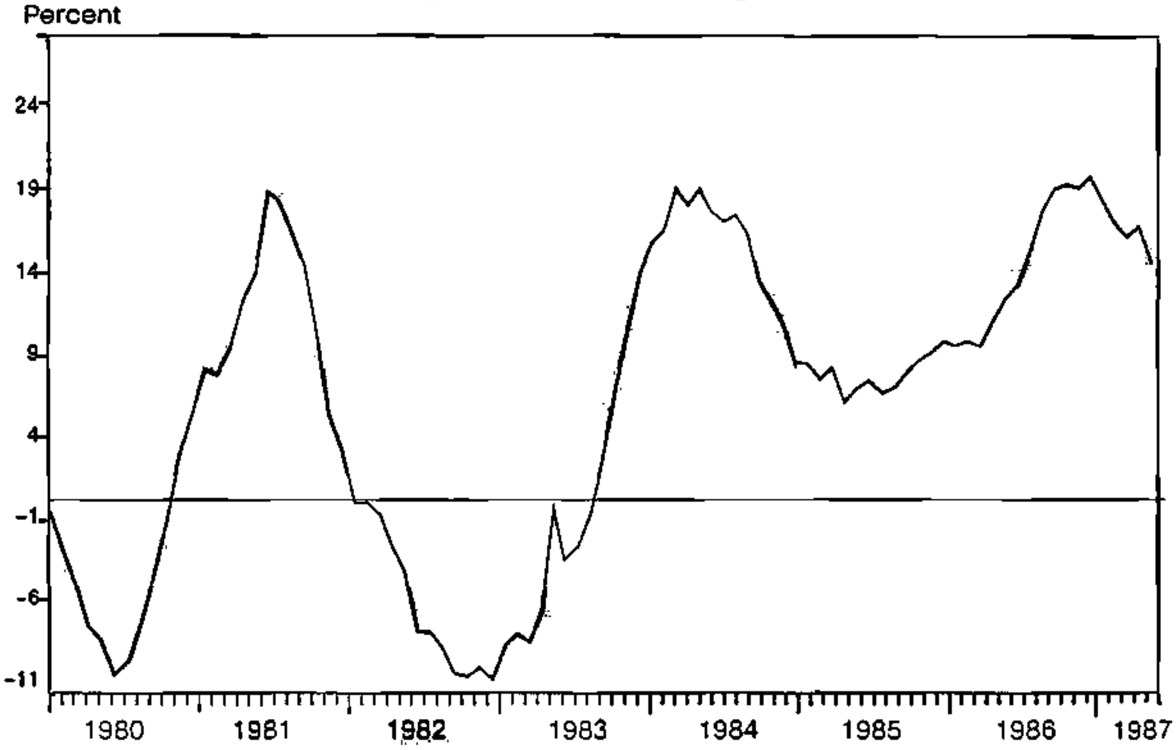
WOW will make Julie entirely in the United States. The company expects to sell 1 million units in the first year. (TI's ability to provide the DSP chips is considered to be the limiting factor.) WOW's decision to manufacture in the United States is significant to semiconductor vendors because Julie provides a high-volume consumer electronics semiconductor market located in North America--a dying breed to say the least.

This is a very interesting opportunity for semiconductor manufacturers. TI has found a semiconductor application that has high-volume potential for DSP chips. This will allow TI to bring down the cost of manufacturing the ICs due to the economies of scale. In fact, this could bring the cost of DSP chips down to a price where they will be used in other high-volume consumer electronics products.

The most recent DOC data show the radio and television category (which we compare to our consumer application market) reaching 16.9 percent in a 12/12 rate-of-change curve (See Figure 4). We expect the number to drop closer to 10 percent by the end of the year, due to the large debt American consumers built up during 1986.

Figure 4

RADIO AND TELEVISION SHIPMENTS
(12/12 Rate of Change)



Source: U.S. Department of Commerce
Dataquest
August 1987

Military

We expect the total military market to continue its decline as Congress continues to cut the growth of U.S. government military spending. Dataquest forecasts that the military application market will decline 4.4 percent this year and decline 0.4 percent from 1987 through 1991.

The military market continues to need state-of-the-art technology. Thus the real opportunity for semiconductor manufacturers lies in retrofitting older equipment with new electronics. This is especially true in aircraft where navigational systems are being revamped using 32-bit microprocessors and graphics displays. For these reasons, we expect semiconductor consumption by the military market to grow 13.9 percent this year and continue to grow at a 5.4 percent CAGR from 1987 through 1991.

Transportation

Because automotive sales continued to be disappointing in the first half of 1987, economists for the Big 3 U.S. automakers have cut their automotive-sales forecast. According to Automotive News, the average of the revised forecasts puts total automotive and truck sales at about 14.8 million units in 1987, down 9 percent from 1986's 16.2 million.

Weaker than expected U.S. economic performance and 1987 sales stolen by 1986 incentives were cited as the reason for poor automotive sales this year.

With sales expected to be weak throughout 1987, motor vehicle production continues to be below 1986 levels. Table 4 shows automotive production statistics for January to July, 1986 and 1987. Automobile production in 1987 is 8.5 percent below production during the same period in 1986.

Table 4

NORTH AMERICAN AUTO PRODUCTION
(Units)

	January 1 to July 5, 1986	January 1 to July 4, 1987	% Change 1986-1987
American Motors Corp.	28,595	15,539	(45.7%)
Chrysler Motors	741,048	595,868	(19.6%)
Ford Motor Co.	946,285	996,120	5.3%
General Motors	2,384,460	1,959,219	(17.8%)
Honda	96,719	170,036	75.8%
Nissan	21,517	67,784	215.0%
Nummi	95,172	99,805	4.9%
Volkswagen	47,916	41,150	(14.1%)
Total U.S. Car	4,361,712	3,945,521	(9.5%)
Total Canadian Car	611,453	430,210	(29.6%)
North American Car	4,973,165	4,375,731	(12.0%)
North American Truck	2,377,790	2,352,279	(1.1%)
North American Car and Truck	7,350,955	6,728,010	(8.5%)

Source: Automotive News
Dataquest
August 1987

Some manufacturers continue to outshine the rest. Ford is the only one of the Big 3 U.S. automakers to continue to increase production in 1987 compared with 1986. Japanese manufacturers' 1987 auto production in the United States increased dramatically compared with the same period in 1986. Nissan and Honda have increased production in the first half of 1987 215.0 percent and 75.8 percent, respectively.

The increase in U.S. automotive production by Japanese manufacturers does not translate into new sales for U.S. semiconductor manufacturers. Dataquest believes that Japanese companies building automobiles in the United States still buy a large majority of the components and subassemblies from Japan.

Although U.S. automotive production is declining this year, Dataquest believes that semiconductor consumption by the automotive industry will grow 13 percent this year and register a 10.7 percent CAGR from 1987 through 1991.

How can there be growth in electronics when automobile production is declining? It is because the use of electronics is relatively new to the industry. Compared with previous years, the increasing pervasiveness of electronics in the automobile provides the impetus for growth of electronics in this market.

The electronic possibilities in the automobile are slowly making their way to the consumer in high-end cars and eventually trickle down to the midrange and low-end automobile. There is still plenty of room for new uses of semiconductor technology in cars. Products such as sensors, smart power devices, and microprocessors typically are marketed to the automotive industry.

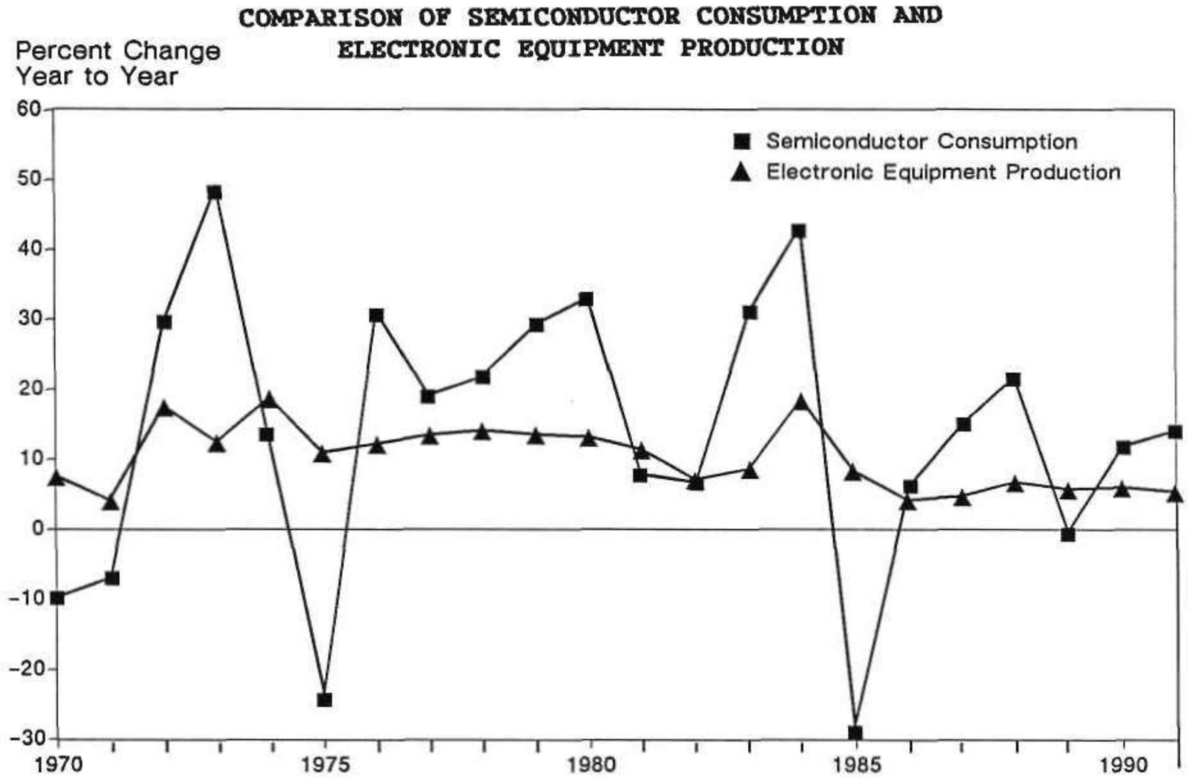
DATAQUEST CONCLUSIONS

The good news for North American semiconductor suppliers is that the largest semiconductor end market, data processing, has pulled out of its slump and is in a period of accelerating growth.

The bad news is that historically, whenever the semiconductor industry goes into a period of accelerating growth, the pattern has been subsequent decline. Figure 5 displays the historical relationship (1970 through 1986) between semiconductor consumption and electronic equipment production and includes our forecast through 1991.

Figure 5

COMPARISON OF SEMICONDUCTOR CONSUMPTION AND ELECTRONIC EQUIPMENT PRODUCTION



Source: Dataquest
August 1987

Based on the historical data, semiconductor suppliers should watch their customers' needs very closely to avoid the overordering that occurred in past upswings in the industry. Users may get nervous about lead times stretching out and product shortages, and may start to hoard product for future growth. The SAM monthly procurement survey brings this point home. The main concern of users continues to be memory, microprocessor, and ASIC supply shortages.

David G. Norman

Dataquest
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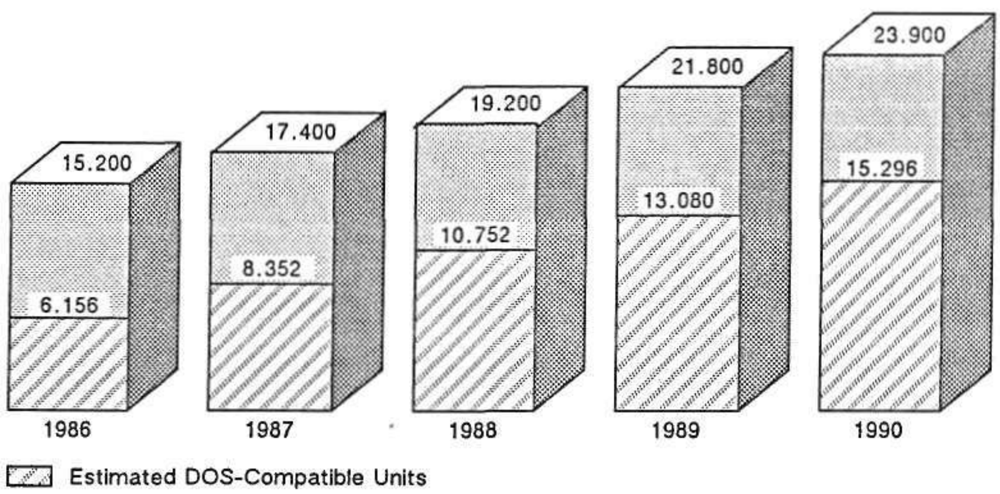
THE CLONES ARE COMING: CHIPS & TECHNOLOGIES INTRODUCES FIRST PS/2 MODEL 30 CHIP SET

EXECUTIVE SUMMARY

Less than four months after IBM's introduction of its next-generation PCs--the Personal System/2--Chips & Technologies, Inc. (C&T), has announced a chip set that allows clone makers to copy IBM's lowest-end unit--the Model 30. Although the Model 30 is really just an 8086 XT with a 3.5-inch floppy disk drive and not a true PS/2 because it lacks the Micro Channel architecture, the announcement does represent the commitment of chip set and PC clone makers alike to copy IBM no matter what it does. And although no one knows exactly how the PC market will divide between original IBM- and PS/2-type boxes over the next few years, one thing is certain--a lot of revenue is at stake. Dataquest estimates that worldwide shipments of PCs will grow from about 15 million in 1986 to almost 24 million in 1990. As illustrated in Figure 1, we expect DOS-compatible machines to account for almost 65 percent of world- wide shipments and nearly 75 percent of U.S. shipments.

Figure 1

PC MARKET--WORLDWIDE SHIPMENTS



Source: Dataquest
July 1987

Dataquest Incorporated, 1290 Ridder Park Drive, San Jose, CA 95131-2398, (408) 971-9000, Telex 171973

JUST HOW BIG IS THE PC CHIP SET MARKET?

Virtually every DOS-compatible PC manufacturer is a candidate for PC chip sets. This being the case, Dataquest believes that the total available market for PC chip sets could exceed $1 billion by 1990.

C&T, of Milpitas, California, was an early pioneer in the market in 1985 when it introduced a PC AT chip set that integrated the functions of more than 70 standard logic devices and controllers into just 8 VLSI parts. The primary significance of this development, aside from a reduced component count, is that the chip set has enabled competitors to quickly enter the market with reliable, low-cost, 100 percent compatible PC ATs.

Interestingly, these advantages proved so valuable that the 8-part chip set was able to command a price close to that of the 70 devices it was replacing. C&T became another of Silicon Valley's success stories, with revenue reaching $12.7 million in its first fiscal year and reported revenue of more than $80 million for fiscal year 1987, with about $48 million from PC system logic chip sales. Sikander Naqvi, vice president of marketing at C&T, claims his company has won AT designs at more than 90 companies, including Tandy, ITT, Mitec, Apricot, and Wang.

EVERYBODY IS JUMPING ON THE CHIP SET BANDWAGON

An opportunity as good as this was unlikely to be overlooked by competitors for long. Surprisingly, however, it was not until recently that a host of others decided that the market had real potential. New chip sets claiming fewer chip counts and lower costs soon appeared on the market. Table 1 provides an overview of current competitors shipping parts, the system performance, the number of chips in each set, and the total number of chips and cost for a complete AT system, excluding the microprocessor and memory.

It is likely that the list will not stop here. In Fremont, California, a company named Logic Star is becoming a clone's clone by introducing a chip set that is pin-for-pin compatible with C&T's products. In Japan, Kanematsu Semiconductor has teamed up with Sans Electronics and Award Software, of Los Gatos, California, to market an AT chip set. In addition, Dataquest has heard of several major Asian and U.S. semiconductor houses that are considering developing PC chip sets.

OEMs, too, such as Epson, Compaq, and Wyse, are starting to build their own chip sets. Even IBM, with its PS/2 line, has started to integrate system logic and controller functions into custom chips, as illustrated in Table 2.

Table 1

OVERVIEW OF PC AT CHIP SET MAKERS

Company	Chip Set	System Clock	Number of Chips for System	Total ICs for System	Total IC Cost for System*
C&T	N/A	10 MHz	6	47	$139
C&T	N/A	12.5 MHz	6	46	$145
Erso	N/A	12 MHz	2	73	N/A
Faraday	N/A	10 MHz	4	49	N/A
Faraday	N/A	12 MHz	2	65	$133
UMC	N/A	12 MHz	2	73	$147
VLSI Technology	VL Series	12.5 MHz	5	36	$124
Zymos	The Poach/AT	12 MHz	2	42	$133
Zymos	N/A	10 MHz	4	66	$132
Comparison with IBM PC AT		8 MHz	N/M	108	$150

*Excluding 80286 microprocessor and memory
N/A = Not Available
N/M = Not Meaningful

Source: VLSI Technology Inc.

Table 2

IC EVOLUTION IN IBM PERSONAL COMPUTERS

	IBM PC	PC AT	PS/2 Model 50
Total ICs	250	182	118
Standard Logic	200	128	82
Memory	41	41	26
RAM	256K	512K	1MB
Microdevices	9	9	4
Microprocessor	8088-4	80286-6	80286-10
8259A Interrupt Controller	X	X	X
8237 DMA Controller	X	X	
8253 Counter/Timer	X	X	
8255A I/O Port	X	X	
6845 CRT Controller	X	X	
D765 Floppy Controller	X	X	X
8250 Async Comm. Controller	X	X	
ASICs	0	4	6
PAL-Type		System Logic	System Logic
Custom VLSI			Control Graphics O/S2 Control?
System Features	No RDD Controller No Graphics	No RDD Controller No Graphics	RDD VGA Graphics

Note: An X means that the chip is included in that model. A blank space means that those functions have been transferred into ASICs.

Source: Dataquest
July 1987

WHY A SYSTEM 30 CHIP SET?

Contrary to what many industry observers, including Dataquest analysts, originally believed, IBM's PS/2 Model 30 is proving to be a fairly successful product. IBM claims that it has shipped more than 250,000 PS/2 machines, of which more than 50 percent are Model 30s.

The Model 30 provides IBM loyalists with low-cost entry into the PC market, and it shares the same 3.5-inch floppy as other PS/2 models. Reportedly, other differences exist between the Model 30 and other XT machines, including the following:

- The Model 30 can conduct DMA memory-to-memory transfers, allowing faster big block memory transfers.

- Several I/O ports of the Model 30 are mapped differently, which could affect connectivity to other IBM machines.

- The Model 30 has a more efficient power management mode, which effectively reduces system power consumption.

C&T's new Model 30 offering, the 82C100, is a single-chip CMOS implementation of most of the system logic and control functions required for the machine. C&T claims that its 10 MHz, 0 wait state 82C100 (with use of 100ns DRAMs) incorporates all of the unique features of the Model 30 and, in addition, provides on-chip interface to the Lotus/Intel/Microsoft Extended Memory System (EMS), allowing access to 2.5MB of system memory. Combined with three other C&T chips--the 82C606 CHIPSpak (combining two serial ports, one parallel port, and a real-time clock); the 82C754A (floppy drive data separator); and the 82C435 (an EGA-, CGA-, MDA- and Hercules-compatible graphics chip)--the company claims that a complete Model 30 can be built with about 13 components excluding memory. Figure 2 provides an overview of the C&T Model 30 system solution.

While C&T-based Model 30 clones are not expected to appeal to the IBM loyalists, the company foresees a large market for the $500 to $700 16-bit units that its chip set will spawn. C&T anticipates that these clones, by offering a 20 percent performance improvement over the Model 30 as well as compatibility at less than half the price of an IBM machine, can capture a large portion of the 3 million unit worldwide XT market. Additionally, the company perceives that the possibility of a "notebook-size" board with lower power consumption will win it a number of portable computer designs as well.

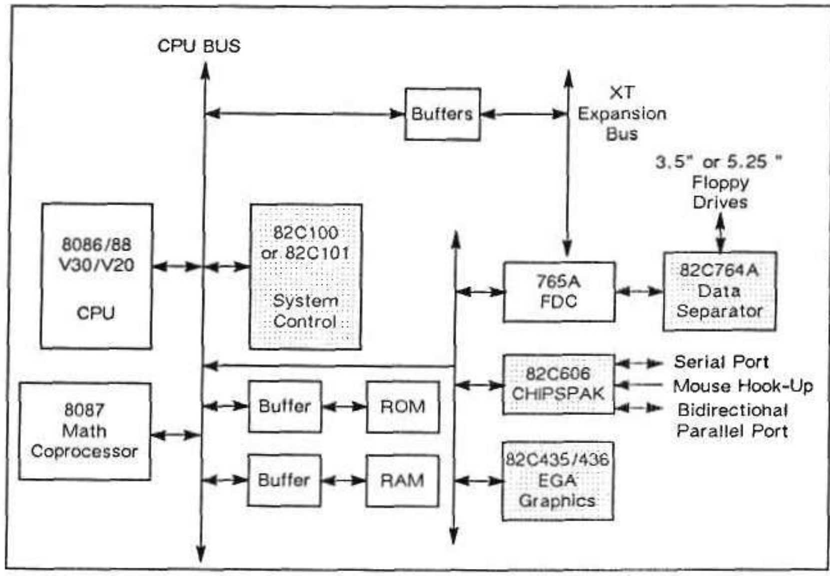
C&T's 82C100 system chip, packaged in a 100-pin plastic flat pack, is available for sampling in August, with production scheduled for October. The 82C100 is priced at $51.30 in OEM quantities of 100. The 82C606 CHIPSpak device, which also contains 114 bytes of CMOS SRAM for system configuration backup, comes in a 68-pin package and is priced at $23.40 in quantities of 100. It is currently available for sample, with production scheduled for August. C&T's 82C764A analog floppy disk data separator chip comes in a 28-pin plastic dual in-line package (DIP) and is priced at $7.80 in quantities of 100.

Figure 2

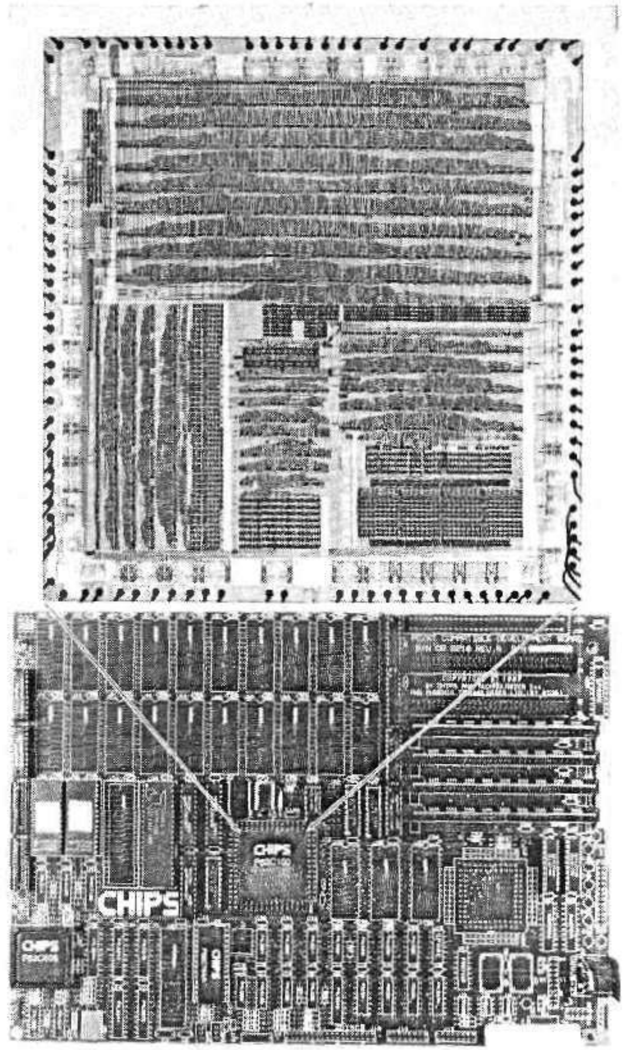
CHIPS & TECHNOLOGIES MODEL OVERVIEW

82C100 Integrates:

- 8284 Clock Generator
- 8288 Bus Controller
- 8237 DMA Controller
- 8253 Timer Counter
- 8255 Parallel Port
- Static RAM Control
- Keyboard Control
- Parity Generation and Checking
- EMS Logic
- Power Management
- Miscellaneous System Logic



System Board Block Diagram



C&T Model 30 Compatible System Board

Source: Chips & Technologies
Dataquest
July 1987

WHAT COMES NEXT--COULD IBM BURST THE MARKET'S BUBBLE?

Not surprisingly, several companies have announced intentions of cloning the entire PS/2 family. C&T, probably the most aggressive of these companies in terms of scheduling, has announced plans to "show something" at the Comdex show in Atlanta this fall. However, several issues will make this task difficult and perhaps insurmountable for today's clone chip builders.

Cloneability

Unlike IBM's old systems, the PS/2's Micro Channel architecture has not been well documented, nor has the innards of the machine's custom chips. Although C&T and others admit that this lack of documentation makes the job tougher, they are confident that their engineers will be able to accomplish the task. If so, perhaps the question should not be "Can they?" but rather "Can they get away with it?"

Issues of Legality and the Wrath of IBM

IBM reportedly is filing a number of patents to protect Micro Channel and has warned outsiders that its design is not free for the taking. Prospective competitors have argued that although IBM can legally (and deservedly) protect its exact designs, functionality belongs in the public domain. Although these legal fine points may have to be decided in a court of law, one thing is certain. Few, if any, of the chip builders have the resources to sustain a drawn out legal battle with IBM, the industry giant with more than $50 billion in annual revenue. This situation probably explains why no one except C&T is waving the PS/2 banner too forcefully. The cloners have handed C&T the right to be first, if it can survive as the sacrificial lamb.

If the Market Opens, Will the Foundries Close?

If and when the first two obstacles--cloneability and legality--are overcome, the market will begin to look much more attractive to many traditional semiconductor houses whose participation in the chip set business to date has been mainly as foundries. It is possible that chip makers not owning foundries may find themselves being squeezed out by their old sources, which have become new competitors.

Capacity still may become an issue, even with major companies that do not necessarily want to participate as PC chip set builders. Naturally, while the industry was experiencing its slump, it was advantageous to find any means to fill capacity. As the market begins its rebound, however, internal demands are rebuilding, which could potentially displace outsiders.

A final foundry issue affecting capacity is the Japanese trade restrictions. This issue has implications that go far beyond the relatively small chip set market but are worthy of consideration nonetheless.

Are Clone Builders Prepared for Surface-Mount and Automated Manufacturing?

A last "if" in the potential of the PC chip set business lies not with the IC makers, but with the box manufacturers. The PS/2 is truly a machine of manufacturing genius. It has been estimated that IBM invested more than $250 million in the advanced surface-mount and automated manufacturing capabilities for its new line of PCs.

The cost of entry into such advances, which is seen as necessary to compete in terms of systems integration and performance, runs at a minimum of $40 million to $50 million. Some Asian clone leaders such as Gold Star and Samsung, of Korea, as well as most Japanese manufacturers, have access to these resources; however, the slew of Taiwanese companies that rely on archaic production techniques and literally survive on margins of several dollars per unit may be headed for obsolescence. Furthermore, the large companies, which are capable of advanced manufacturing, are also capable of building their own chip sets.

We anticipate that many developments will be unfolding in the upcoming months in this most interesting market, and we look forward to closely tracking the progress.

Nanci J. Magoun

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STORAGE IMPACT OF THE PS/2 ANNOUNCEMENTS: AN ANALYSIS AFTER THE SETTLING OF THE DUST

INTRODUCTION

In April, IBM announced its new Personal Storage/2 (PS/2) Systems. These systems comprise four basic models that are the company's successors to its PC family of systems. Included in the four new systems were new configuration methods of bundling storage peripherals into systems, new data bus structures, new storage devices, and new interfaces and methods of connecting these devices to the respective systems. Because of the influence of IBM in the personal computer marketplace, its announcements are especially significant to all facets of the industry including manufacturers of storage peripherals. This newsletter picks up where the CSIS newsletter, "The IBM Personal System/2: Assessing the Impact," published in April, left off. It also provides details about the storage devices announced by IBM with the systems, addresses the overall impact of the PS/2 family on the storage device industry, and identifies areas of opportunity for storage peripheral manufacturers that will result from the new systems family.

THE NEW SYSTEMS' STORAGE DEVICES--AN AUDIT

The following is a summary, by model, of the new systems' storage-device offerings.

PS/2 Model 30

The Model 30 is IBM's entry-level system and is positioned by IBM to be the successor to the PC XT. It is a desktop, horizontally oriented system. The model 30 became available in April.

General Storage Characteristics

The Model 30 can be purchased with two 752-Kbyte, 3.5-inch floppy disk drives; or, with one 752-Kbyte, 3.5-inch floppy disk drive and one 20-Mbyte, 3.5-inch rigid disk drive.

Model 30 Bus

The Model 30 bus is functionally and electronically the same as the PC bus. Expansion boards designed for the PC family will function in the three available expansion slots.

Model 30 3.5-inch Flexible Disk Drives

Only one flexible drive model is offered with the Model 30. This is a 752-Kbyte (1-Mbyte, unformatted), 3.5-inch drive. The drive has a standard height 3.5-inch physical form factor.

The flexible drives attach to the computer motherboard (and its integrated flexible drive control unit) via a cable. Of the PS/2 systems that Dataquest has observed, all the flexible drives were manufactured by Alps. We believe that Toshiba and Hitachi also have contracts to supply these drives to IBM.

Model 30 Rigid, Fixed-Media Disk Drives

Just one hard disk model is offered with the Model 30 and it must be ordered for installation with the system in which it is used.

The following are the basic specifications of the drive:

- Average access time: 80 msec
- Maximum access time: 180 msec
- Bytes per sector: 512
- Sectors per track: 17
- Capacity: 20.8 Mbytes (formatted)

The Model 30 rigid disk has a standard 3.5-inch physical form factor; but the drive incorporates, on its circuit board, the entire control unit with a PC bus interface. It cables directly to a special system motherboard connector. The drives that we have seen were manufactured by IBM at its Fujisawa, Japan, plant. We believe that IBM has begun (or will shortly begin) shipments from alternate source(s) for the drive. Miniscribe is said to be one of these alternate sources under contract to IBM and has been developing the IBM proprietary interfaces for the drives that it will ship to IBM for its Models 30 and 50.

Model 30 Optical Disk Drive

The Model 30 can have two of IBM's new 5.25-inch optical disk drives attached. The drive models for the PS/2-30 are the 3363 Model A01 and the 3363 Model B01. The Model A01 includes a special controller card that inserts into one of the three expansion slots in the Model 30. The drives are freestanding external models. The basic specifications are as follows:

- Capacity: 200 Mbytes (formatted)
- Burst data rate: 2.5 Mbits per second
- Average seek (over 1/3 of the surface): less than 230 msec
- Average seek (up to 101 tracks): less than 45 msec
- Bytes per sector: 512
- Sectors per track: 23
- Tracks (spiral): 17,100
- Interface: IBM unique
- Media: WORM (believed to be ablative)
- Media price: $65.00

IBM claims to purchase the mechanical assembly from Matsushita, but the electronics PCBA is manufactured by IBM. The 3363 will be available during the second quarter of 1987.

The 3363 is also available for attachment to the new PS/2 Models 50, 60, and 80. Also it can be attached to, and is supported for, the existing PC and PC XT. Table 1 lists the various possible configurations:

Model 30 5.25-inch External Diskette Drive

A 5.25-inch, 360 Kbyte drive is available for external attachment via a half-length feature card to permit use of data and software on 5.25-inch diskettes.

Model 30 Data Migration Facility

IBM has provided a data migration facility at low cost ($33) comprising a special cable and software (on a 5.25-inch diskette). This enables transfer of data from an installed 5.25-inch based PC system directly to a PS/2 system and its 3.5-inch diskettes, thereby alleviating the need for an extra 5.25-inch flexible drive. This facility uses a printer output port on the sending PC.

Table 1

IBM PS/2 AND PC OPTICAL DISK DRIVE OFFERINGS

Model	Physical Location	Availability	PC, XT, and ST	PS/2 Models 30	50	60	80	Price
A01	External	2Q87	X	X				$2,960
A11	External	3Q87			X	X	X	$2,960
#8700	Internal	4Q87				X	X	$2,700
B01*	External	2Q87	X	X	X	X	X	$2,365
Maximum Drive Pairs and Used Expansion Slots**			1	1	3	4	4	
Maximum capacity (Mbytes)			400	400	1,200	1,600	1,600	

*The B01 is a "slave" drive attaching via an A01, A11, or #8700. The only B01 can be attached to an A01, A11, or #8700.
**One expansion slot is required for each drive pair.

Source: IBM
Dataquest
July 1987

PS/2 Model 50

The Model 50 is the new system entry that has been positioned by IBM as a replacement for the AT. It is a desktop, horizontally oriented system. The Model 50 became available in April 1987.

General Storage Characteristics

The Model 50 comes with one 1.44-Mbyte, 3.5-inch flexible disk drive, a 20-Mbyte, 3.5-inch Winchester disk drive, and a hard disk controller. It comes with four 16-bit input/output slots with one being occupied by the hard disk controller. Space is provided within the chassis for a second flexible disk drive.

Model 50 Bus

The bus used in the Model 50 employs the new IBM Micro Channel Architecture. This bus is unique to the new Models 50, 60, and 80. IBM publishes the following technical manuals that describe the Micro Channel Architecture:

- The Technical Reference Manual is intended for use by engineers and programmers who are developing hardware and software for use with the IBM 8550 and IBM 8560 systems.

Major topics in this manual include system bus interface, adapter design, system board components and operation, system board I/O controllers, power supply, keyboard, instruction sets, characters and keystrokes, and compatibility. BIOS listings and interface information are not included.

- The Personal System/2 and Personal Computer BIOS Interface manual documents the BIOS interface for the IBM Personal System/2 and IBM Personal Computers.

Model 50 3.5-inch Flexible Disk Drive

The basic Model 50 includes one 1.44-Mbyte, 3.5-inch flexible disk drive. A second drive can be added, also as an internal drive. As is true of all the new PS/2 systems, the flexible disk controller is integrated into the system motherboard. The drive has two modes of operation. In low-density mode, it is compatible with the 720-Kbyte drive used on the Model 30. The high-density mode takes full advantage of the drive's 1.44-Mbyte capacity. Specifications of the drive in the standard mode include:

- Media capacity: 2 Mbytes (unformatted)
  1.44 Mbytes (formatted)
- Capacity per track: 12.5 Kbytes (unformatted)
  9 Kbytes (formatted)
- Track density: 135 tpi
- Tracks per surface: 80
- Heads: 2
- Transfer rate: 500 Kbits per second
- Access time:
  - Track to track: 6 msec
  - Seek settle time: 15 msec
- Maximum motor start time: 500 msec
- Diskette speed: 300 rpm

Model 50 Rigid, Fixed-Media Disk Drive

One fixed-media drive comes as standard with the Model 50. Its performance specifications are identical to the drive in the Model 30. The head and disk assembly (HDA) is the same as the 3.5-inch drive in the Model 30 and is initially being manufactured by IBM at Fujisawa, Japan. Unlike the Model 30's drive, the drive in the Model 50 has a modified ST412 interface with a unique printed circuit board-edge connector. The drive is situated on the center of the system cabinet and its board-edge connector fits directly into the drive control unit board, which occupies the expansion slot farthest right. There appears to be physical space for just the one 3.5-inch drive; and IBM, with its recent announcement, does not offer any options to the basic 20-Mbyte drive.

Model 50 Optical Disk Drive

The Model A11 and B01 optical disk drives are available for the Model 50. Up to three optical drive controller cards can be installed in the Model 50's expansion slots, permitting up to six drives (1.2 Gbytes). The optical disk for Models 50, 60, and 80 will be available in the third quarter of 1987.

Model 50 5.25-inch, External Flexible Disk Drive

Like the Model 30 (and 60 and 80), an external 360-Kbyte, 5.25-inch flexible disk drive is available to enable direct compatibility with 5.25-inch diskettes. This external drive attaches via a half-length feature card in one of the expansion slots.

Model 50 Data Migration

The same capability offered with the Model 30 (as described earlier in this newsletter) is available for the Model 50.

Model 50 Tape Drive Adapter

The PS/2 Models 50, 60, and 80 have available a 1/4-inch streaming tape drive adapter (requires one expansion slot) for IBM's 6157 tape drive (supplied to IBM by Cipher Data). The adapter will be available in September 1987 at a price of $350.

Disk Cache Program

A software package is available to enhance disk performance for most applications wherein a user-selectable block of system memory is set aside as cache memory under the control of this special software.

PS/2 Model 60

The Model 60 is a new tower, floor-standing (deskside) configured system based on the 80286 processor. The Model 8560-41, with a 44-Mbyte fixed-media disk, was available as of April 1987; and the Model 8560-71, with a 70-Mbyte fixed-media disk, will be available in the second quarter of 1987.

General Storage Characteristics

Both basic models come standard with one 1.44-Mbyte, 3.5-inch flexible disk drive and with either a 44-Mbyte or a 70-Mbyte, full-height, 5.25-inch, fixed-media disk drive. There is physical space in the system cabinet for a second full-height, 5.25-inch fixed-media drive and for a second 3.5-inch flexible disk drive.

Model 60 Micro Channel Architecture Bus

The Model 60 Bus uses the new Micro Channel Architecture (as described previously in the Model 50 section of this newsletter). There is provision in the Model 60 cabinet for eight expansion slots. (One is occupied by the fixed-disk controller.)

Model 60 3.5-inch, Flexible Disk Drive

The Model 60 uses the same 3.5-inch flexible drives as described for the Model 50--one standard and one optional. The flexible disk control unit is integrated into the system motherboard.

Model 60 Rigid, Fixed-Media Disk Drives

The Model 60 allows two separate approaches to incorporate rigid drives into the system. The approaches are based on the ST412 and the ESDI interfaces, respectively.

ST412-Based Drives - The 8560-041 Model 60 is available with only the 44-Mbyte, ST412-interfaced, full-height, 5.25-inch drive. The disk drive adapter (controller) is designed for operation of only ST412-interfaced drives. The 44-Mbyte drive will initially be produced by IBM at its Rochester, Minnesota, plant. (Dataquest believes that the company can also produce these drives at its Havant, United Kingdom, plant.) As the system is now offered, a second 44-Mbyte drive is the only option that can be ordered from IBM to meet increasing capacity requirements on the 8560-041. The 44-Mbyte (Model 3046) add-on drive will be available in the third quarter of 1987 and is priced at $1,395. The drive's basic specifications are as follows:

- Average access time: 40 msec
- Track-to-track access time: 10 msec
- Maximum access time: 80 msec
- Bytes per sector: 512
- Sectors per track: 17
- Cylinders: 733
- Capacity: 44 Mbytes
- Transfer rate: 5 Mbits per second (formatted)

ESDI-Based Fixed Disk Drives - The 8560-071 Model 60 is provided with a 70-Mbyte, ESDI-interfaced drive and with an ESDI control unit board in the expansion slots. This board cannot work with the 44-Mbyte drive mentioned above. Two avenues of capacity expansion are currently provided by IBM: adding a second internal 70-Mbyte drive or adding a second drive of 115-Mbyte capacity. (The ESDI interface is believed to be the modified ESDI interface that IBM began using on its RT PC drives in mid-1986.) The 70-Mbyte drive as an add-in unit will become available in the third quarter of 1987 and is priced at $2,395. The 115-Mbyte drive as an add-in unit will become available in the fourth quarter of 1987 and is priced at $3,495. Both of these drives are being produced in IBM's Rochester, Minnesota, plant (with probable backup manufacturing planned for Havant, United Kingdom).

The basic specifications of the 70-Mbyte drive (Model 3051) are as follows:

- Average seek: 30 msec
- Track-to-track seek: 5 msec
- Maximum seek: 60 msec
- Bytes per sector: 512
- Sectors per track: 36
- Cylinders: 583
- Capacity: 70 Mbytes (formatted)
- Transfer rate: 10 Mbits per second
- Form factor: Full height, 5.25-inch

The basic specifications of the 115-Mbyte drive (Model 8730) are as follows:

- Average seek time: 28 msec
- Track-to-track seek time: 6 msec
- Maximum seek time: 60 msec
- Bytes per sector: 512
- Cylinders: 915
- Capacity: 115 Mbytes (formatted)
- Transfer rate: 10 Mbits per second
- Form factor: Full height, 5.25-inch

Model 60 Optical Disk Drives

As shown in the discussion in the Model 30 section of this newsletter, the Model 60 can accommodate all models of the new 3363 optical disk drive. In its Model 8700 configuration, one drive can be mounted in the system cabinet. (It requires the extra rigid disk drive mounting position for this, however.) In its Model A11 and B01 configurations, these optical drives can be external to the system cabinet. A total of eight drives can be attached to the Model 60. (However, these will require four controller cards and four of the available expansion slots.) The drives are supplied with the necessary support software (including a save/restore function) and a diagnostic diskette. The A11 version will be available in the third quarter of 1987, the 8700 in the fourth quarter of 1987, and the B01 in the second quarter of 1987.

Model 60 External 5.25-inch Flexible Disk Drive

The same drive that is available on the Model 50 is available on the Model 60.

Model 60 Data Migration Facility

The same facility that is described in the Model 30 section is available for the Model 60.

Model 60 Tape Drive Adapter

The same adapter that is described for the Model 50 is available for the Model 60.

Model 60 Disk Cache Program

As with the Model 50, a disk cache program is available on the Reference diskette (shipped with the system) that allows the user to optimize the disk performance of his/her system for his/her application by assigning appropriate amounts of disk cache storage.

PS/2 Model 80 (8580-041 and 8580-071)

This 80386-based system in a tower, floor-standing (deskside) configuration offers a list of storage options identical to the Model 60. Refer to that section of this newsletter for details. These Model 80 systems are scheduled to be available in July 1987.

PS/2 Model 80 (8580-111)

This system is similar to the 8580-041 and 8580-071 models listed above. However, from a storage device perspective, the Model 8580-111 differs only in that it is supplied with a 115-Mbyte fixed-media disk as standard. The system can be augmented with either another 115-Mbyte drive or with a 70-Mbyte drive. The details of these drives have been covered in preceding sections of this newsletter and will not be repeated here. The Model 80 (8580-111) will be available in the fourth quarter of 1987.

GENERAL PS/2 STORAGE IMPLICATIONS

IBM's moves in the personal computer marketplace have far-reaching implications for all facets of the industry, including the storage peripheral industry. IBM's 1986 U.S. personal computer market share led the industry at 19 percent. (Apple was second with 10.7 percent.) IBM's share of the IBM PC and compatibles market, while declining steadily from its 100 percent share in 1981, was a respectable 41.9 percent in 1986. With these percentages, IBM commands significant influence, and it is clear that the new PS/2 product line is the vehicle that IBM hopes to use to reverse its declining market share trend.

Flexible Drive Formats

The PS/2 systems family marks IBM's total move to the newer 3.5-inch format. Dataquest believes that this move into the 3.5-inch format means the definite decline of the 5.25-inch flexible drive market. IBM is being followed into the 3.5-inch era by a growing number of companies who have supplied software for IBM systems. In spite of the large installed base of systems that use 5.25-inch media, Dataquest believes that software producers must now offer products in both formats and that systems designers must base their future systems designs on the 3.5-inch format.

It is clear that IBM is making this move after providing as easy as possible a migration path for users of 5.25-inch media to the new format. The company has provided three methods of allowing program and data interchange between the 5.25-inch installed base of PC systems and the new 3.5-inch based PS/2 systems:

3.5-inch Drives for Installed-Base PCs

All PS/2 systems can read 720-Kbyte (formatted) diskettes. (The PS/2 Model 30 uses the 720-Kbyte drive and PS/2 Models 50, 60 and 80 use 1.44 Mbyte flexible drives that have a 720-Mbyte diskette read capability.) Flexible drives of the 3.5-inch, 720-Kbyte format are available for previous PC models to enable media interchangeability with the new systems. This is the recommended approach if it is likely that the PS/2 systems at a site will outnumber the installed base of PCs.

While IBM has in its drive stable all the models needed for attachment to its various PCs, Dataquest believes that there is still a significant installed-base market available to non-IBM drive and subsystems suppliers with price-competitive 3.5-inch drives.

5.25-inch Drives for the New PS/2 Systems

IBM has also provided 5.25-inch flexible drive models to enable media compatibility at the PS/2 systems side. This is most attractive if the number of PS/2 systems is fewer than the number of installed PC systems at a specific site or organization.

Again in this instance, IBM has provided the necessary drive models (all external units) in its product stable to cover this requirement. As with 3.5-inch drives, we believe that a significant short-term market may exist for 5.25-inch drive sales by third-party participants.

Data Migration Facility

IBM has provided for a low-cost ($33) facility for one-time transfer of existing data and/or software from an installed PC to a new PS/2 system's 3.5-inch format. This, of course, requires proximity of the two systems. The facility comprises a cable for attaching the printer output port on the PC to the input port on the PS/2 system and a special 5.25-inch diskette with the data transfer program for the PC. (The program for the PS/2 system side of the transfer is provided on the standard 3.5-inch set up diskette for the PS/2.)

Dataquest believes that this offering is a very astute move by IBM and will reduce the cost of conversions by its installed base (and perhaps by that of the competitive PC clone installed base) to the new systems. For colocated systems, the facility will probably be the users' preference for media compatibility, and will reduce the market for independently supplied 3.5- and 5.25-inch flexible drives for that purpose.

Rigid Drive Form Factors

IBM's rigid drive choices are basically conservative. The company has not gone very far out on the new technology limb. For the low-end Models 30 and 50, the company has chosen the 20-Mbyte 3.5-inch drive. While it is a relatively new drive from IBM's Fujisawa factory, the 20-Mbyte 3.5-inch drive is well down the industry's learning curve. IBM's use of 20-Mbyte drives indicates, we believe, a conviction within IBM that there will be significant numbers of new entry-level systems buyers to whom 20-Mbyte drives offer more than enough storage capacity for their business computing jobs. Dataquest concurs with that conviction and anticipates a future need for 20-Mbyte drives (of increasingly lower prices).

We believe, however, that IBM will find that Model 50 buyers are soon likely to be asking for more capacity than the 20-Mbyte drives now offered by IBM. If IBM is slow in responding to this need, a solid opportunity may emerge for the fast-moving third party suppliers of drives and/or subsystems.

IBM's choice of formats for the Models 60 and 80 were also technically conservative. The drives are all full-height, 5.25-inch drives, and the peak capacity drive offered today is the 115-Mbyte drive. It appears to us that, depending on BIOS, power supply, and physical mounting limitations, a potential for a significant add-in drive business exists using either half-height or full-height drives of higher capacities, faster performance, and lower costs per Mbyte than the drives offered by IBM. Regardless of the development of the add-in market, we believe that the computing power (particularly of the Model 80) will fuel a capacity demand that will fast outdistance the peak of 230 Mbytes available from IBM.

Rigid Drive Interface Standards

Has IBM contributed to a clearing up of interface standards issues for rigid drives in its new PS/2 systems? At the drive level, IBM's new PS/2 systems have incorporated no less than four interfaces. Therefore it appears that, if anything, the standards picture may have become somewhat more cloudy. The following discussion addresses each of the interface approaches taken by IBM in its new systems, and suggests an apparent interface loser in the race for use on the new IBM systems.

PC Bus Interface

In a step that Dataquest expects to become more common among the larger systems manufacturers, IBM chose for its model 30 to integrate the full PC bus interface onto the 3.5-inch rigid drive's printed circuit board. This drive mates directly to the PC bus via a direct cable. This control unit implementation approach follows that used in systems announced by Compaq in the fall of 1986. IBM achieved the necessary circuit density via VLSI and surface mount techniques. Perhaps the most surprising thing about IBM's PS/2 systems announcements is the fact that the Model 30 was the only one to use the proprietary bus approach.

Modified ST412 Interface

For its Model 50, IBM uses a modified ST412 interface on the 20-Mbyte 3.5-inch drive that is offered with that system. While Dataquest has not had an opportunity to make a technical evaluation of the electrical composition of the Model 50 drive's interface, it is evident that the physical interface is nonstandard. IBM uses a board-edge connector to attach this drive directly to the control unit board which mounts at right angles to the drive and occupies the right-most expansion board slot in the Model 50 chassis. We believe that the electrical interface may also be modified, perhaps with a data separator that is located on the drive. To date, we have been unable to confirm this. The control unit board is, of course, unique to the new system and handles the control attachment to the new Micro Channel Architecture.

There is some conjecture as to why IBM did not develop a new control unit in the drive so that this drive could connect directly to the Model 50's bus in an approach similar to the one taken with the Model 30. There may be one or several plausible reasons for this:

- While being a company of seemingly unlimited resources, IBM may simply have been unable to tackle a second VLSI disk controller design program in the time frame allowed for the release of the PS/2 systems.

- The control unit in the Model 50 may not be substantially different than the ST412 controller used in the Models 60 and 80. Therefore, the company effectively got two controllers for the price of one. (All of these systems are based on the new Micro Channel Architecture.)

- IBM may have plans to offer a higher capacity drive for the Model 50 in the near future. Using the more standard drive interface approach allows the company to offer upgrades while sidestepping an entire drive circuit redesign effort.

We believe that it is likely that IBM will eventually cut manufacturing costs of the Model 50 by designing the full drive control unit capability into the rigid drives offered with the system. This would eliminate the costly extra full-slot controller board now required. (Reports are that Miniscribe is currently doing this for some of the drives that it will ship to IBM.)

<u>ST412 Interface</u>

The 44-Mbyte drive offered with the new Models 60 and 80 uses the standard ST412 interface (electrically and physically). This full-height drive uses the standard cable attachments for the system's power source and control unit. To handle the control unit functions, IBM has designed a new control unit board for the interface to the new Micro Channel Architecture. Dataquest has witnessed non-IBM drive operation of the Model 60 via this control unit and this seems to confirm that the ST412 interface on these models is the "plain vanilla" ST412. It appears that, within the limits of the BIOS format tables, this interface can handle most ST412-interfaced drives.

<u>ESDI Interface</u>

The 70- and the 115-Mbyte drives available with the Models 60 and 80 use what IBM calls the "extended" or the "high-performance" ESDI interface. This is the IBM implementation of ESDI as first offered for the RT PC system. (In fact, coincident with the PS/2 systems announcements was the announcement of availability of the 114-Mbyte version of the drive for RT PC systems.) To attach these drives to the system, they are cabled to an ESDI-to-Micro Channel Architecture control unit. (The Models 60 and 80 are supplied with only one rigid drive controller ST412 or ESDI depending on which drives are ordered with the system.) IBM's use of ESDI allows the connection of the higher bit-density, higher transfer-rate drives with its high-end systems. Dataquest feels that it is less probable than in the Model 50 situation that IBM will integrate control unit functions into the drives for these high-end systems.

<u>SCSI Interface</u>

The loser in this flurry of interface introductions by IBM is the SCSI interface. Dataquest still anticipates that the SCSI interface will become a very prominent interface for small-diameter drives in the future. This is particularly true for systems developed by the smaller systems integrators and subsystems manufacturers who do not have the resources to design (or to fund design) of a proprietary bus interface as IBM did for the Model 30. As mentioned earlier, we expect IBM to take the proprietary interface approach for its Model 50 in the future. IBM's strategy seems, therefore, to be one of using embedded proprietary controllers at the low end and higher-performance device interfaces (ESDI) at the high end.

IBM's middle-road selection of the ST412 interface allows the company to satisfy the requirements of the Model 60 and/or Model 80 entry-level user by using the existing 44-Mbyte drives being manufactured by IBM and/or its outside vendors. It is likely that IBM will offer higher-capacity drives (particularly for field upgrades of drive capacity) either through captively produced drives in the 70- to 80-Mbyte range or through acquisition of such drives from outside OEM vendors. (Dataquest speculates that IBM's recent contract with Seagate for ST412-interfaced 51- and 96-Mbyte drives may be a step in this direction.)

In conclusion, Dataquest sees the new IBM announcements not as a vote against SCSI as an interface, but rather as a commitment to proprietary interfaces (at least at the low end) and to higher-performance (ESDI), device-level interfaces at the high end.

Optical Disk Implications

As a part of the PS/2 systems announcements, IBM made its first major systems commitment to optical storage for general use. The 200-Mbyte, 3363 5.25-inch, write-once read many times (WORM) drive is fully supported by IBM's software as a general storage device for its PC, PC XT, PC AT, 3270 PC AT, and all PS/2 systems. IBM's software provides the general support to enable the optical disk to appear to the user application as a general rewritable storage device. IBM, at least in its initial release, has not provided application-specific software; so the optical drive is provided to the systems user a storage tool. IBM's software allows the use of multiple versions of files with new commands that look like standard DOS commands. A new save/restore feature allows an automatic audit trail and data archive capability.

Dataquest believes that, as in many initial optical offerings, IBM's strategy is to provide users with a capability for user-specific applications. The drive is provided as a supplement to a fixed, (magnetic) disk for high capacity storage, and for applications where removability of the disk is important (for example, security, archive, portable data, and personal disks for individual uses). The drive's 200-Mbyte capacity is relatively conservative and appears to indicate IBM's conservative approach to entry into this new technology. The technology's availability from and endorsement by IBM may lead to a growing number of applications-oriented subsystems and/or software companies that will develop uses for this tertiary-level storage technology.

IBM's conservative product offering (in terms of capacity) may open up a plug-compatible, higher performance/higher capacity market for other optical disk drive manufacturers.

Tape Drive Implications

IBM's PS/2 systems can utilize the 6157 tape drive adapter previously used on IBM's PC systems. A new adapter board that requires one of the expansion slots was announced with the PS/2 systems. The 6157 (made for IBM by Cipher Data) is a 1/4-inch streaming drive that uses standard cartridges and is an external drive (as presently announced). Speculation is mounting regarding IBM's plans for an internal-mount tape drive for the PS/2 series. IBM has released requests for quotes to potential suppliers for 1/4-inch streaming tape drives in both the 5.25-inch and the 3.5-inch form factors. Also possible is the addition of an external drive based on the 3480 cartridge technology that IBM has cross-licensed to Cipher. Regardless, there may be an ongoing market opportunity for manufacturers of 3.5-inch form factor drives for add-on installation in one of the flexible drive slots.

IBM chose not to incorporate into the initial release of the PS/2 family any new tape drive designs or any new tape drive interfaces. In doing this, IBM has waived the advantages of using tape drives having the SCSI or the ESDI interfaces while at the same time skirting the potential disadvantages of using these new interfaces. By choosing the 6157 for the PS/2 systems, IBM had to design a new control unit board to connect the drive to the new Micro Channel Architecture bus and in each of the systems (Models 50, 60, and 80) the tape feature requires one expansion board position. The cost of that control unit board and the lost slot could have been avoided by using either the ESDI or the SCSI interface sharing the attachment cost with the system's rigid disk drives. Reasons why IBM chose the more conservative approach of a separate tape drive control unit probably include:

- High development costs (both dollar and time)
- Lack of multiple source availability or tape drives with the SCSI or ESDI interface
- Significant unresolved performance problems of controlling both serial access tape drives and random access rigid disk drives using just one control unit

It is still possible that future storage options for the PS/2 family may allow coexistence of tape and rigid disk drives using interfaces like SCSI or ESDI. Today the risk seems to outweigh the advantages.

PS/2 General Storage Market Implications

IBM's PS/2 systems announcements have several significant effects on the storage peripheral market. The following discussion will address this impact from three points of view: IBM as an OEM buyer, the IBM aftermarket, and the OEM sales potential to manufacturers of IBM clone systems.

IBM as OEM Buyer

Depending on the device, IBM acquires the storage peripherals for its new systems from both the OEM marketplace and captive manufacturing.

Flexible Drives - IBM is purchasing all its 3.5-inch drives from OEM channel suppliers. We would not expect this to change unless the prices for such drives rise too high because of economic conditions such as continued devaluation of the dollar against the yen. It appears, however, that at least one of IBM's suppliers of flexible drives (Alps) is assembling these drives on U.S. soil, in southern California.

__Rigid Drives__ - All of the drives announced for the new PS/2 systems are manufactured captively by IBM. Dataquest believes that IBM will establish alternate suppliers for these drives from suppliers in the OEM segment. Thus far, IBM appears to have established the following external suppliers:

- Miniscribe for 3.5-inch drives for Models 30 and 50
- Seagate for the 44-Mbyte 5.25-inch drive on Models 60 and 80
- Seagate for (we speculate) a future 80-Mbyte drive extension to the ST412 interface-based Models 60 and 80

IBM's current source for the 3.5-inch drives that it uses on the Models 30 and 50 is its Fujisawa plant in Japan, which now is producing 3.5-inch drives to the near-total exclusion of 5.25-inch drives from that factory. (The short life cycle of the 10- and 20-Mbyte, 5.25-inch drives produced at the Fujisawa plant from mid-1984 to the end of 1986 must stand as a record for the shortest storage peripheral product life in IBM's history.) As such, IBM must be experiencing the same cost pressures as native Japanese producers when they address the U.S. markets with the dollar so deflated. Recent Japanese trade press articles have appeared suggesting that IBM is considering moving the production of its peripherals to either Korea or Taiwan (or both). Dataquest has been unable to find any concrete evidence that this kind of move is underway. It is likely that IBM does make these business evaluations on a regular basis, and such a move could be made in the future to help control its drive costs. Also likely is the continued evaluation of non-Japanese alternate sources of 3.5-inch drives (in addition to Miniscribe). We believe that IBM's long-term supplier, Seagate, would be high on the list of possible of alternative sources for these commodity-like products.

It is also possible that IBM may place nearly full dependence for some of its low-end drives on outside vendors as it equips its factories to produce future higher-capacity, higher-performance drives, thus allowing IBM to continue captive manufacturing of its state-of-the-art main-line drives. This may be part of the strategy at work in Seagate's recent announcement of a contract with IBM for 51-Mbyte, 5.25-inch drives. These drives may replace IBM's captively produced 44-Mbyte (formatted) drives.

Dataquest believes that IBM must be considered as a prospect for higher-capacity 3.5-inch drives, either for these or follow-on PS/2 family members. IBM is undoubtedly developing higher-performance, higher-capacity 3.5-inch drives; but IBM will probably find it necessary to rely on outside-sourced drives here, as well.

__Optical Drives__ - IBM now procures the mechanical assemblies for its 5.25-inch optical drive from Matsushita. (IBM manufactures its own printed circuit boards for the drive.) We believe that it is likely that IBM will rely on outside sources for these optical drives, at least until shipment volumes begin to accelerate.

Also probable from IBM in the near future will be CD-ROM drives to enable use of the new PS/2 systems as workstations using the emerging variety of applications on CD-ROM media.

Aftermarket Prognosis

IBM's new approach to marketing these systems will have a negative impact on the aftermarket business. IBM clearly intends to reserve a major portion of the rigid drive storage market for itself. The Models 50, 60, and 80 must all have a minimum of one rigid disk drive when the systems are sold. We believe that it is unlikely that (barring very large OEM systems sales by IBM) IBM will sell the PS/2 systems in an unbundled fashion. Even the Model 30 requires a configuration of either two flexible drives or of one flexible and one rigid drive. This policy will definitely place a large dent in the time-of-sale rigid drive add-in market.

An immediately available market for aftermarket market sales is the drive-on-a-card (DOAC) market. However this DOAC market is initially limited to the Model 30 with its PC bus architecture. The one negative factor in this approach is that it consumes one of the limited (three) expansion slots in the Model 30.

An additional market may develop in the removal and replacement of one of the two flexible drives in the Model 30 with a higher-capacity and higher-performance 3.5-inch drive than the one offered by IBM. This requires writing off the cost of a flexible drive, which causes the approach to lose some of its appeal.

We believe that other aftermarket opportunities exist such as the development of DOACs that are compatible with the new Micro Channel Architecture (and the new two-level BIOS) for installation in the 50, 60, and 80 models. Also, we believe that a new opportunity exists for disk arrays and/or higher-performance and higher-capacity drives for attachment to these high-end systems. Crucial to aftermarket success, however will be the flexibility of the new BIOS. We suspect that, over the next few months, much time will be invested in studying these options and identifying the opportunities. IBM has basically left the architecture open, albeit different. There is some truth in the statement that this will offer new opportunities; but to identify and cultivate them will take time, and some of the current suppliers to the PC markets may see some lean times until they unlock the new opportunities offered by the PS/2 systems.

Generally, Dataquest believes that the aftermarket will see a downturn in sales once momentum builds for the new PS/2 systems. This will be softened somewhat by the large installed base of PC systems. Also, the major buildup in PS/2 sales may (fortunately for the aftermarket suppliers) be delayed until 1988 when IBM's new Operating System/2 becomes available. In the meantime, aftermarket participants have some breathing space in which to plan strategies for life in the new PS/2 future. As new applications emerge for the PS/2 systems, we believe new opportunities for storage device suppliers will follow.

The IBM-Clone OEM Drive Market

In 1986, IBM commanded 41.9 percent of the U.S. PC compatible market. The remainder of that market was won by companies with clone products. Dataquest believes that the PC compatible market is softening as a result of the new PS/2 systems announcements while businesses evaluate strategies to meet their computing needs. IBM will not have its Operating System/2 available until the first quarter of 1988 (with its Version 1.1 that will support graphics and windowing some time later). Therefore not all the hardware features of the new systems will be usable this year. Thus, partly for this reason, we expect a short-term recovery in the PC clone market. This should extend the tagalong sales of storage peripherals to this market.

The challenge presented by IBM's PS/2 designs to the traditional and would-be clone manufacturers is significant. IBM has integrated many of the system's proprietary features via surface-mount devices right on the motherboard. That, coupled with IBM's design protection either by patents or copyrights, will stretch out the developments of the clone producers while they emulate IBM features in independent designs. Some believe that it will be a minimum of 18 months before clone systems hardware will be available. It is possible that competitors to IBM for the PS/2 markets may shorten the time to market by using hardware implementations that are different from PS/2 but that offer equivalent performance and are still compatible with the new Operating System/2. These extended development periods (notwithstanding the effects of the delayed delivery of IBM's Operating System/2) may result in a six- to nine-month slump in storage peripheral sales to these companies beginning in the third or fourth quarter of 1987.

IBM's pricing of its new systems is higher than expected. This fact (along with IBM's price reductions on its previous generation of PC systems) will tend to encourage continued acquisition of the previous generation of PC systems, either from IBM dealers or from the jobbers of clone systems. That should help support the demand for clone systems at least through third or fourth quarter of this year. An examination of the new PS/2 systems designs indicates at least two things: very high IBM-produced component complement; and a physical systems design that enables a high degree of automated assembly and test (and that also facilitates very easy field replacement of defective components). Both of these factors indicate that IBM has plenty of room for price improvement should competition warrant it. We anticipate neither significant clone competition nor price adjustments by IBM until 1988.

DATAQUEST CONCLUSIONS

As is true of most IBM announcements, the PS/2 systems bear both good and bad news for storage peripheral producers. These systems will alter, more than eliminate, the traditional markets for storage peripherals used on IBM and IBM-compatible systems. The industry is now in a transition phase: the waning moments of the IBM-PC era and the early moments of the new PS/2 and PS/2-compatible era. We believe that, as this segment evolves toward the PS/2 environment, opportunities will continue for storage peripheral manufacturers. These opportunities will occur in all the traditional channels for storage peripherals: OEM to IBM, aftermarket, and OEM to clone manufacturers. IBM clearly is making a strong bid both to improve its position as a systems supplier by reversing its continuous loss of market share in the market it has created and, also to retain at least the initial-sale business for rigid disk drives on its new systems. Even though IBM assures itself of at least most of the initial rigid drives sales with its systems, it will still probably have to purchase at least a part of its drives from outside OEM suppliers to ensure adequate supply and a backup production source.

IBM has made the ante higher than ever for clone and would-be clone systems suppliers to enter this market. As the demand for the new IBM systems begins to build (probably beginning in earnest after IBM releases its new Operating System/2 in 1988), demand for storage peripherals from the clone producers may drop off until these producers finish implementing clone or competitive systems to the new IBM family.

IBM's new systems have not substantially extended the rigid-drive capacity and performance technology. This opens possibilities for upgrade and/or add-in sales of rigid drives with higher capacities, faster performance, smaller form factors, and lower costs per Mbyte. To be able to cash in on this potential market, competitors must flip over and reveal a number of the design characteristic "stones" of the new systems. Most specifically, the new two-level BIOS must be studied to ascertain the potential for advanced drives in these systems.

IBM did not close the bus architecture of the new systems (as many had feared the company might). Rather, it created a new higher-performance bus architecture and included expansion slots for additional function boards made by IBM or third-party participants. IBM has deprived some of the former PC expansion board manufacturers their markets in the PS/2 world by implementing many of these functions into the standard system motherboards. Dataquest believes, however, that the new PS/2 architecture will encourage new levels of expansion board development and will eventually fuel its own new market for additional storage devices.

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Research *Bulletin*

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1987-19

JULY PROCUREMENT SURVEY: THE SUMMER LULL SETS IN

BAD NEWS AND GOOD NEWS

Semiconductor Application Markets' (SAM's) third monthly procurement survey reflects the slowdown in activity that was revealed in the Semiconductor Industry Association's (SIA's) just-released U.S. market flash report. Most of the respondents in our survey indicated slightly lower levels for semiconductor orders than last month. Billings were flat across the board (even for companies that had reported higher billings in the last survey), with the exception of one computer manufacturer that saw a rather large drop in billings.

This lull, however, appears to be short-term, as companies continue to report improvement in their equipment sales. Shipment growth in the first two quarters has almost assured 15 percent industry growth even if semiconductor purchases remain at their second-quarter levels. Dataquest is forecasting that the market will do even better, with 1987 North American semiconductor growth near 18 percent, according to our latest quarterly forecast.

PRICES, LEAD TIMES, AND INVENTORIES

Buyers at the companies we survey report moderately higher prices and longer lead times this month. Lead times are reported to be roughly two weeks longer than last month, while prices ranged from no change to as much as 10 percent. Generally, companies seem to be allowing inventories to rise somewhat this month, apparently indicating their desire to be able to support growing sales of their products. It will take several months of data to tell if this is really a trend. Target inventory levels from commercial companies range from 10 to 45 days. Actual inventories seem to be 5 to 10 days over target in July.

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MEMORIES MOST DIFFICULT TO BUY

Memories top the list of semiconductor devices that are the most difficult to buy, apparently as a result of the U.S.-Japan trade agreement and related restrictions of memory shipments by Japanese manufacturers. Microprocessors and ASICs are next on the list, as a result of the strong demand for these products in workstations and PCs. Few or no problems are reported for standard logic, linear, opto, or discrete semiconductors.

Overall, while the industry appears headed for a short period of somewhat slower activity, we see continued growth ahead. With difficulties already happening with microprocessor, memory, and ASIC procurement, 1988 should bring even more pressure on these products. Anything that users and semiconductor companies can do to smooth out the bumps in these areas will help make 1988 an easier year.

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Research Newsletter

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1987-39

HIGH-SPEED CMOS STANDARD LOGIC SURVEY: USERS LEANING TOWARD FACT

SUMMARY

The ongoing demand for electronic systems with increased speed and reduced power has opened a new market for a high-speed CMOS (HSCMOS) logic family to replace the current higher-power TTL and slower CMOS logic devices. Two dominant suppliers of HSCMOS, National/Fairchild and Texas Instruments, now offer unique HSCMOS product families that differ in package configuration and perceived performance capabilities. The two families are: Fast Advanced CMOS Technology (FACT) developed by Fairchild, and Advanced CMOS Logic (ACL) developed by Texas Instruments. Much was written earlier this year comparing each company's products.

To better understand the logic user's perspective regarding these two alternatives, Dataquest recently conducted a survey of high-performance computer manufacturers to determine which, if any, had made decisions to use National/Fairchild's FACT or TI's ACL line. As shown in Figure 1, the sample of high-performance computer companies chosen represents a market that would likely push the limits of this technology. The survey revealed that although the majority of respondents have not decided on which type of HSCMOS to design into their systems, the FACT-compatible product was being looked at favorably by all for the following reasons:

- It has compatible pin-outs with older designs.
- There are more sources for FACT-compatible products.
- There are more FACT logic functions available.
- The product line provides necessary performance at an attractive price.

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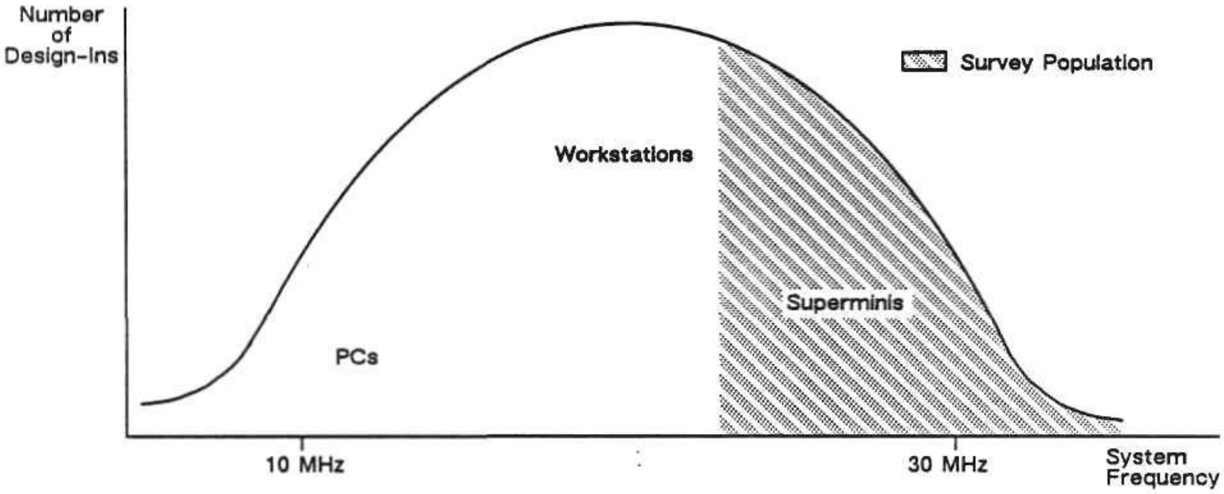
Figure 1

Advanced CMOS Standard Logic Applications



Source: Dataquest
December 1987

BACKGROUND

At the heart of the FACT/ACL controversy is a potentially fatal design problem known as the ground bounce effect (GBE). Ground bounce causes an unstable logic state that occurs in certain CMOS logic device applications. In its worst form, it causes false logic states in a system. GBE is usually not a concern in low-performance systems less than 20 MHz), but many believe that high-speed CMOS logic is particularly susceptible to it. National/Fairchild and TI have addressed GBE in their HSCMOS offerings using two entirely different methods.

The TI-ACL solution to the ground bounce effect has been to change the package configuration by adding an extra ground pin and moving the power voltage pins to the middle of the package. This reduces lead frame inductance and corresponding ground bounce and increases speed for all applications.

The National/Fairchild-FACT solution has used the old, standard pin configuration, enabling easy conversion of existing designs to the newer, higher-performance technologies. National/Fairchild purports that GBE is not a threat the majority of designs, and good design techniques could prevent it for the rest.

SURVEY RESULTS

Using a sample of six representative high-performance computer companies, Dataquest asked the following questions:

- Are you currently using high-speed CMOS logic in your designs? Two said yes, four are currently deciding.

- What type of high-speed CMOS are you using? Two respondents (33 percent) are using Fairchild's FACT family, four respondents (66 percent) favor the FACT solution.

- What determinants were used/are being used to decide on a HSCMOS solution (in order of importance)? All six respondents rated pin-out/package compatibility most important, multiple sourcing of product as second, and perceived performance equivalence as third most important. Four respondents considered the idea that FACT can be used as a TTL replacement to be important, ranking after those listed above.

- What is the decision flow used in deciding to go with HSCMOS? R&D decides system requirements, component engineering determines product availability/ manufacturability, and procurement determines cost.

- If you have decided on a HSCMOS vendor/solution, are you still studying alternatives? Of the two who are using HSCMOS, both said yes.

DATAQUEST CONCLUSIONS

The FACT-compatible product line appears to be the emerging volume HSCMOS family of choice by some high-end computer OEMs because of its adherence to design consistency, its availability (both vendor and number of products), its perceived performance equivalence, and its competitive pricing. Although all of the respondents to our survey were leaning toward or using the standard pin-out solution, those that are using FACT are also reviewing new designs where new sockets are needed. As additional products and sources become available for ACL, we believe that this family will become more attractive. In addition, another product line based on BICMOS technology (which TI and others are currently developing) promises to far exceed HSCMOS in GBE resistance, and offer superior performance as well.

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Research Newsletter

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1987–38

THE RIGID DISK DRIVE INDUSTRY—PREPARING FOR THE FUTURE

SUMMARY

Taking a wide-angle view of the rigid disk drive industry in 1987, the following facts emerge:

- There will be 10 million total rigid drives sold.
- At year's end, there will be 31 million drives in use.
- Therefore, one-third of all rigid drives were sold in 1987.
- Seagate is producing drives at a rate equal to one-half of 1987's total shipments.
- Almost two-thirds of the drives will use Western Digital controllers.
- All drive and controller vendors are increasing production rates.
- Approximately 70 percent of all PCs in the more than $1,000 price category have rigid disk drives installed.

Combining these facts with some other significant developments in this industry, Dataquest concludes that it is time for disk drive and controller manufacturers to make strategic plans in preparation for a dramatic change in the storage market.

This newsletter reviews the current situation, projects what is likely to happen in 1988, and suggests some possible tactics for survival.

TODAY'S MARKET

The 1987 product mix based on sheer unit volumes has leaned heavily toward 20MB and 40MB 3.5-inch and 5.25-inch rigid drives with ST-506 PC and AT controllers. SCSI and native bus interfaced drives have grown to 25 percent of the market. The 85MB products are still in wide use but are rapidly being challenged by the 170MB drives.

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Major OEM accounts are being won by those manufacturers with high production volumes, faster access times, and exceptionally high mean time between failure (MTBF) records. Price is always an important factor, but OEM users are now sophisticated enough to know the value of ship-to-stock and low return rates. An example of this shift in buying is the immediate success of Conner Peripherals' 3.5-inch drives that command a premium of more than $50 per drive at the OEM level, based on field reliability in excess of 99 percent.

The market for small rigid drives is dominated by Seagate Technology. Seagate has proven to be the most innovative marketing organization in the history of the storage industry. Despite the company's decline from a 1985 position of 40 percent revenue from IBM to its current level of 17 percent, it increased sales by a factor of 3 and profitability by a factor of 15 by its year end in June 1987. Other companies, such as Miniscribe, have shown significant gains since the loss of IBM revenue, but Seagate's methodology has pointed the way to success for all players.

Seagate's latest annual report and 10-K documents reveal that one-third of its sales were through the "Super-VAR" channel. These figures equate to nearly the total amount of its domestic sales, less IBM's purchases. In raw numbers, this comes out to 1 million drives, or $319 million. These VARs purchase high volumes of disk drives at favorable prices with purchase order releases on a weekly basis. They couple the drives with low-cost PC, XT, and AT controllers (usually Western Digital's) and sell these kits through small distributors worldwide. (When you see an ad in your local paper for a 20MB Seagate ST-225 and controller for $265, the products have likely been channeled through VARs.) Significant players in this market are CMS Enhancements, Osicom, and Entertainment Marketing. Some sources say that the VAR channel is selling in excess of 100,000 drives per month. Most of these VARs are working on volume with a gross profit of 8 to 10 percent and a net of only 1 percent, feeding a computer dealer network that still commands 20 percent gross profit margins.

This high dealer upgrade revenue is not lost on the OEM computer makers. IBM has stated at the most recent Dataquest Storage Conference that it expects to ship 90 percent of the PS/2 computers with IBM product disk drives. Compaq was the first to tightly couple disk storage to its 286 and 386 computers, closing out dealer upgrades. Apple Computer is selling disk drives in all of its Macintosh SE and II models. Granted, there is still a large PC AT clone business that is tailored for dealer enhancements, but the OEMs are starting to make a loud statement.

INDICATIONS OF CHANGE

The disk drive industry has experienced a sharp erosion in profits in the second and third quarters of 1987. Seagate is the only supplier reporting lower sales in both of these periods, but the overall industry growth rate has begun to slow under the strain of market saturation. The pressures of competitive pricing through the VAR channel have forced average selling prices for low-end units to a level that is nearly $50 below that of one year ago. The difficulty experienced in volume production of thin film heads has also contributed to lower sales and profits for Maxtor, a producer of high-capacity hard drives. The controller industry has followed the September 1986 Dataquest predictions. The shift in interface mix from separate disk controllers to intelligent SCSI or native bus interfaced disk drives has caused the total revenue of the controller chip and board industry to actually decrease on increased disk drive unit sales volumes. The 1987 leader in revenue will be Western Digital (WD) because of its low-cost production of PC, XT, and AT controller boards and its strength in the VAR channel. Dataquest estimates WD's 1987 market share to be 60 percent, in spite of its loss of the IBM AT controller business. Current IBM sales are estimated at 13 percent of total sales revenue.

Adaptec is the only "pure" producer in the disk controller and chip market, deriving almost all of its sales from these products. In spite of Adaptec's strong position of being the supplier of controller chips to most of the major drive vendors (Conner, Miniscribe, NEC, and Seagate, to name a few), its sales have flattened in all quarters of 1987 and profit margins have fallen each reporting period. Chip sets sell for much less than controllers and do not seem to support high profit margins either.

IBM has announced sales of 1 million PS/2 computers since their announcement in April. Most of these products have been Model 30s shipped without a rigid drive. Many of these PCs have found their way into the gray market where disks are installed by dealers. Plus Development Hard Cards have been popular add-in products. The success of the MicroChannel-based PS/2s will be fully understood when the OS/2 operating system is released and the full proprietary nature of IBM's patented I/O architecture is revealed.

The clone makers are still pumping out large volumes of low-cost AT bus computers, fueling the last days of the add-in market. The Far East producers of XT clones shut down volume production shortly after the PS/2 introduction. Everex has long been a leader in mass storage subsystem sales and has recently entered the AT clone market, producing 7,000 systems each month. Awareness on the part of Everex management of the impending demise of the AT market caused the company to make an early move at Comdex/Fall '87 to form Everex Computer Systems and sell in direct competition with its network of successful mail-order houses. Suppliers normally resort to this technique to milk sales from a dying market.

All VARs are broadening their product bases and corporate marketing strategies in an effort to replace their shrinking storage upgrade revenue. The largest VAR—CMS Enhancements—has concentrated on new, high-margin subsystems and file servers and has just announced its entry into the consumable supplies market.

In spite of record unit sales of disk drives and controller products, the industry is experiencing the beginning of a major adjustment. To maintain continued sales revenue and restore higher profits, it is obvious that new marketing strategies are required.

PROBABLE 1988 MARKET CONDITIONS

IBM's likely support of the SCSI interface will create a large requirement for SCSI protocol chips, controllers, and subsystems (for more information, see Dataquest Research Newsletter No. 1987-32, "IBM PS/2 SCSI Architecture"). Disk drives with PC AT and MicroChannel interfaces will ship in substantial volumes. Dataquest estimates that SCSI and native bus interfaced disk drives will reach a level of 43 to 45 percent of all 3.5-inch and 5.25-inch disk drives sold in 1988.

The 3.5-inch rigid disk suppliers will be in full production, and OEMs will announce new products that use this new form factor. Seagate's entry into this arena will bring fierce competition in OEM sales negotiations. Start-up companies will enter the 3.5-inch market but will face the specter of Seagate's and Miniscribe's production volumes and efficiencies, Control Data's and Maxtor's performance ratings, and Conner Peripherals' quality standards.

Capacity requirements will shift from 20MB to 40MB in the high-volume market, and the 170MB market will mature and become profitable. The 380MB drives will begin to ship in volume, and a few of the promised 760MB products will be evaluated, but production will be limited.

The current sales channels will come to an unprofitable end, with manufacturers and dealers working together in a fatal squeeze on the VARs. VARs will expand to much broader product areas and even into the distribution of products from other industries, leveraging off of their experience in the storage business.

Dealer sales of storage products will become a much smaller portion of retail revenue as a result of the incorporation of disk drives by computer makers. The upgrade aftermarket will increase as a result of the growing size of new software and existing data bases, and the subsystem market will grow as predicted.

The memory of 1985's slump in the storage industry is still fresh. In the final analysis, it appeared that the sales channel inventories became filled with products, part of which were near obsolescence. A slump similar to 1985 is probable in our industry by the fourth quarter of 1988 because of today's increased production levels, the impending saturation of the time-of-sale storage market, and OEM drive incorporation.

SUGGESTED SURVIVAL TACTICS

This set of grim predictions must be tempered by the projected 13 percent growth in the personal computer industry and the remaining 30 percent of the installed base that may purchase rigid drives. The market is not going away, it is merely entering a controlled growth phase. There appear to be some obvious moves that disk and controller companies can make to assure their survival through some tough times.

In the "if you can't beat them, join them" category, following Seagate's marketing plans would appear to be a key move for every vendor in this business. Seagate's revenue was derived from nondomestic sales of 40 percent in 1986 and 44 percent in 1987, with 13 percent of the total sales in Europe. Recently, Seagate announced a concentrated global sales program with a goal of increasing sales by 45 percent. European sales goals are $250 million for fiscal 1988. In the "Market Summary and Trends" section of the 1987 CSIS Storage Subsystem Binder, Dataquest points out that industry participants should have at least a 30 percent contribution to revenue from Europe in 1988. Possibly, a successful Seagate push will cause that figure to be increased substantially. The European computer market traditionally lags that of the United States by at least a year, suggesting that the storage VAR market is about to break wide open on that continent. Helping traditional European distributors develop this sales structure could be a low-cost approach for controller and drive makers to gain an advantage in this explosive market.

Another tactical move would be to establish even stronger OEM ties with computer companies. The move toward proprietary bus interfaces is a unique opportunity for controller and disk drive vendors. Contracts for products that use these designs assure long-term relationships and a strong volume base for suppliers.

Some disk drive and controller companies have already made mergers and acquisitions to position themselves in different growth markets or to take stronger control of their market channels. Scientific Micro Systems (SMS) has made its move in acquiring Super Mac and LEVCO. Super Mac was one of SMS's largest buyers of controllers for incorporation into Macintosh rigid disk subsystems. Maxtor made similar acquisitions in the U.S. Design and Storage Dimensions. U.S. Design builds Digital Equipment Corporation storage subsystems out of Maxtor drives, and Storage Dimensions uses Maxtor products in high-performance PC subsystems. Buying your customers, however, can be dangerous because you will probably alienate those that you cannot acquire. The advantage lies in the higher profit margins inherent in integrated systems and marketing know-how, as well as brand-name recognition in specific retail markets.

WD has taken an approach that broadens its product base horizontally. Being the only major controller chip supplier with IC foundry capability, it has acquired Faraday and Paradise, both designers and sellers of LSI products into nonstorage PC applications. WD has also entered into a joint-manufacturing agreement with Tandon to produce unique 3.5-inch rigid disk drives with intelligent PC interfaces. The company has also acquired Vianetix, a LAN software house. Each of these new business ventures puts WD in new, high-growth areas that will make up for the decreased profits and sales in the storage controller and chip markets.

Many of the storage-related companies have a strong cash position as a result of issuing subordinated debentures earlier in 1987. In fact, several corporations have seen their stock prices dip below their cash value. While the market is depressed, it is probable that this cash will be used to acquire complementary businesses. Dataquest expects computer chip makers to show great interest in acquiring peripheral chip and controller companies.

The profile of a surviving storage product company includes products that demonstrate the following:

- High reliability (50,000 hours MTBF)
- Large production capacity and efficiency
- Extra performance benefits
- Extra capacity benefits
- Competitive cost at good profitability levels
- An obvious growth path to new products and markets

The storage market in 1988 will experience its greatest change in its short history. Guiding a teenager into adulthood is one of the greatest challenges facing parents. Executives and planners will be taxed to their limits guiding this industry into maturity.

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David Norman
Phil Devin

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Research *Bulletin*

SAM CODE: 1987–1988 Newsletters: October–December
1987–37

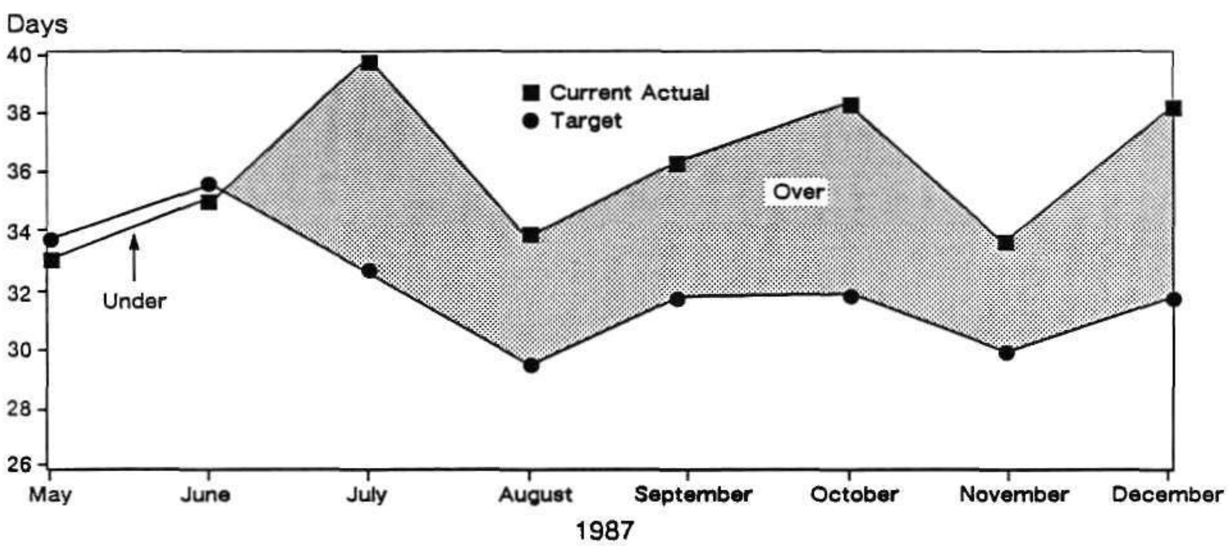
DECEMBER PROCUREMENT SURVEY: STATUS QUO

As 1987 comes to a close and backlogs are formed for first quarter 1988, the semiconductor and electronic OEM industries continue in relative good health. Although December's semiconductor inventory excess will increase to 19 percent from November's 13 percent, it is still less than October's 21 percent excess, as shown in Figure 1. December's excess is a result of actual levels rising 14 percent and target levels rising less, at 9 percent. Computer OEM's inventory excess is 21 percent in December, compared with 18 percent in November.

Offsetting the potential problem of too much inventory is December's semiconductor shipments' decline by 8 percent for all OEMs and by 4 percent for computer OEMs. Overall, December's semiconductor orders are expected to remain flat with November.

Figure 1

Current Actual versus Target Inventory Levels



34.5
31
JAN

Source: Dataquest
December 1987

Dataquest, 1290 Ridder Park Drive, San Jose, CA 95131-2398, (408) 971-9000, Telex 171973

After several months of relatively stable pricing, some OEMs are reporting that overall pricing is up 3 to 5 percent in December. Memories, microprocessors, and discrete devices continue to be cited as hard to secure within reasonable lead times.

Overall, OEM equipment sales were reported to be running 5 percent ahead of last year's at this time. Computer OEMs stated that their sales are up an average of 9 percent compared with last year. When asked about their outlook for 1988, the overwhelming majority of respondents indicated that their companies would grow as much as or more than they did in 1987. Furthermore, the stock market retrenchment was seen as having little effect on their hiring and investment plans.

Gregory L. Sheppard

Dataquest
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Research Newsletter

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EIA'S FALL 1987 SYMPOSIUM: A PESSIMISTIC OUTLOOK FOR THE DEFENSE INDUSTRY (BUT WITH OPPORTUNITY FOR SOME)

EXECUTIVE SUMMARY

Proclamations of declining spending in the defense industry seemed to hit hard at the Electronic Industry Association's (EIA) Fall Symposium held in Los Angeles last month. The EIA predicted reductions in the DOD budget authority until 1991, followed by nearly negligible growth for the following five years, as seen in Figure 1. In dollar terms, this translates to a total military budget of $301 billion in 1986, dropping to a low point of $273 billion in 1991, finishing the 10–year forecast period in 1997 with authorizations of $287 billion. In addition to assumptions of a relatively peaceful and stabilized world atmosphere, the EIA cited the following factors as key influencers of the declining budget:

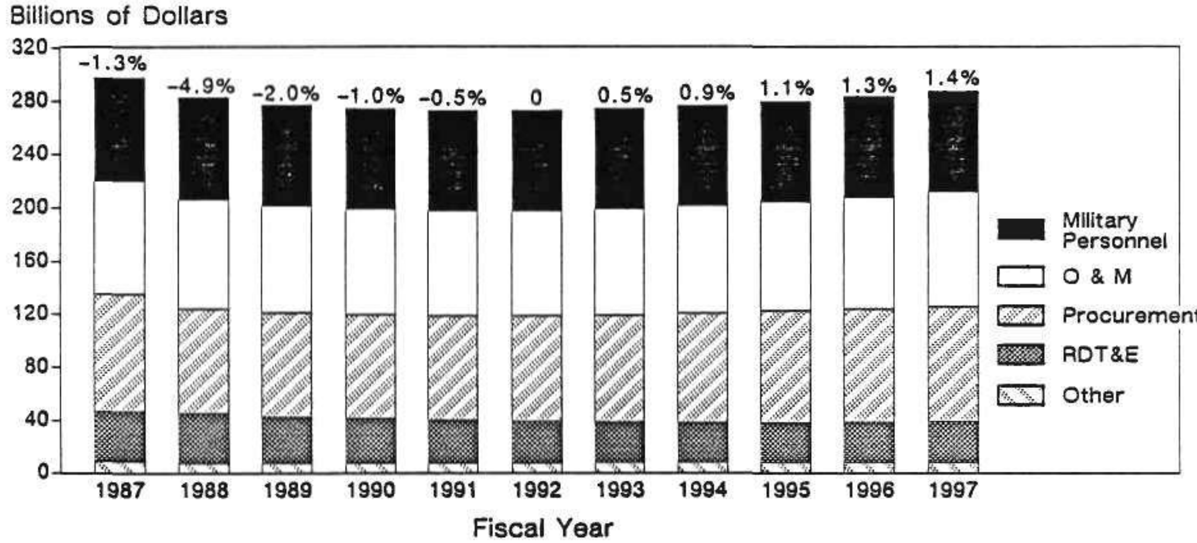
- An all–time high federal deficit
- The shrinking size of military entitlement programs
- The public perception of reduced defense needs
- The long–term stability of Gorbachev's government
- The cooperation of NATO allies in reducing the burden on the United States
- The perceived inefficiency (needed cost reductions) of the military complex

The electronic content portion of defense spending (as shown in Figure 2) fared only marginally better than the overall budget, with a predicted cumulative 10–year effective growth of 4.5 percent versus a 0.7 percent reduction in total military authorizations. Table 1 summarizes electronic procurement and RDT&E (research, development, test, and evaluation) spending by program category as well as the electronic content portion of the O&M (operations and management) budget.

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

Figure 1

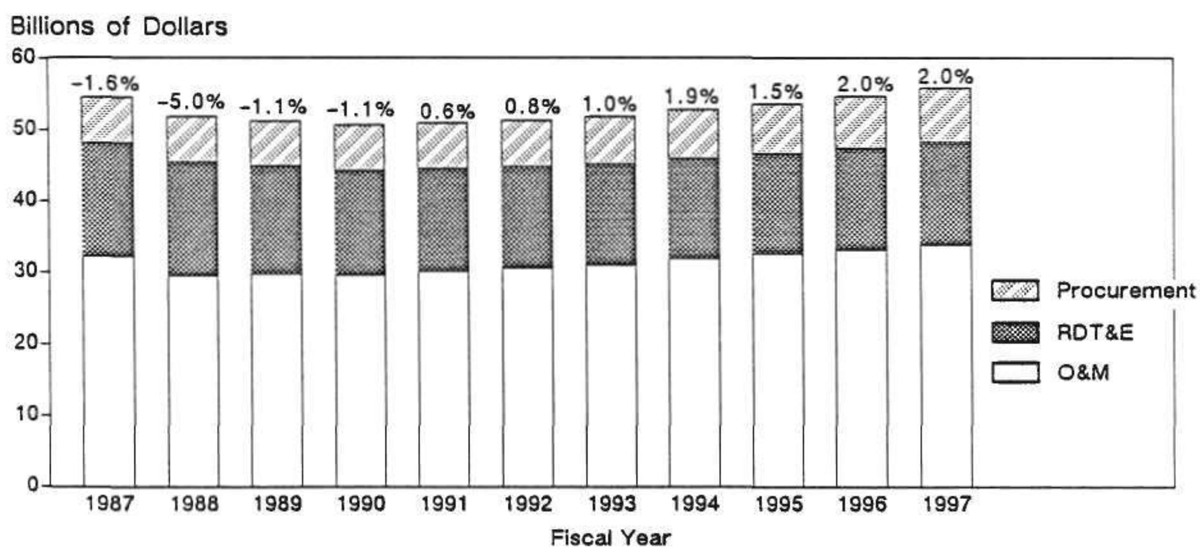
DOD Budget Authority Trends
(Billions of Constant 1988 Dollars)



Source: EIA

Figure 2

Total DOD Electronic Content Forecast
(Billions of Constant 1988 Dollars)



Source: EIA

Table 1

Breakout of DOD Electronic Content Forecast (Billions of Constant 1988 Dollars)

Program	1986	1987	1988	1989	1990	1991
Aircraft	$11.9	$10.7	$ 8.9	$ 8.9	$ 9.0	$ 9.2
Missiles	8.5	8.4	8.2	8.0	7.8	7.8
Space	5.3	6.0	6.3	6.5	6.6	6.7
Ships	5.4	5.7	4.8	4.3	4.0	4.0
Ordnance and Weapons	1.2	1.2	1.2	1.2	1.2	1.2
Vehicles	0.9	0.9	0.8	0.8	0.8	0.9
Electronics and Communications	9.1	9.1	9.3	10.1	10.0	10.0
All Other	6.9	6.3	5.9	5.3	5.1	4.7
Total Procurement and RTD&E	$49.3	$48.2	$45.5	$45.0	$44.5	$44.6
O&M (Electronics Portion)	6.2	6.4	6.4	6.3	6.3	6.4
Total Electronics	$55.5	$54.6	$51.9	$51.3	$50.7	$51.0

Program	1992	1993	1994	1995	1996	1997
Aircraft	$ 9.4	$ 9.8	$10.1	$10.5	$10.9	$11.2
Missiles	7.8	7.8	7.9	8.0	8.0	8.0
Space	6.9	7.0	7.2	7.2	7.3	7.4
Ships	3.8	3.6	3.6	3.7	3.7	3.8
Ordnance and Weapons	1.3	1.3	1.4	1.3	1.3	1.4
Vehicles	0.9	0.9	0.8	0.8	0.8	0.9
Electronics and Communications	10.0	10.1	10.2	10.2	10.4	10.5
All Other	4.7	4.8	4.9	5.1	5.2	5.3
Total Procurement and RTD&E	$44.9	$45.3	$46.1	$46.8	$47.6	$48.4
O&M (Electronics Portion)	6.5	6.6	6.8	6.9	7.2	7.5
Total Electronics	$51.4	$51.9	$52.9	$53.7	$54.8	$55.9

Note: Columns may not add to totals shown because of rounding.

Source: EIA

ELEMENTS OF THE EIA DEFENSE FORECAST

The EIA 10-Year Forecast Subcommittee and associated study teams and subcommittees comprise representatives from virtually every major defense-related corporation in the United States. Twice each year, these members contribute their own assumptions and observations and conduct more than 100 interviews with DOD and other government agencies, as well as with nationally recognized think tanks and economists.

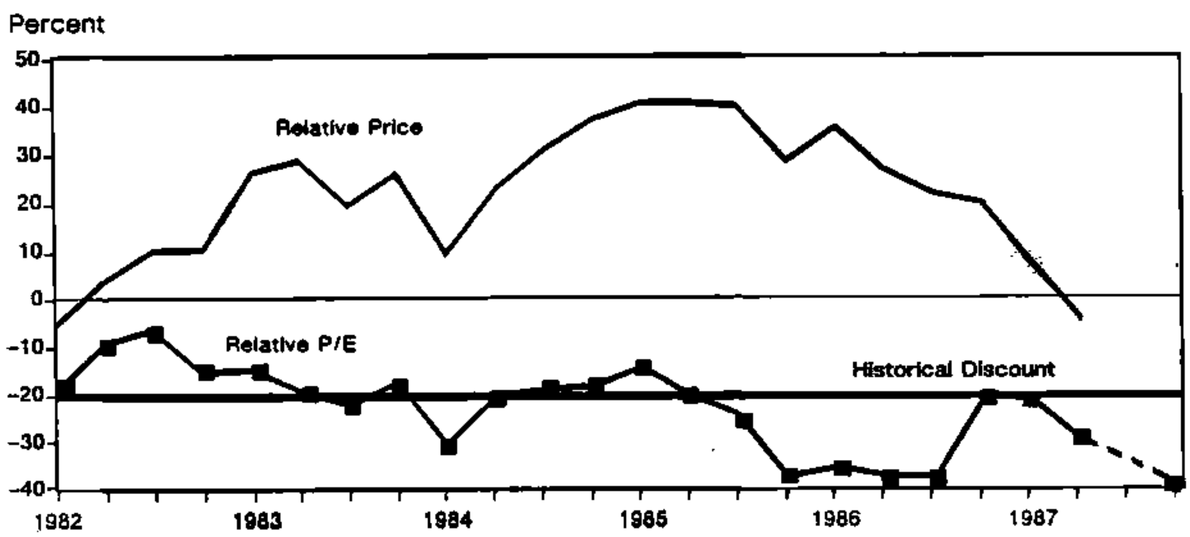
Aside from looking at overall defense spending, the recent EIA symposium provided an overview of DOD programs, along with detailed assessments and program opportunity ratings (good, fair, poor) in the categories of space electronics, training and simulation, and missiles and precision-guided weapons. In addition, representatives from the financial community presented their assessments of the investment and business climate for the defense industry.

The Financial/Business Perspective

Although some differences of opinion were voiced from individual financiers, the overall tone was harmonious—the defense industry is becoming much less attractive to current and potential investors. Many contributing causes were cited, but the following price-to-earnings (P/E) performance summary of the Standard & Poor (S&P) aerospace group seems to illustrate the effect of all of the factors combined (see Figure 3).

Figure 3

S&P Aerospace Group Relative Price and P/E

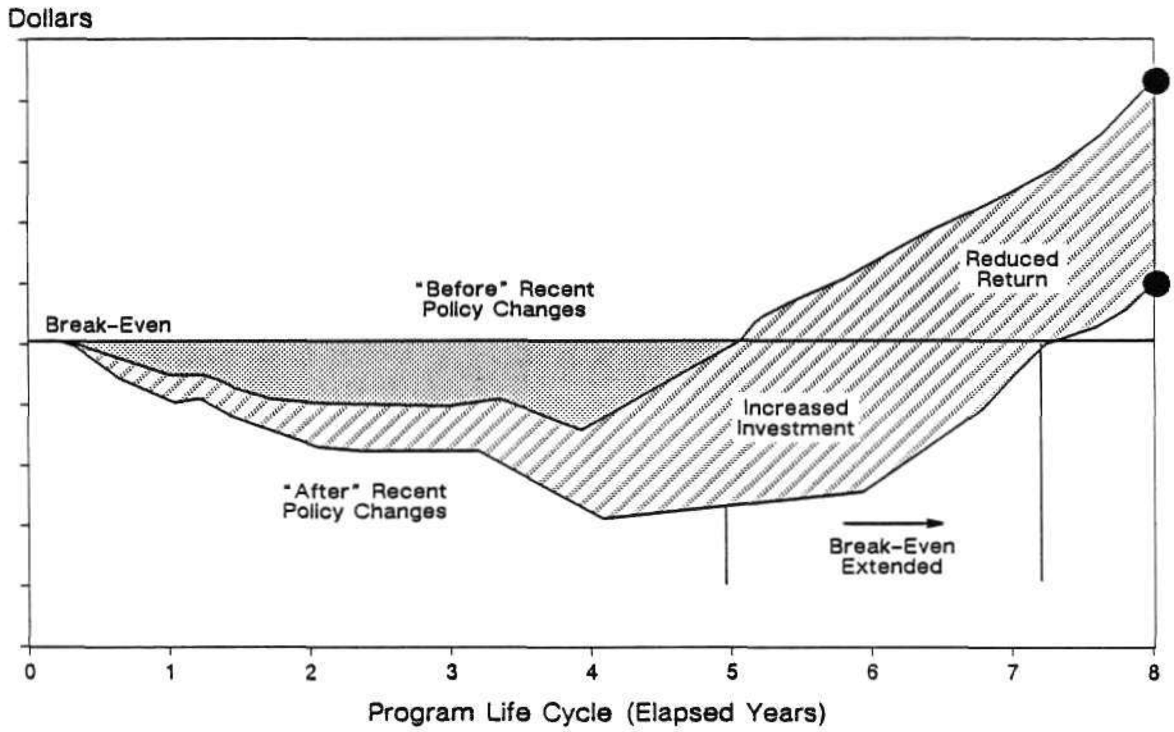


Source: EIA

In terms of future programs, the financial experts complained that the basic business equation is out of balance, citing increased investment and risks for a decreased rate of return that is realized much later in the defense program cycle than in years past. (This was the scenario for a "successful" program.) Figure 4 illustrates the effect.

Figure 4

"Now" versus "Then" Military Program Payback

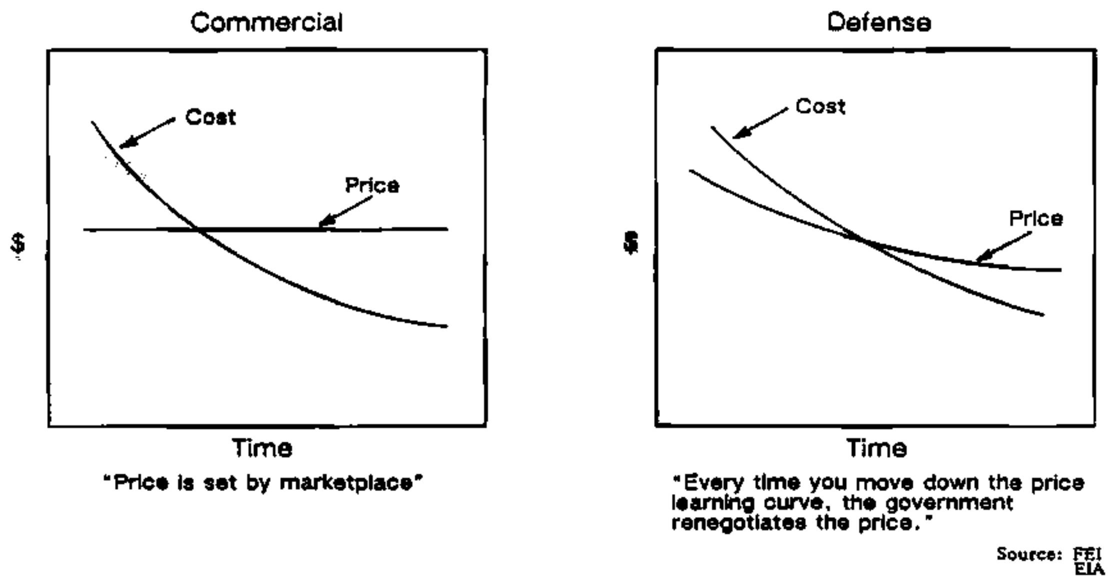


Source: FEI

Government procurement policies were seen as the chief culprits of this dismal picture. One example listed was the "cost-plus" programs that reportedly create a no-win situation for military contractors trying to reduce overhead, which over the long term would benefit the government as well. Unlike the typical commercial venture, in the military arena, profit margins remain the same regardless of cost (see Figure 5), thereby eliminating incentives for cost reduction.

Figure 5

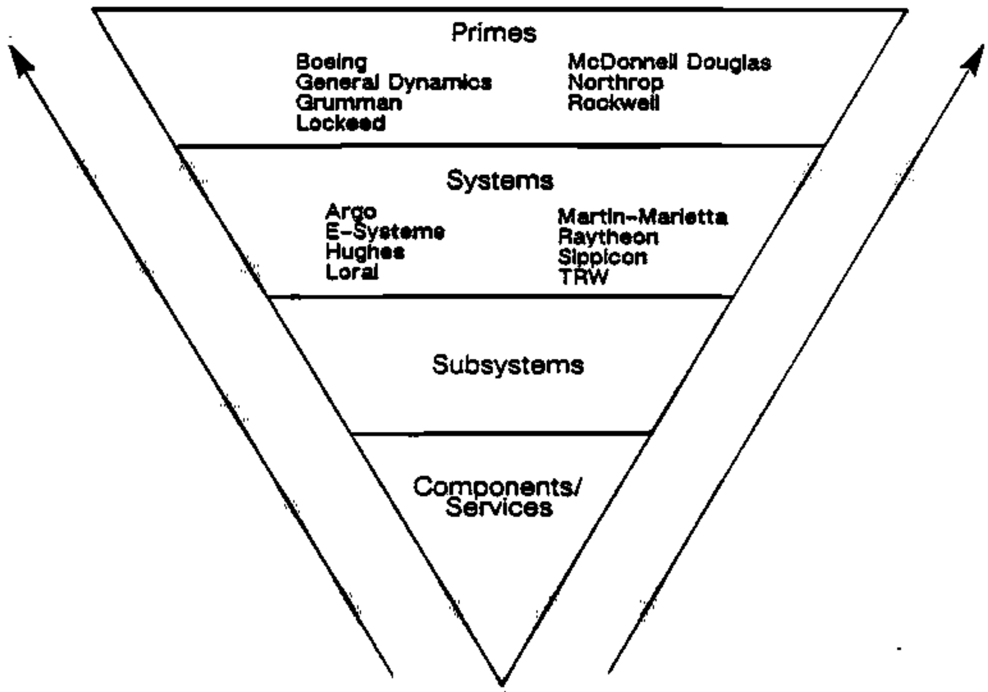
Cost-Plus versus Fixed-Price Environments



Furthermore, with defense companies competing for pieces of a shrinking pie, a trend toward consolidation has begun and is likely to continue for some time, it was stated. Figure 6 shows a kind of food chain that has evolved in the defense industry, wherein subsystems companies are acquiring smaller components/services companies, and are in turn being acquired themselves by larger systems companies. Finally, these systems companies are absorbed by the giant prime contractors (platform and airframe builders). While such occurrences need not necessarily be labeled good or bad, they are a strong indicator of a market able to feed fewer hungry mouths. Table 2 lists several of the acquisitions that have occurred during the past 18 months.

Figure 6

Defense Industry "Food Chain"



Source: Security Pacific Bank
Dataquest
November 1987

Table 2

Defense Company Takeovers

Company Acquired	Price Paid (Millions of $)
Hughes	$5,260
Sanders	$1,180
Tracor	$ 694
Electrospace	$ 367
Argo Systems	$ 275
PRC	$ 220
Syscon	$ 91

Source: Security Pacific Bank

Overall, the financial community characterized the military industry as monopolistic—an environment where a single buyer imposes strict contract rules, demanding visibility of all operations and costs from its suppliers, severely limiting a company's ability to benefit from its unique management strengths—all resulting in the removal of most weapons that make a company competitive. Other government policies of concern included the declining resources for R&D and tooling, elimination of contract completion tax credits, lowered progressive payment rates and lowered earnings targets. Two publications addressing these issues are available from the Financial Executives Institute (FEI) Committee on Government Business located in Washington, D.C.

The Program/Electronics Perspective

While a top-down look at the defense industry appears dismal indeed, a bottoms-up program perspective offers signs of hope and opportunity. Most promising to OEMs and semiconductor manufacturers alike is the fact that while the overall DOD budget continues on a downward slide, the electronic content portion is an increasing (albeit slowly) share of the total. It is also encouraging that the military will continue to see an increase in the number of electronics-intensive program starts. Table 3 provides a listing of some of the most significant military program starts and associated funding for fiscal years 1988 and 1989.

Beyond these programs are opportunities involving modifications to existing systems, recompetition and second-sourcing for ongoing programs, and technology development contracts. In the field of superconductivity, for instance, government agencies are expected to raise funding from $23 million in fiscal year 1987 to $50 million to $100 million next year. Table 4 identifies the top 10 technologies and associated products for development in the defense industry.

A final area of opportunity (or loss to nonparticipants) is seen in R&D programs now being funded under the Nunn amendment and other similar allied cooperative efforts. (The Nunn amendment involves legislation introduced by Senate Armed Services Committee Chairman Samuel Nunn, which allocates some defense spending to designated cooperative research and development programs among U.S. and NATO participants.) The EIA forecasts that more than $500 million will go to U.S. companies for new design starts in fiscal years 1986 through 1989 under the Nunn amendment and about another $500 million from other non-Nunn cooperative allied R&D programs. As pressure seems to mount for U.S. allies to assume more of the burden for western defense, doors are expected to open both in the United States and Europe for joint development and military equipment production.

Table 3

Key Military Program Starts and Associated Funding (Millions of Dollars)

		Millions of $ FY88	FY89
Army	AAWS-H	$ 29	$116
	ESAM		$ 3
	Armored Family of Vehicles	$ 10	$ 45
	Family of Medium Tactical Vehicles*	$ 12	$ 14
	Family of Heavy Tactical Vehicles*	$ 23	$ 9
	HEL/DE Components	$ 8	$ 32
	Special Operating Forces Equipment	$ 20	$ 22
	Airborne Adverse Weather Weapon System**	$ 98	$ 87
	FAAD Aerial Sensor FSD	$ 0	$ 69
Air Force	WWABCP System Replacement#	$ 14	$ 14
	B-1B Flir*	$ 21	$ 57
	B-1B ECM MODS*	$ 19	$110
	F-111 Self-Protection System#	$ 58	$ 53
	Modular Standoff Weapons	$ 39	$ 39
	ADI Surveillance Technology	$ 86	$139
	DSP Follow-On*	$ 0	$ 22
	Dycoms	$ 12	$ 9
	Meridian**	(Classified)	
Navy	V-22 ASW Variant*	$ 4	$ 18
	P-3G (now LRAACA)*	$ 14	$ 39
	AMSS (now ATSA)*	$ 0	$ 3
	Dual Role ARM*	$ 0	$ 8
	NATO AAW System (Nee LAAWS)	$ 10	$ 8
	Ship Laser (Medusa)**	$ 1	$ 3
	ADI	$ 47	$ 67
	Retract Larch**	$ 93	$229
	Retract Elm**	$ 39	$ 41
	Chalk Weed**	$ 9	$ 10
	Chalk Poinsetta**	$ 15	$ 25
	Link Plumeria**	$ 14	$ 12
	Link Evergreen**	$ 74	$118
	Link Cypress**	$169	$244
SDIO	Advanced Launch System* ##	$433	$606
	HP/HF Interceptor* #		

*Project within a program element
**Description classified
#Since Deferred or terminated
##Kicked-off with $75 million in FY '87 supplemental

Source: EIA

Table 4

Top 10 Technologies for Military Development

Technology	Products
Computers and Software	Software development Parallel processing Distribution procedure hardware and algorithm Artificial intelligence Exotic technologies New hardware/computer development Reconfigurable systems
Automated Sensors and Sensor Fusion	Sensor fusion Algorithm development Advanced FP arrays Radar Multisensory algorithm development ATR
Guidance and Navigation	Digital map Large multicolor displays Fiber optics High-reliability, low-cost IRU Optical networking
Advanced Materials	Advanced composites High-temperature materials Ceramics Armor Tribology Superconductors
Microelectronics/ICs	MIMIC VLSI VHSIC Fault-tolerant/fail-soft RF-hardened circuits Distributed, secure ICs
Robotics and Machine Intelligence	Manipulators and end effectors Computer vision/image understanding Machine plan/decision making Knowledge engineering/knowledge-based systems Language understanding/speech recognition Machine learning/adapt, tutor Special-purpose AI

(Continued)

Table 4 (Continued)

Top 10 Technologies for Military Development

Technology	Products
Integrated Active and Passive Surveillance	Reduced signatures Integrated electronic warfare Deception NCIFF
Directed Energy Weapons (DEW)	Radio frequency HPM Lasers Hardening and susceptibility
Propulsion and Conventional Warheads	Liquid propellant Electromagnetic launch Electrothermal launch Advanced penetrators Improved shaped charges Smart fuses Smart/brilliant munitions High-energy LP and SP Insns. Prop.
Life Sciences	Biotechnology Soldier survivability Soldier sustainability Soldier performance enhance Chemtechnology

Source: EIA

WHAT THIS ALL MEANS

With what appear to be conflicting signals, options may seem bewildering at best. But such an environment truly does offer opportunities to companies able and willing to react to and accommodate the new industry dynamics.

The first step lies in realizing that there is, and will be, no more "business as usual." The industry is in what Dataquest believes is its infancy of change. There will be many more shake-ups, mergers and acquisitions, and entries and exits with regard to the defense industry over the next five years. Not everyone will survive.

Those who do continue to participate must become more selective in the programs they pursue and must carefully monitor changes with respect to funding, technology focuses, and DOD relationships with primes and subcontractors.

In light of trends toward consolidation and internationalization, it behooves military suppliers, small and large alike, to team up—to develop relationships that allow leveraging of each company's particular strengths and bid on projects as a team. Such alliances will allow individual companies with limited resources to focus on developing their niche specialties, thereby keeping ahead of companies acting alone, which are being spread out in too many directions.

In today's military industry, the old warning against putting all the eggs into one basket seems apropos. This applies both to alliances with other vendors (as not all teams are a good fit for all programs), as well as serving the military market exclusively. Several primes, in fact, are taking the latter point seriously and are exploring the diversification of products into the commercial sector.

Dataquest's most important suggestion to companies is to start moving now; that is, do homework, decide what role to play in tomorrow's military industry, chart a course of action, and begin implementation. National defense is, and in all likelihood will continue to be, a top priority in U.S. and allied governments. The military industry is not going away, but it is changing, and electronics will be more a significant part than ever in overall military defense strategies and funding.

Nanci J. Magoun

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Research Newsletter

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GOMAC-87: "CHALLENGES FACING GOVERNMENT ELECTRONICS IN THE 1990s"

The 1987 Government Microcircuits Applications (GOMAC) conference was held in Orlando, Florida, on October 27 through 29, 1987. Approximately 1,000 attendees participated in 21 sessions on subjects ranging from IC design concepts to discontinued parts. Due to time constraints, parallel sessions were held, up to four at a time, making it necessary for those involved in defense programs to split up their delegations in order to attend as many sessions as possible. Exhibits of products, services, and capabilities of more than 30 companies were on display in an area adjoining the lecture halls. This newsletter discusses some highlights of this important conference.

VHSIC INSERTION

Progress in VHSIC insertion was reported by most of the participating companies. Many of the exhibits featured examples of VHSIC chips and their application to defense electronics systems. The presentations indicate that VHSIC technology has been applied to a wide range of hardware including ruggedized computers, imaging systems, digital signal processing (DSP) functions, and radar electronics.

SIGNAL PROCESSING

Applications of silicon or Si/GaAs IC technology to signal processing problems have been accomplished by numerous defense electronics suppliers. For example, TRW described its superchip family and presented data on its high-performance 6-bit analog-to-digital converter (ADC). The TRW ADC uses a GaAs front end to drive a silicon bipolar flash quantizer.

Bipolar Integrated Technology, Inc. (Beaverton, Oregon), presented a family of integer and floating-point DSP circuits based on its 2.0μ silicon bipolar process. The company claims that the process offers the higher speeds of ECL at the VLSI functional density of CMOS.

VTC (Bloomington, Minnesota) has developed a bipolar cell library of analog/digital cells for signal processing applications. The bipolar structures use complementary transistors with f_T of 6 GHz (NPNs) and 1 GHz (PNPs). The cell library is augmented with components for use in customization.

MIL–STD–1750A

Performance Semiconductor presented and displayed information on its 40–MHz VHSIC–class PACE 1750A system. The system is a CMOS three–chip set consisting of a central processor unit, a processor interface chip, and a memory management unit/combination support chip. The set provides system performance greater than 2 mips. Performance Semiconductor supports its PACE 1750A with a product line consisting of the world's fastest CMOS SRAMs, with chip densities ranging through 256Kx1.

Other companies presenting information on 1750A architectures and products included Allied Signal, General Electric, IBM, Loral, Texas Instruments, TRW, and UTMC.

GaAs SEMICONDUCTORS

GaAs has been applied to high–performance military electronics for several reasons, among which are frequency response and speed superior to silicon, and inherent radiation hardness. General Electric described innovations in using GaAs to implement radar transmit/receive modules.

Several companies, including AT&T, GAIN Electronics, Raytheon, TriQuint, and TRW, made presentations or displayed information about their progress in developing and producing GaAs ICs. AT&T is offering a 1–GHz divide–by–128/129 prescaler, the DG1096AX. The circuit is fabricated using GaAs E/D MESFET process and comes in 8–lead flatpack or DIP. The chip consumes less than 40mW and has TTL/MOS–compatible I/Os.

GAIN Electronics Corporation is marketing a family of gate arrays including its GFL6000. This product is a 5,776–gate array with 204 I/O buffers, 3W maximum power dissipation, and unloaded gate delays of 100ps. I/Os may be CMOS–, TTL–, or ECL–compatible. Package options include chip carriers and pin–grid arrays. The company is processing production orders for its gate arrays.

Raytheon offers GaAs IMPATT diodes for selected applications. The devices are specified to 60–GHz frequency and 10W output power, and to 44–GHz and 25W output. The devices are produced at the research division in Lexington, Massachusetts.

TriQuint is producing a 3,000–gate ASIC array called the TQ3000, which has 1,020 core cells and 64 I/Os. NRE charges are $80,000 including design manual and workstation software. The ASIC is supported by Daisy, Mentor, and Tek/CAE workstations.

TRW is developing microwave and millimeter wave ICs for communications and other defense applications. TRW, Honeywell, and General Dynamics compose one of the DOD teams developing this technology; TRW is the prime contractor for this team.

RELIABILITY AND FAULT TOLERANCE

The United States Air Force has launched a program called R&M 2000. In implementing this program, the Air Force Systems Command is challenging the electronics industry with specific goals, such as "double-R, half-M" (double the reliability and half the maintenance) and 2,000-hour MTBF for line-replaceable units (LRUs), to be met by defense contractors.

TRW summarized the historical development of fault diagnosis and presented fault-tolerant methodologies that lend themselves to present-day design activities. The discussion emphasized the need for increased focus on fault-tolerance in future designs.

Fault-tolerant software was the subject of a joint paper by Westinghouse, SRI International, and NASA. The authors described a distributed general-purpose, fault-tolerant operating system for use on VHSIC 1750A processors.

Intel reported close work between its Military Operation (Chandler, Arizona) and one of its major accounts to significantly reduce incoming VLSI reject rates. The company said it plans to extend the approach to other customers.

Lockheed described a design methodology for extending traditional fault-tolerant design techniques to analog functions. Included are techniques for self-test, self-diagnosis, and self-correction, previously used only in digital circuit design.

TESTABILITY

Honeywell made two presentations on VHSIC testability and maintainability. The first described a control function block to be included on-chip. The second described a standard design methodology for producing inherently testable systems on a consistent basis.

Teradyne has developed a tester calibration architecture for VHSIC modules. The company says the system calibration allows maintaining a maximum of ±1.5ns skew at 40-MHz frequency across more than 400 pins.

Silicon Compiler Systems described the growing importance of integrating test development into the design process. The company's exhibit included a demonstration of its automatic test generation (ATG) system.

A joint presentation was made by VTC, Inc., and Control Data Corporation describing a rad-hard standard cell testability structure. Other companies presenting information on testability included Mitre, Unisys, and UTMC.

RADIATION HARDNESS

Two of the GOMAC sessions and more than a dozen papers were devoted to radiation hardness. LockHeed, M/A-COM, Motorola, VTC, and others made presentations on this subject.

The UTMC exhibit included information on its UTB-R and UTD-R rad-hard gate array families and other rad-hard products. The UTMC products are designed to withstand these levels of radiation:

- Data sheet specification operation to $2x10^5$ rads (Si) total dose
- Functional to 10^6 rads (Si) total dose
- No upset of less than 10^9 rads (Si)/s dose rate
- Dose rate latch-up $>10^{10}$ rads (Si)/s
- Neutron fluency 10^{14} N/cm

DISCONTINUED PARTS

The life cycles of many commercial IC devices and families are shorter than those of most military electronics equipment. As the rate of technological change increases, discontinued parts generate a growing set of problems to defense contractors. Four organizations made presentations of methods useful in resolving some of these problems.

Honeywell, for example, has developed a replacement for many of the (DTL) functions that are no longer procurable. The replacement device is a 16-pin bipolar generic array. Another company, SAIC, has worked with DESC on an R&D program to develop TTL, LSTTL, ECL, linear, and other emulation devices for fabrication on a bipolar baseline process at a silicon foundry.

PACKAGING AND INTERCONNECTION

Kyocera Corporation, Kyoto, Japan, displayed state-of-the-art packages at its exhibit. The company claims world leadership in technical ceramics. One of the more exotic of Kyocera's products was a 1,700-pin grid array (PGA) of approximately 15-square inches.

Kyocera has steadily increased its account penetration in the United States and is a leading supplier to VHSIC chip houses. This raises an interesting issue regarding DOD's dependence on foreign suppliers.

Dow Corning Corporation has developed materials for implementing a novel hermetic package concept for improved chip reliability. The approach is called surface protected electronic circuits (SPEC) and involves applying multiple layers of polymeric materials directly to the circuits.

Honeywell discussed a package design that may in many instances solve the problem of having to tool separate packages to accommodate various chip designs and multiple chip suppliers. A joint paper by Interamics and Texas Instruments described a package development to support multiple VHSIC chips in a single ceramic module.

DATAQUEST CONCLUSIONS

Although much progress has been made in semiconductors for military applications, major challenges remain. The R&M 2000 initiative, requiring doubling of MTBFs and halving maintenance, is but one example.

Although great strides are being taken in domestic chip technology, it appears that the U.S. defense industry still relies heavily on a sole foreign source for large-volume production of IC packages. This is not new; the situation has existed for several years. Two questions remain:

- Is reliance on non-United States-based sources of electronic parts <u>really</u> a high-priority matter?

- If so, who in the industry or in Washington is responsible for working on the packaging issue, and what is the timetable for resolution?

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The Dun & Bradstreet Corporation

Research Newsletter

SAM Code: 1987–1988 Newsletters: November
1987–34

NOVEMBER PROCUREMENT SURVEY: MARKET CRASH IMPACT?

The effect of the "Black Monday" stock market crash activity does not seem to have significantly impacted semiconductor procurement trends through November. Although 55 percent of the survey respondents indicated a reduction in orders since October, a great deal of this decrease is due to seasonality and an already established slowing trend addressing building inventories.

Average billings are estimated to be up 3 percent in November compared with October. Actual inventory levels are expected to exceed target figures by 13.4 percent in November, but this represents a significant easing from October's 21.4 percent excess, as shown in Table 1.

Table 1

Current Actual versus Target Inventory Levels
(Days)

	May	June	July	August	September	October	November
Target	33.7	35.0	31.8	28.8	31.3	31.3	29.1
Current Actual	33.2	34.6	39.7	33.1	36.1	38.0	33.0
Percent Over or Under	(0.01%)	(0.01%)	24.8%	14.9%	15.3%	21.4%	13.4%

Source: Dataquest
November 1987

The average lead time on securing products remained even with last month, at 12.5 weeks. Memory products are still found to be the most difficult to secure, with discretes and military ASICs also being mentioned.

Although the continuing inventory overhang could be interpreted as a negative forecast factor for semiconductor sales, 56 percent of the users are reporting November electronic equipment business to be better than last year.

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Research Newsletter

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1987–33

MINISUPERCOMPUTER SEGMENT SUMMARY—1987 UPDATE

SUMMARY

Since 1982, many new companies have been formed with the common objective of building and selling computers that would bridge the performance gap between high-end superminicomputers (e.g., Digital Equipment's VAX) and supercomputers. Dataquest closely follows the developments in the emerging market for these systems, which we call "minisupercomputers." From a 1986 base of about $180 million, worldwide factory revenue for minisupercomputers is expected to reach $1.3 billion in 1991 (see Table 1). Over the same period, total technical computer systems factory revenue, including sales of systems that range from personal computers to supercomputers as used in technical applications, will grow from about $14.5 billion in 1986 to $34.5 billion by 1991. Minisupercomputer revenue is growing faster than the rest of the market, although it remains a small part of the total. What is behind this remarkable growth potential?

Table 1

Worldwide Factory Revenue and Unit Shipments
for Minisupercomputers
1982–1991

Estimated	1982	1983	1984	1985	1986	CAGR 1982-1986
Factory Revenue ($M)	$2.6	$26.5	$57.3	$131.5	$176.0	-
Percent Growth	N/A	919.2%	116.2%	129.5%	33.8%	286.8%
Shipments (Units)	7	65	130	237	318	-
Percent Growth	N/A	828.6%	100.0%	82.3%	34.2%	262.0%
Forecast	**1987**	**1988**	**1989**	**1990**	**1991**	**CAGR 1987-1991**
Factory Revenue ($M)	$309.4	$480.0	$688.0	$955.0	$1,289.0	-
Percent Growth	75.8%	55.1%	43.3%	38.8%	35.0%	39.3%
Shipments (Units)	475	752	1,162	1,739	2,589	-
Percent Growth	49.4%	58.3%	54.5%	49.7%	48.9%	45.7%

N/A = Not Available

Source: Dataquest
November 1987

Dataquest Incorporated, 1290 Ridder Park Drive, San Jose, CA 95131-2398, (408) 971-9000, Telex 171973

What Is a Minisupercomputer?

To qualify as a minisupercomputer, a system must meet the following criteria:

- It must perform at least some scientific and engineering applications using 64-bit floating-point arithmetic at a peak speed of not less than one-tenth that of a low-end supercomputer.

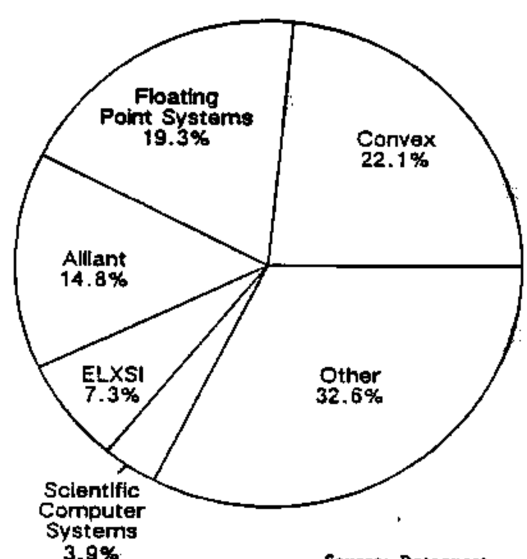
- It must be capable of running an entire compiled program.

- The typical price should range between $200,000 and $1 million. The maximum price for a fully configured system can be as high as $5 million.

Common minisupercomputer features include large memories and some combination of vector, parallel, or multiprocessing support. Floating Point Systems was the first company to produce minisupercomputers in 1981, with the FPS-164 system. We have identified roughly twenty companies that currently ship minisupercomputers or that we expect to eventually produce them. In 1986, the market was led by three vendors (see Figure 1), with considerable market share gain made since 1985 by Convex and Alliant.

Figure 1

**Estimated Market Share
Minisupercomputer Vendors
Based on 1986 Factory Revenue**



Source: Dataquest
November 1987

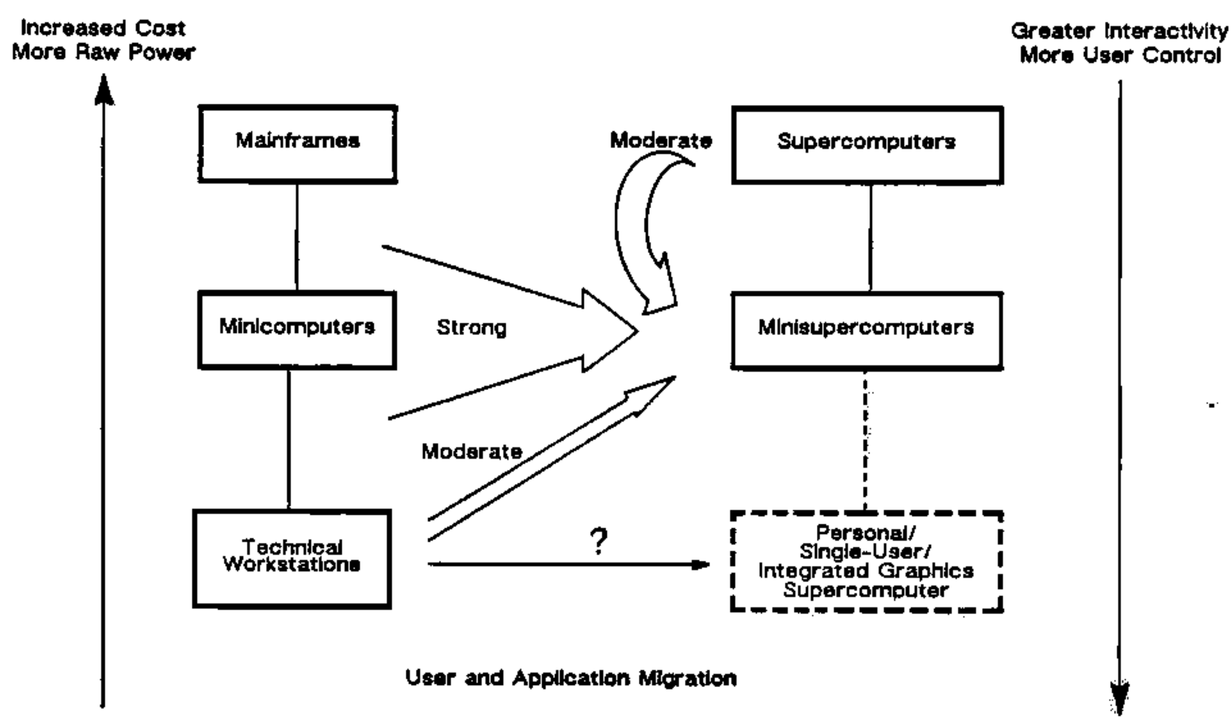
Where Do Minisupercomputers Fit?

There are few, if any, methods short of a full–fledged, real–work user benchmark that can be reliably used to accurately compare computer systems, although attempts have been made at developing standard performance benchmarks. Dataquest does not endeavor to propose or defend any particular benchmark scheme. However, the full–precision, all–FORTRAN 100–by–100 Linpack program serves as well as any to illustrate the performance gap that exists between supercomputers (e.g., Cray systems) and superminicomputers. With Linpack performance normalized at 1.0 for a Cray 1/S, supercomputers have performed in the range of 0.28 to 1.0, while high–end minisupers range from 15.0 to 100.0. The vast difference between these two ranges is the gap at which minisupercomputer vendors have directed their strategies.

Another way to look at minisupercomputers is to consider an analogy. By moving from mainframe to minicomputer to workstation (see Figure 2), computer system users receive less raw performance but greater interactivity and system control for a lower price. In fact, the improved control over computing resources and costs was a major driving factor behind the emergence of minicomputers some fifteen years ago.

Figure 2

Minisupercomputer Positioning



Source: Dataquest
November 1987

Minisupercomputers occupy a cost-effective position relative to supercomputers that is analogous to that held by minicomputers with respect to mainframes. Minisupers offer decentralized control over computing resources, cost less to purchase and operate, and increase human interactivity with the system as compared with supercomputers. Two companies, Stellar and Dana Computer, plan to extend interactivity and our analogy further when they introduce personal/single-user/integrated graphics (take your pick) supercomputers later this year.

Going after the "Early Adopters"

As an integral part of our market research effort, Dataquest monitors the motivations and purchasing patterns of technical computer systems buyers. Our ongoing surveys have confirmed several characteristics about the market for minisuper-computers, described in the following sections.

Who Is Buying Minisupercomputers?

Most systems have thus far been acquired by researchers at universities and government labs that have a need for specialized systems to help solve mathematical problems in support of experiments.

What Criteria Are Used to Evaluate Minisupercomputer Purchases?

When shopping for a minisupercomputer, current users were most interested in peak system performance, the ease of transporting existing production software, and communicating with other computing resources (primarily VAX systems and technical workstations).

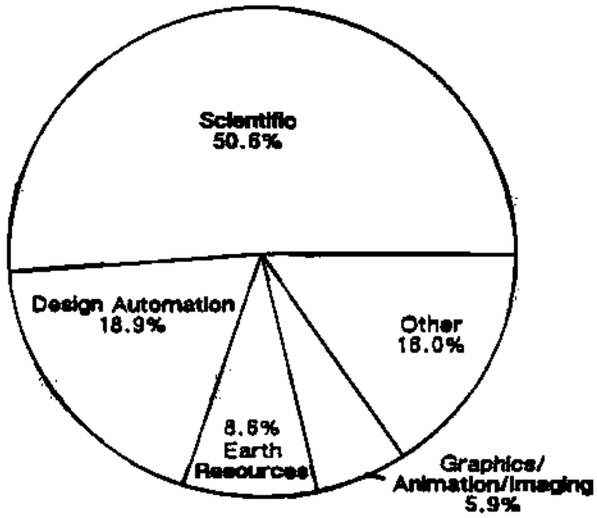
How Are Minisupercomputers Being Used?

Of the major technical application disciplines, 1986 minisupercomputer factory revenue was dominated by the scientific category (see Figure 3), with design automation placing a solid second. Minisupercomputers are very commonly found in networked environments, acting as computational servers to complement workstations and other computers. As evidenced by the flow of applications and users from other systems (see Figure 2), minisupers compete for budget dollars with workstations and superminis, particularly VAXes.

In short, the market for minisupercomputers has been in an early stage of development. Most systems have been sold to early adopters who can justify the purchase of a system based on potential speedups of a limited set of applications. Minisupers have been successful because of their price/performance advantages when compared with other computing alternatives. How can the minisupercomputer market grow beyond the comfortable confines of the scientific and engineering risk-takers that have embraced it so far?

Figure 3

Estimated Percentage Shares of 1986
Minisupercomputer System Factory Revenue



Source: Dataquest
November 1987

Strategic Emphasis on Commercial Markets

Pressure is building on scientific, engineering, and manufacturing communities to achieve faster time to market for new products that are better tested, of higher quality, and less costly to produce. These factors have driven the need for more sophisticated tools to replace physical modeling techniques with computer simulation.

Similar pressures are growing in other technical applications. For example, securities traders with sophisticated analytical tools can make investment decisions, improve portfolio opportunities, and increase profits faster than the competition. Product planners can analyze market data and make appropriate modifications to product mix in specific competitive situations. In these cases, the availability of timely information translates into well-informed decisions and profitable opportunities.

Supercomputers are often too expensive and superminicomputers not sufficiently powerful to provide adequate departmental solutions in these areas. Examples like these illustrate that the growth of the minisupercomputer market will be fueled by increased commercial acceptance of the systems for use in computationally intensive applications. In fact, a shift in emphasis toward commercial customers is clearly underway among minisupercomputer vendors:

- Over the last six months, almost 70 percent of Alliant's revenue has come from customers in aerospace, military, and industrial areas.
- Convex has formally reorganized its marketing staff along both product and industry marketing lines.

- Greater effort is being expended at all firms on broadening and deepening application software catalogs with quality third-party products.

- New products, such as the Trace systems from Multiflow and the Cydra-5 from Cydrome, represent a second wave of minisupercomputers. Where earlier minisuper vendors relied on architectures that required some user intervention to obtain optimal program performance, the new products promise to offer general speedups on a variety of application programs without extensive code restructuring.

- "Single user graphics supercomputers," combining high levels of scalar, vector, and graphics capabilities, will be introduced by several vendors later in 1987. These systems will aid in the visualization of three-dimensional physical phenomena in real time. The primary market for such systems will be in design automation disciplines, particularly in areas such as structural dynamics, kinematics, and fluid dynamics, as well as in chemistry, molecular modeling, styling, and image processing.

Digital has clearly been affected by the growth of minisupercomputers, primarily in terms of sales opportunities lost to new vendors. Our research has confirmed the strong lateral flow of applications and users from superminicomputers (mainly VAXes) to minisupers, and a somewhat less powerful diagonal movement from workstations, primarily from Apollo and Sun (see Figure 2). Several vendors have encouraged this migration by providing VMS-compatible compilers and software environments, as well as some measure of DECnet connectivity. However, most vendors are wary of positioning their products as direct replacements for VAX systems, and for a good reason. Even among early minisuper adopters, there seems to be no near-term diminution in the desire to purchase new VAX systems (good news for Digital). Digital hardware will certainly be a fixture in technical environments for some time. By maintaining price/performance superiority and a loyal customer base, vendors can help to lessen the impact of Digital's possible moves against them.

Digital has recently tried to counter the migration of users and programs by offering two alternatives for prospects whose needs cannot be met solely by a VAX solution—the VAX Supercomputer Gateway between dedicated Digital systems and Cray supercomputers, and with Digital/Floating Point Systems machines sold through a sales agency agreement with Floating Point Systems.

In 1985, IBM announced the Vector Facility, a vector processing unit designed to work in conjunction with the 3090 series of mainframes. IBM has also opened four Numerically Intensive Computing (NIC) field marketing centers, bringing greater attention to IBM's commitment to technical computing markets. IBM is interested in the minisupercomputer market, but is likely to grow with it through vector extensions to the 3090, and possibly to the 4381 and 9370 product lines.

Cray Research categorically states that it has no plans to produce anything other than supercomputers, though it is clear that Cray has been impacted by minisupercomputers. This is evident in the delay that such systems have caused in the decision-making process of some marginal, low-end supercomputer prospects. Cray's recent backlog contraction, though small, illustrates this situation. The introduction of the X-MP/14SE, an entry-level supercomputer, and alliances with Digital for a high-speed gateway are the near-term extents of Cray's movement into minisupers.

DATAQUEST CONCLUSIONS

- The market window for new minisupercomputer entrants is closing rapidly. Vendors without a viable product by the end of 1987 will face momentum from the market leaders that will be very difficult to overcome.

- The exception to the previous rule is Digital, which is now well positioned to offer a minisupercomputer-class system as an upward extension of the VAX product line to fit between current systems and supercomputers. Until Digital offers an all-DEC solution a DEC minisupercomputer is likely to be an "enhanced VAX" which maintains continuity with the VMS-based family and avoids "cannibalization" of VAX sales. In this sense, Digital probably will act as a systems integrator by bringing together new VAX systems with supplementary processors.

- Because the worldwide market for minisupercomputers is still relatively new and small, and because of emerging entry barriers such as the availability of application software, issues of service and support, and emotional issues surrounding U.S.-Japan trade agreement, we do not expect Japanese manufacturers to offer minisupers for worldwide sale in the next few years. Japanese firms will seek to establish development and marketing relationships with minisupercomputer manufacturers that can help vendors succeed in the Japanese market.

- Over the next five years, a spectrum of minisupercomputer products will evolve. Increasing numbers of systems under $200,000 will exert price pressure in one direction, while systems with improved performance will drive growth at the high end. In the middle, features that enhance computational performance will be available on superminicomputers, so that today's minisupercomputer will become tomorrow's supermini.

- Non-U.S. markets will provide an increased share of minisupercomputer revenue, growing from 18 percent of factory revenue in 1986 to 43 percent by 1991.

- By 1991, the design automation category will divide the market with the scientific category as the largest application disciplines for minisuper-computers. This is to be expected as more software is ported to the systems.

Surviving the Shakeout

We expect that a contraction in the number of minisupercomputer market participants will occur in 1988 and 1989. Several indicators of the shakeout include the following:

- With about 20 companies competing for a $1.3 billion market, average company sales will be around $65 million by 1991, a figure likely to provide insufficient returns to venture investors and corporations that have already invested more than $400 million (with more to come) in the industry. Already in 1987, there has been less enthusiasm for the funding of new or marginal minisuper firms, as evidenced by the recent demise of the computer operation at Vitesse Electronics and the discontinuance of standalone operations at Culler Scientific.

- The level of price discounting is beginning to intensify. This is evident in certain competitive situations where the prospect is a university or other institution that would be a particularly prestigious addition to a vendor's customer list.

- A few crucial third-party packages in certain technical applications are frequently demanded by end users. With many new vendors clamoring to transport such software to their platforms, software houses are faced with the chore of converting, maintaining, and revalidating software releases for a plethora of systems. Minisupercomputer makers must convince key software vendors that the resultant license revenue is worth such an effort.

The days of easy sales to early adopters are nearly over. Successful vendors have foreseen this eventuality and have shifted strategic emphasis to the penetration of commercial accounts and the cultivation of relationships with application vendors. A few major players and several niche vendors with narrowly focused marketing strategies allowing them to serve markets too small to attract the attention of a major firm will survive.

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Research Newsletter

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1987–32

INTEL TARGETS "HIDDEN" MCU APPLICATIONS

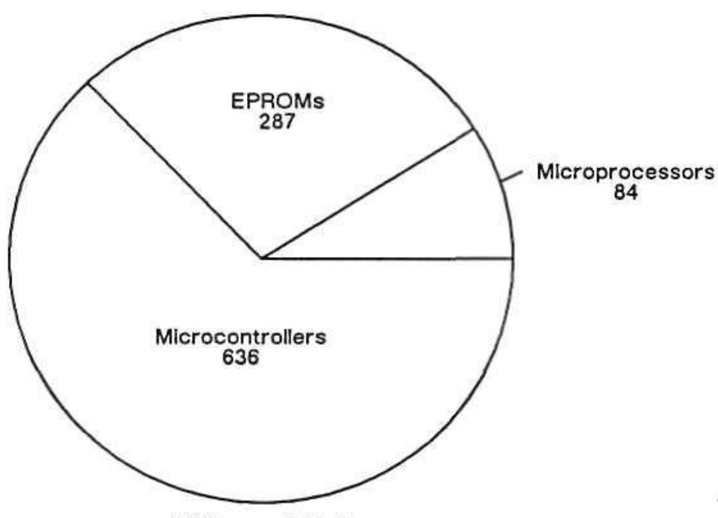
SUMMARY

Intel has launched an aggressive strategy to capture demand from users of systems incorporating embedded controllers—the "hidden intelligence" in everyday products like automobiles and VCRs. Embedded control is defined as nonreprogrammable applications that remain unchanged during a system's product life cycle. Figure 1 depicts the three component markets served by Intel. Key points in Intel's program are as follows:

- Strategy: to combine architectural leadership and low-cost manufacturing to win design-ins of systems with long life cycles
- Implementation: to cash in on Intel core architecture by growing a family of standard and application-specific products
- For users: a critical decision of whether to go with Intel for the long haul or to choose an alternative supplier

Figure 1

Markets Served by Intel in 1987



Source: Dataquest
October 1987

Dataquest Incorporated, 1290 Ridder Park Drive, San Jose, CA 95131-2398, (408) 971-9000, Telex 171973

THE TARGETED MARKETS

As shown in the figure, the microcontroller business offers the largest market opportunity: more than half a billion units will be shipped on a worldwide basis in 1987. Designers of systems using 8-bit parts can expect a strong commitment from Intel now and in the future, and the company will certainly participate in the ramping up of 16-bit production that should occur later in this decade.

THE CORPORATE STRATEGY

Intel's strategy for serving demand for microcontrollers and microprocessors that are used in nonreprogrammable applications (i.e., "hidden intelligence" applications) derives from its three-pronged corporate strategy. The Intel corporate attack calls for the following:

- Technological leadership
- World-class manufacturing capability
- "Vendor of choice" status among the customer base

INTEL'S SEMICONDUCTOR APPLICATION MARKETS (SAMs)

Figure 2 depicts Intel's SAMs for embedded controllers as of 1985. Although these end markets are shifting, the figure gives a good picture of Intel's current demand mix, provides a basis for discussing future trends, and holds one surprise, given Intel's high visibility in the office automation business. The surprise is that computers and office systems constitute less than half (i.e., 46 percent) of the end demand for Intel microcontrollers. The other semiconductor application markets represent significant business opportunities that the firm fully intends to cultivate over the long term.

Other Significant SAMs

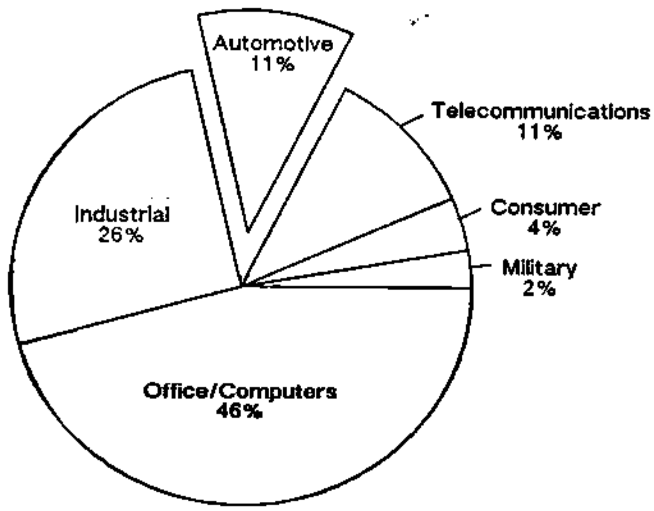
As Figure 2 shows, Intel's other SAMs include the following: industrial (26 percent); automotive (11 percent and growing), telecommunications (11 percent), consumer (4 percent), and military (2 percent). The exploding automotive electronics marketplace represents a major growth opportunity for the company. Intel takes great pleasure in pointing to the fact—unbeknownst to most users of the product—that the Ford Taurus uses Intel's embedded controllers, which are crucial to its award-winning performance. In fact, Ford Motors is Intel's second largest customer (IBM is first).

The relatively small consumer and military segments have also caught the eye of Intel corporate strategists. The military segment may be small in terms of overall revenue, but it is a strong contributor to profits and product positioning/development (e.g., the 80386 chip).

Similarly, Intel sees an opportunity for application-specific 8- and 16-bit designs geared for the consumer market. Service to users with application-specific objectives like this marks a keystone of Intel's future product direction.

Figure 2

Intel Embedded Controllers by Segment
(Intel Shipments—1985)



Source: Intel
Dataquest
October 1987

IMPLEMENTATION OF INTEL'S STRATEGY IN THE 8-, 16-, and 32-BIT MARKETS

Architectural Leadership

The first prong of Intel's embedded microcontroller market strategy entails the preservation and extension of its leadership position in microcontroller/microprocessor architecture. The strategy is quite straightforward: to build upon successful 8-bit parts (e.g., 8086/8, 8048, 80C51) as the road to achievement in 16-bit (80186/80C186, 8096/80C196) and 32-bit segments, as well as application-specific standard products (for high-volume applications) and ASICs. In the 32-bit arena, Intel plans to introduce the 80376 device during the second quarter of 1988.

Designer's Vendor of Choice

To win new design-ins, Intel offers design engineers three "flexible" product delivery vehicles derived from given Intel microcontroller core architectures. The three product vehicles are standard products, application-specific standard products (as noted, for high-volume applications), and ASICs.

Intel will use its large microcontroller sales and field-application forces to aggressively implement the corporate strategy. Another key to establishing the firm as the vendor of choice for systems designers is expansion of the global network of training and support centers, and the development of new CAD/CAE and hardware tools.

World-Class "Low-Cost" Manufacturing Capability

To establish itself as the vendor of choice among purchasing managers, Intel has strengthened its capacity toward the goal of high-volume/low-cost production that competes in terms of both cost and quantity against Asian manufacturers. Intel tripled its capacity between 1985 and 1987.

AGGRESSIVE PRODUCT DEVELOPMENT STRATEGY

Intel plans a very aggressive product development strategy in the embedded controller marketplace for two reasons. First, these devices are consumed in a wide diversity of applications. Second, the life cycles of both the microcontrollers and the systems using them can be quite long: 10 to 15 years for the embedded controllers and up to 50 years for some systems (e.g., power distribution systems). These twin realities—the tremendous diversity of applications and long product life cycles—create both opportunity and challenge for Intel in terms of customer support.

To illustrate, a design-win leader like the 80186 part can secure as many as 2,000 applications. Embedded usage contributes to both the broader utilization and longer life cycle of the 80386 device. The long-term results can be summarized by the 8048 chip: its wide diversity of applications and consequently long life cycle has resulted in the greatest number of these embedded controllers being shipped in its tenth year of production (i.e., 1987).

Embedded Microcontroller Applications

A representative (although nonexhaustive) listing of the applications for embedded controllers is as follows: alarm clocks, thermostats, TV channel decoders, VCRs, lighting systems, electronic scales, watering systems, hot water systems, CD players, coffee makers, microwaves, automobiles (four per auto), pool control systems, traffic light systems, automotive radar, gas pumps, cash registers, facsimile equipment, copiers, personal computers (keyboards, disk drives/controllers, interface, and printers), PBXes, typewriters, and telephones.

A Challenge for Intel: Expanding 8-Bit Functionality

Although Intel promises users of 8-bit through 32-bit embedded controllers that it will dependably and "flexibly" meet demand over long product life cycles, some concern exists among users of 8-bit devices regarding the pressing need for increased on-board functionality.

For designers and builders of systems employing 8-bit embedded controllers, systems innovation could be stifled and costly upgrades mandated because of the lack of timely availability of desired features.

8– and 16–Bit Cash Cores/Prolific Calves

Nevertheless, users of 8– and 16–bit microcontrollers and microprocessors should find themselves in a supportive environment. Intel's strategy calls for a set of "cash cow" (or "cash core") devices like the 8051 and 80186 families to serve as the basis for a prolific set of application–specific cash calves. For example, the 8051 device leads simultaneously to a growing set of standard parts (80C51, 8052), application–specific standard parts (80C452, 80C51FA, 80C152) and ASICs (UC51). Users should receive a dependable supply of low–cost, high–volume standard products and application–specific standard parts, and an option for proprietary ASICs. In turn, Intel earns revenue and profits on its technological expertise at every turn without killing the original cash core.

IMPACT ON USERS

Intel's embedded controller strategy is part and parcel of the well–defined megatrend in the semiconductor industry toward closer, long–term vendor/customer relationships. Intel plans to win the hearts and minds of systems designers through technological leadership and customer support, and to win purchasing managers through dependable, lower–cost supply over long product life cycles.

Users of Intel's embedded controllers consistently report several system advantages through use of these devices, and just as consistently demand more of the same in terms of Intel product improvement. Users report enhanced system–design flexibility and associated ease of software configuration. Embedded control reduces system size and component count, and thus cost. Superior system maintenance capability also contributes to cost savings. By "converting" system hardware into firmware, embedded control loads many mundane system processes from the main control complex and pushes system functionality downward from the main complex to the portboard. The overall result is smaller, more reliable, and less costly systems that offer higher levels of performance and functionality.

For future systems, users demand higher performance (e.g., high–speed direct memory access), increased on–board functionality (such as 14–bit A/D conversion), and lower cost. Intel will be pressed to meet these kinds of user needs quickly.

DATAQUEST CONCLUSIONS

For Users in General

The Intel embedded controller strategy signals the supplier's effort to reassert itself in the microcontroller arena. This is a large market and still growing. The prospect of Intel core architecture in high volume and at competitive cost marks a genuine opportunity that should be explored by systems designers and purchasing managers. For users, embedded control can mean smaller, less costly systems offering higher performance. Intel faces a dual challenge, however, in carrying through as a dependable low-cost supplier and in meeting on a timely basis users' incessant demands for increased on-board chip functionality.

Regarding Intel-Committed Customers

For users already committed to Intel as the vendor of choice for embedded controllers, the strategy should simplify long-term procurement. Intel's strategy calls for a host of 8-, 16-, and 32-bit devices and three vehicles for delivering these products. Strong vendor support from Intel for users can be expected into the 1990s. Intel is committed to supplying users over the long life cycle of the users' systems, but as noted, a tension will exist between user demand for increased on-board chip functionality and Intel's ability and willingness to serve that need in a timely fashion.

For Uncommitted Users

For users who have not made a long-term commitment to a vendor, careful assessment must be given to the major points contained herein. Uncommitted designers and buyers should also give careful scrutiny to alternative suppliers like AMD, Motorola, National Semiconductor, NEC, Signetics, and Zilog, which are also aggressively pursuing this growing market.

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Anthea C. Stratigos
Ronald Bohn

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Research Newsletter

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PERSONAL COMPUTERS DRIVE THE TURNAROUND: THIRD QUARTER ELECTRONIC EQUIPMENT UPDATE

SUMMARY

Dataquest continues to see 1987 as a turnaround year for the electronics industry, leading into higher growth in 1988. We expect total electronic equipment production to grow 6.4 percent this year. Admittedly, this is not the high growth the industry has seen in the past. However, the largest semiconductor application market, data processing, is growing at a much faster pace than the industry total—10.4 percent in 1987.

This newsletter outlines our forecast for various equipment markets. The following observations are those we believe to be the most important to semiconductor suppliers:

- Personal computers continue to drive the current upturn in semiconductor industry sales. Dataquest estimates that semiconductor consumption by PCs will grow 38 percent this year.

- The communications application market will provide the highest growth for North American semiconductor suppliers in the long term. We estimate semiconductor consumption by the communications application market will grow at a 14 percent compound annual growth rate (CAGR) from 1991 to 1987.

- The current slump in automotive production has caused a decline in robotics shipments. However, the resurgence in the semiconductor industry has pushed growth up in other segments of the industrial application market, such as automatic test equipment (ATE) and semiconductor production equipment.

- The large amount of consumer debt accumulated in 1986 will have a moderating effect on the growth of the consumer electronics market. Dataquest estimates that the consumer application market will grow 8 percent this year.

- Limits in congressional spending will cause the military electronics market to slow in growth through 1991; however, the need for state-of-the-art technology will allow the military semiconductor market to grow 14 percent this year.

- Automotive production is expected to decline this year by 9 percent. However, Dataquest expects semiconductor consumption by the automotive industry to grow 16 percent due to the increasing pervasiveness of electronics in automobiles.

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OUTLOOK FOR APPLICATION MARKETS

Table 1 displays Dataquest's latest electronic equipment forecast. As mentioned above, we expect the industry as a whole to grow 6.4 percent in 1987, a small increase from the 4.5 percent growth of 1986. But if we extract the military market from the total the growth, increases are a little more dramatic—9.5 percent in 1987 versus 5.6 percent in 1986. We forecast the market excluding military to grow at a 7.8 percent CAGR from 1987 to 1991.

Table 2 displays Dataquest's estimates of North American semiconductor consumption by application market. We forecast communications to be the fastest growing market from 1987 to 1991, with the industrial and data processing application markets following very closely.

The following sections discuss each application market forecast, highlighting the markets we believe to be the most important to semiconductor suppliers.

Data Processing

Resurgence in the computer and peripherals markets is the source of accelerating growth in the data processing application market. Dataquest expects this market to grow 10.4 percent this year and accelerate to 9.8 percent in 1988. Personal computers will push the computer segment's growth to 13.4 percent this year. The computer storage and input/output segments will follow personal computers as the fastest growing segments with growth of 10.8 and 8.0 percent respectively. We expect the dedicated systems and terminals segments to decline in 1987 by 13.0 and 4.0 percent respectively.

As in the past, the computer segment continues to drive the current upturn in semiconductor industry sales. Dataquest estimates that the computer industry will consume 27 percent of total North American semiconductor sales in 1987. Of that 27 percent, we estimate that personal computers will make up 37 percent. Our forecast for North American personal computer semiconductor consumption is an 11.8 percent CAGR for the 1987 to 1991 period. The dollar value of semiconductors used in PCs should be $1.689 million in 1988, a strong gain against 1987's $1.252 million figure. After a dip to $1.560 million in 1989, consumption is forecast to increase in 1990 and 1991, to $1.742 million and $1.954 million, respectively.

Recent computer manufacturers' financial results show that the computer industry is doing more than replenishing inventory. Many of the major computer manufacturers' revenue and profits jumped in the first two quarters of 1987 compared with the same period in 1986. Computer manufacturers <u>are</u> selling equipment. Table 3 displays second-quarter financial results for selected data processing companies.

The pickup in new computer sales has had a positive effect on computer storage shipments. Micropolis, National Advanced Systems, and Seagate storage sales have soared this year as opposed to the same time last year. The demand is not only for storage in new computer products but also for increasing the storage capacity in the installed base of computers.

Table 1

North American Electronic Equipment Forecast
(Millions of Dollars)

Segment	1987	1988	1989	1990	1991	CAGR 1987-1991
Data Processing						
Computers	$ 65,010	$ 73,210	$ 78,548	$ 84,406	$ 91,094	8.8%
Data Storage Subsystems	21,014	22,392	25,593	26,494	26,837	6.3%
Terminals	2,769	2,840	2,966	3,093	3,181	3.5%
Input/Output	8,368	9,019	9,539	9,510	10,172	5.0%
Dedicated Systems	4,711	4,373	4,294	4,400	4,500	(1.1%)
Subtotal	$101,872	$111,834	$120,940	$127,903	$135,784	7.4%
Communications						
Customer Premises	$ 10,074	$ 11,084	$ 12,170	$ 13,114	$ 14,158	8.9%
Public Telecommunications	6,834	7,080	7,516	7,881	8,297	5.0%
Radio	6,513	7,608	8,654	9,785	10,556	12.8%
Broadcast and Studio	1,582	1,767	1,892	2,100	2,331	10.2%
Other	1,958	2,010	2,144	2,346	2,575	7.1%
Subtotal	$ 26,961	$ 29,548	$ 32,376	$ 35,226	$ 37,917	8.9%
Industrial						
Security/Energy Management	$ 2,211	$ 2,388	$ 2,388	$ 2,678	$ 2,905	7.1%
Manufacturing Systems	12,487	13,983	14,586	15,686	17,199	8.3%
Instrumentation	7,235	8,167	8,589	9,197	9,938	8.3%
Medical Equipment	5,345	5,757	6,072	6,432	6,858	6.4%
Commercial Aviation	2,216	2,394	2,582	2,657	2,838	6.4%
Other	5,669	6,394	6,964	7,671	8,466	10.5%
Subtotal	$ 35,163	$ 39,084	$ 41,276	$ 44,321	$ 48,204	8.2%
Consumer						
Audio	$ 324	$ 332	$ 357	$ 395	$ 407	5.9%
Video	5,127	5,291	5,647	6,254	6,577	6.4%
Personal Electronics	720	756	794	801	816	3.2%
Appliances	11,068	11,522	12,098	12,891	13,691	5.5%
Other	1,116	1,167	1,218	1,270	1,325	4.4%
Subtotal	$ 18,355	$ 19,067	$ 20,114	$ 21,611	$ 22,816	5.6%
Military	$ 47,500	$ 46,900	$ 46,400	$ 46,300	$ 46,700	(0.4%)
Transportation	$ 10,809	$ 11,799	$ 13,812	$ 15,050	$ 16,209	10.7%
Total	$240,661	$258,232	$274,918	$290,411	$307,630	6.3%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
October 1987

Table 2

North American Semiconductor Consumption Forecast (Millions of Dollars)

Segment	1987	1988	1989	1990	1991	CAGR 1987-1991
Data Processing						
Computer	$ 3,379	$ 4,403	$ 4,168	$ 4,749	$ 5,532	13.1%
Data Storage Subsystems	862	1192	1216	1373	1609	16.9%
Data Terminals	185	207	196	215	243	7.0%
Input/Output	394	480	435	455	542	8.3%
Dedicated Systems	173	189	158	175	196	3.2%
Subtotal	$ 4,993	$ 6,471	$ 6,172	$ 6,968	$ 8,122	12.9%
Communications						
Customer Premises	$ 911	$ 1,112	$ 1,143	$ 1,271	$ 1,493	13.1%
Public Telecom- munications	345	425	400	437	520	10.8%
Radio	326	448	449	528	641	18.4%
Broadcast and Studio	111	139	136	156	189	14.4%
Other	84	106	98	112	141	13.8%
Subtotal	$ 1,777	$ 2,230	$ 2,227	$ 2,504	$ 2,984	13.8%
Industrial						
Security/ Energy Management	$ 132	$ 165	$ 153	$ 176	$ 210	12.2%
Manufacturing System	764	936	923	1057	1205	12.1%
Instrumentation	355	476	435	502	602	14.1%
Medical Equipment	348	417	411	457	528	11.0%
Commercial Aviation	133	165	162	177	206	11.7%
Other	214	302	284	340	432	19.2%
Subtotal	$ 1,946	$ 2,461	$ 2,368	$ 2,708	$ 3,183	13.1%
Consumer						
Audio	$ 29	$ 34	$ 35	$ 42	$ 45	11.4%
Video	495	596	603	686	742	10.7%
Personal Electronics	38	50	49	51	55	9.6%
Appliances	274	320	282	323	382	8.7%
Other	31	37	33	35	41	6.9%
Subtotal	$ 867	$ 1,037	$ 1,001	$ 1,138	$ 1,264	9.9%
Military	$ 1,777	$ 1,923	$ 1,995	$ 2,176	$ 2,195	5.4%
Transportation	$ 984	$ 1,067	$ 1,160	$ 1,319	$ 1,482	10.8%
Total	$12,344	$15,188	$14,924	$16,812	$19,230	11.7%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
October 1987

Table 3

Quarterly Revenue of Selected Data Processing Companies
(Millions of Dollars)

	Second Quarter 1987 Sales	% Change 1986-1987	Earnings	% Change 1986-1987	Second Quarter 1986 Sales	Earnings
Altos Computer Systems	$ 40.5	40.6%	$ 3.0	275.0%	$ 28.8	$ 0.8
Amdahl	341.0	62.9%	31.0	1,048.1%	209.3	2.7
Apollo Computer Inc.	132.2	49.5%	7.6	660.0%	88.4	1.0
Apple	637.1	42.1%	53.5	65.6%	448.3	32.3
Commodore International	190.4	(8.7%)	1.9	68.3%	208.6	1.2
Compaq Computer	267.5	81.8%	30.7	219.8%	147.1	9.6
Convergent Technologies	104.7	41.1%	0.1	98.0%	74.2	(4.8)
Data General Corporation	942.1	189.6%	(104.4)	(5,320.0%)	325.3	2.0
Digital Equipment Corporation	2,669.1	22.7%	377.3	58.1%	2,175.7	238.6
Gould Inc.	232.5	3.0%	5.9	(42.7%)	225.7	10.3
Harris Corporation	562.1	(2.6%)	26.2	55.0%	577.2	16.9
Hewlett-Packard	2,054.0	14.5%	148.0	20.3%	1,794.0	123.0
Honeywell Inc.	1,575.0	18.7%	54.3	50.4%	1,326.4	36.1
IBM Corporation	12,798.0	4.3%	1,178.0	(9.7%)	12,268.0	1,305.0
Micropolis	70.9	28.2%	6.8	54.5%	55.3	4.4
NCR Corporation	1,359.6	16.3%	98.6	25.1%	1,168.8	78.8
Perkin-Elmer Corporation	363.8	4.0%	24.0	15.4%	349.9	20.8
Prime Computer Inc.	236.0	12.1%	15.7	37.7%	210.5	11.4
Seagate	250.1	76.6%	34.2	108.5%	141.5	16.4
Tandy Corporation	741.4	7.3%	44.2	63.1%	690.8	27.1
Texas Instruments Inc.	1,371.6	10.2%	61.9	403.3%	1,244.1	12.3
Unisys	2,275.0	70.1%	121.2	59.1%	1,337.6	76.2
Wang Laboratories	824.0	15.0%	32.0	3,900.0%	716.8	0.8
Xerox	3,624.0	14.9%	154.0	26.2%	3,155.0	122.0
Total	$33,662.6	16.2%	$2,405.7	12.2%	$28,967.3	$2,144.9

Source: Dataquest
October 1987

At first glance, the terminals segment looks mundane. However, one of the fastest growing types of electronic equipment, graphics and imaging terminals, is included in this segment. Dataquest expects graphics and imaging terminals to grow 16.2 percent in 1987 and to continue at a 16.8 percent CAGR from 1987 to 1991. Growth in the graphics industry has been driven by new semiconductor technology and new software applications such as electronic publishing and computer-aided design (CAD).

In the input/output segment, the most attractive equipment continues to be the page printer. The move to decentralized computing has led to decentralized printing. A desire for letter-quality printing and desktop publishing capabilities has opened up an area of opportunity for page printer vendors. Dataquest expects page printer shipments to grow 31.9 percent this year and to taper off to an 18.2 percent CAGR in the long term, from 1987 to 1991.

As the functions that page printers are required to perform become more complex, the need for sophisticated semiconductor technology in these products increases. This market is evolving as an area of opportunity for graphics processor and microprocessor manufacturers. We forecast page printer semiconductor consumption to grow at a 26 percent CAGR from 1987 to 1991, to $211 million.

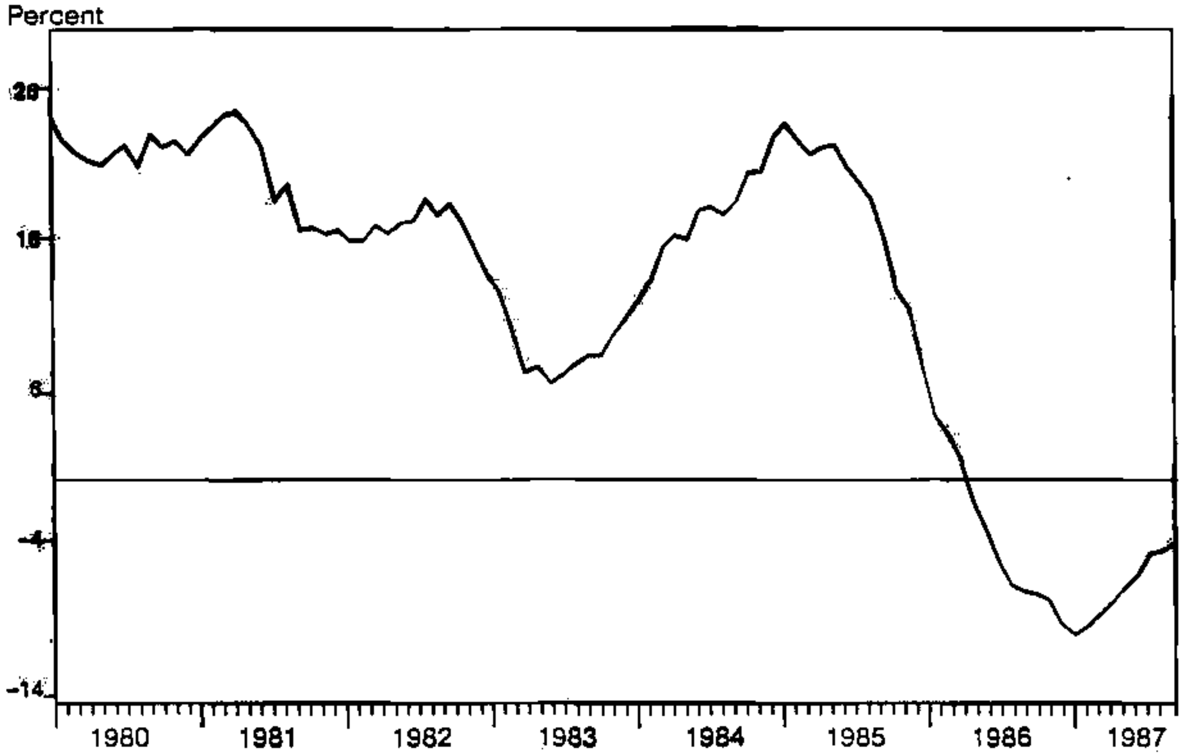
We expect the dedicated systems segment to decline 12.6 percent in 1987 and to continue to decline at a CAGR of 1.1 percent through 1991. Dataquest believes that U.S. manufacturers' dedicated systems segment shipments will shrink for the following three reasons:

- Very high market penetration (mature market)
- Technology obsolescence
- International competition

Although there are definitional differences between Department of Commerce (DOC) data and Dataquest methodology, we believe that the DOC monthly data are a good source for aggregate top-level monthly data. The most recent DOC data shown in Figure 1 indicates that computer and office machines shipments are recovering. The rate of decline of shipments has turned and is heading for positive growth.

Figure 1

Computer and Office Equipment Shipments
(12/12 Rate of Change)



Source: U.S. Department of Commerce
Dataquest
October 1987

Communications

Our forecast for the communications market as a whole continues to be 8.2 percent in 1987, with long-term growth of 8.9 percent from 1987 to 1991.

In the customer premises segment, data communications equipment continues to be the focus of the industry, specifically the following equipment types:

- T-1 multiplexers
- Statistical multiplexers
- Local area networks (LANs)
- Data PBXs
- Modems
- Front-end processors

Table 4 shows our estimates of semiconductor consumption for each of the equipment types listed above.

Table 4

Estimated North American
Semiconductor Consumption
(Millions of Dollars)

Equipment Type	1987	1988	1989	1990	1991	CAGR 1987-1991
T-1 Multiplexer	$ 22.0	$ 35.0	$ 38.0	$ 41.0	$ 44.0	18.9%
Statistical Multiplexer	$ 23.0	$ 25.0	$ 19.0	$ 19.0	$ 21.0	(2.2%)
LAN	$ 84.3	$102.0	$106.0	$119.0	$142.0	13.9%
Data PBX	$ 12.0	$ 13.0	$ 11.0	$ 11.0	$ 11.0	(2.2%)
Modem	$214.0	$279.0	$351.0	$392.0	$394.0	16.5%
Front-End Processor	$ 43.0	$ 56.0	$ 57.0	$ 66.0	$ 81.0	17.2%

Source: Dataquest
October 1987

In the public telecommunications arena, declining growth in central office switching equipment continues to moderate this segment's overall growth (5 percent CAGR from 1987 to 1991). Dataquest forecasts that central office switching equipment revenue will drop 2 percent this year and decline at a 4.5 percent CAGR from 1987 to 1991. However, we expect packet switching equipment to pick up the slack in this segment. We forecast packet switching equipment revenue to grow at a 21.7 percent CAGR from 1987 to 1991.

The 17.8 percent growth in the radio segment is due in large part to the success of cellular mobile radio (CMR). We expect CMR base stations to grow 71.8 percent this year and to grow at a 28.3 percent CAGR fro 1987 to 1991.

Broadcast and studio equipment are expected to grow 5.9 percent in 1987 and at a 10.5 percent CAGR through 1991. Most of this growth will be in transmitters, cable television equipment, and video equipment due to technology replacement.

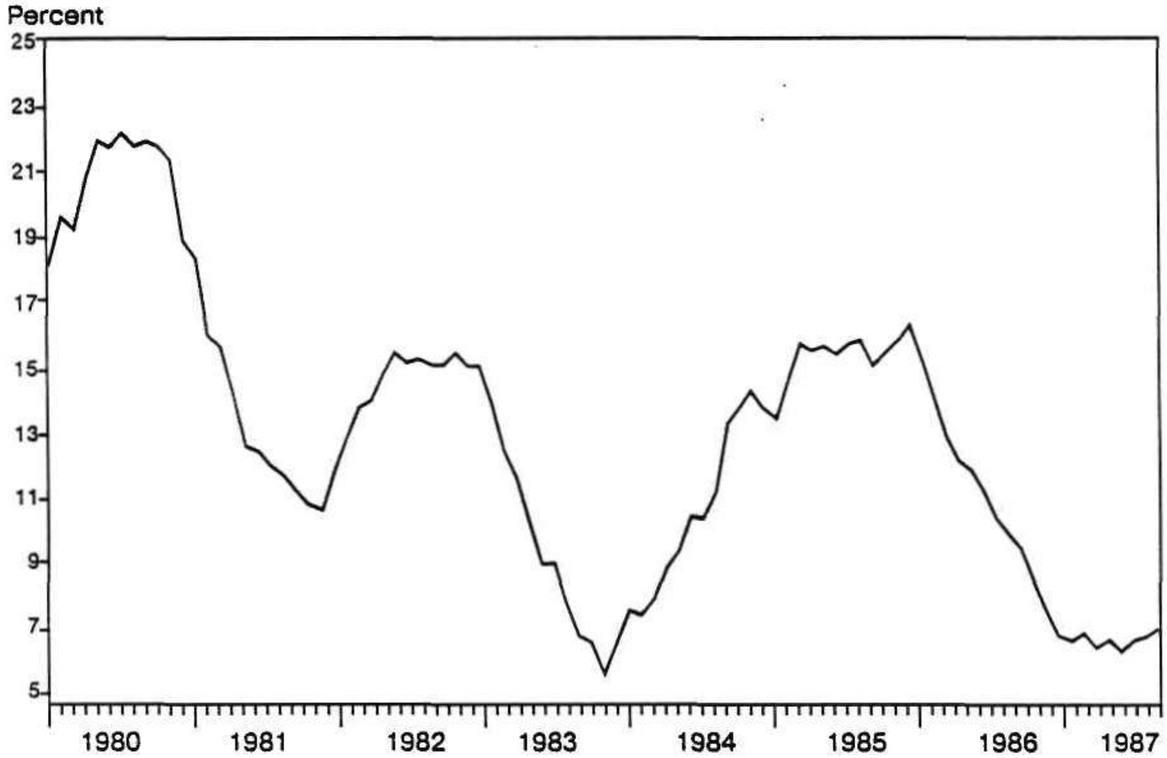
Figure 2 shows a 12/12 rate of change curve for communications equipment shipments. The last data point, August 1987, was 6.6 percent. We expect shipments to finish 1988 with between 7 percent and 8 percent growth.

Dataquest believes that the communications application market will be a consistent growth opportunity for semiconductor suppliers through 1991. We estimate that semiconductor consumption by the communications application market will grow at a 13.9 percent CAGR from 1987 to 1991.

Data communications is the area of greatest opportunity for semiconductor manufacturers. Increasing use of digital technology, cost reductions, and higher bandwidths are trends in the data communications segment that will provide opportunities to semiconductor manufacturers.

Figure 2

Communications Equipment Shipments
(12/12 Rate of Change)



Source: U.S. Department of Commerce
Dataquest
October 1987

Industrial

The turnaround in other electronics industries has had a positive effect on the industrial market, because electronics manufacturers are slowly expanding their capacity to keep up with the new growth. Dataquest expects the industrial segment growth to jump 6 percentage points this year to 7.7 percent. We expect growth to accelerate in 1988 to 11.2 percent, then taper off to an 8.2 percent CAGR for the long term (1987 to 1991).

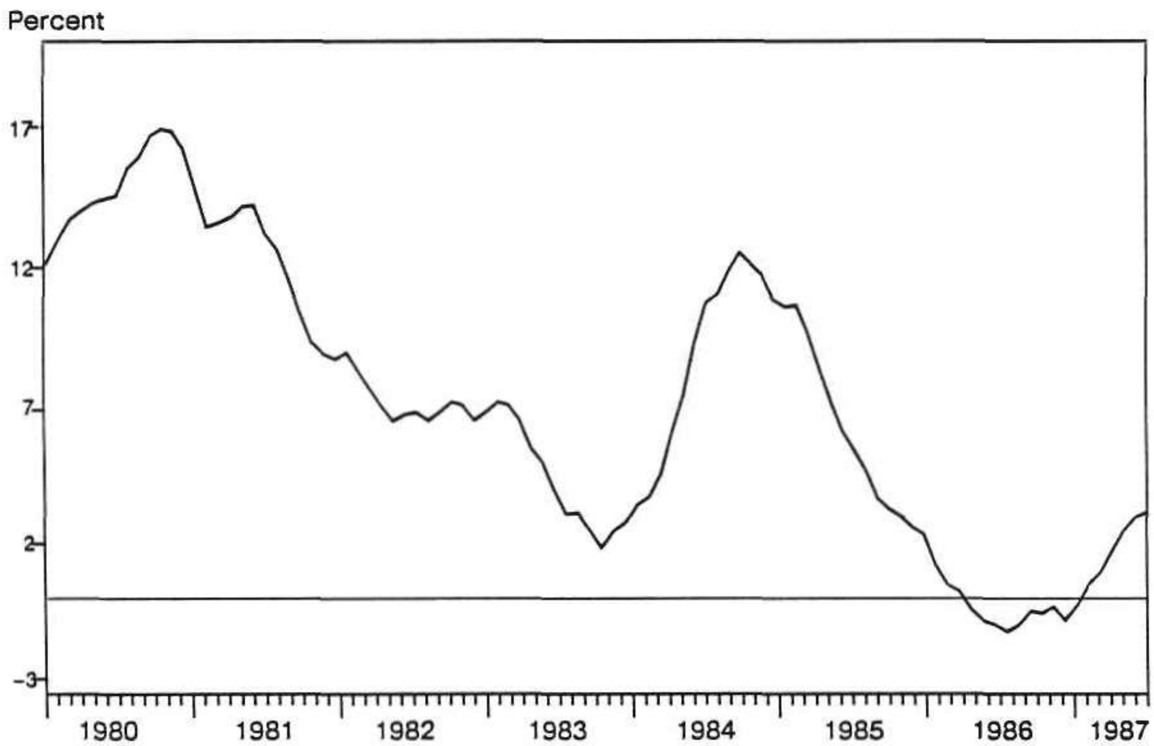
The recovery in the semiconductor industry has had a positive effect on portions of the manufacturing systems segment. However, current decline in automotive production has had a detrimental effect on robotics sales in 1987. We expect robotics shipments to decline by 4.2 percent this year.

The instrumentation market is also positively affected by the upturn in other electronic markets. We expect this segment to grow 9.9 percent this year versus no growth in 1986. In 1988, we forecast that growth in this segment will accelerate to 12.9 percent. Dataquest believes that in the long run (1987 to 1991) the segment will grow at an 8.3 percent CAGR.

The latest DOC electronic instruments shipment data is displayed in Figure 3. The rate of change curve shows that instrument shipments have started to pick up, reaching 3.2 percent in August.

Figure 3

U.S. Scientific and Engineering Instrument Shipments
(12/12 Rate of Change)



Source: U.S. Department of Commerce
Dataquest
October 1987

We expect the medical electronics segment to continue its recovery from the downturn in 1984 and 1985. We believe that this segment will grow 6.9 percent this year and continue to grow at a 6.4 percent CAGR from 1987 to 1991.

New technology continues to be the impetus for growth in medical electronics this segment. Magnetic resonance imaging and implantable defibrillators are two examples of new products that are expected to grow through the forecast period.

Consumer

Overall, Dataquest expects the consumer application market to grow 7.9 percent in 1987 and level off to a 5.6 percent CAGR from 1987 to 1991.

In the audio segment, portable systems and high-end audio systems are the key to new sales today. According to the Electronics Industry Association, sales of "boom boxes" and portable CDs have increased this year over last.

The video segment is expected to grow 10.1 percent this year and continue to grow at a 6.4 percent CAGR from 1987 to 1991. The fastest growing areas in this segment are VCRs and color televisions with stereo sound. Although VCR sales to dealers are virtually flat, Dataquest believes that there is growth in U.S. manufacturing as Japanese manufacturers move more VCR production to the United States to benefit from the strong yen.

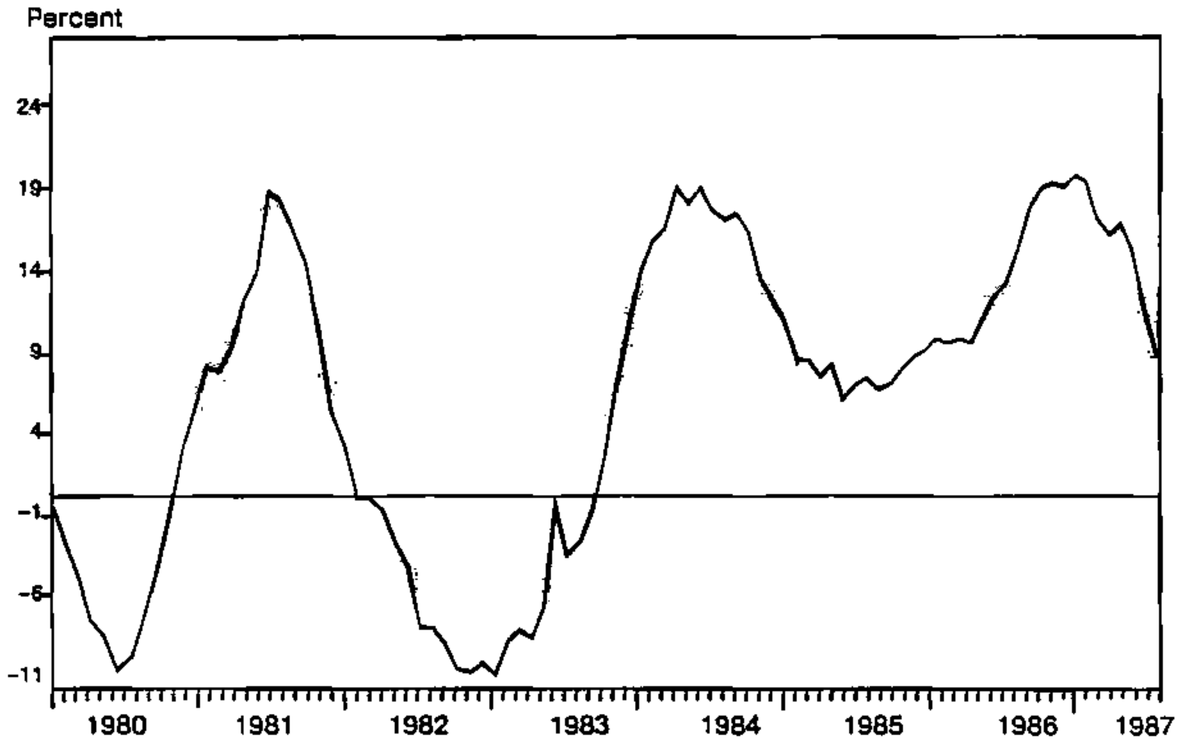
We estimate that color television sets make up 90 percent of the North American semiconductor consumption by the video segment. We expect this ratio to continue to be true out to 1991 because the color television market is the only consumer electronics market that has large-scale U.S. production capacity.

In the personal electronics segment, offshore manufacturing and a lack of new products from U.S. suppliers caused this market to decline in past years. However, Dataquest believes that trade friction and new American players will promote growth in the near future. We expect the personal electronics segment to grow 12.3 percent this year and continue to grow at a 6 percent CAGR from 1987 to 1991.

The most recent DOC data shows the radio and television category (which we compare with our consumer application market) at 9.1 percent in a 12/12 rate of change curve (see Figure 4). We expect consumer electronics shipments to finish 1987 at about 7 percent to 9 percent more than in 1986.

Figure 4

Radio and Television Shipments
(12/12 Rate of Change)



Source: U.S. Department of Commerce
Dataquest
October 1987

Military

We expect the total military market to continue its decline as Congress continues to cut the growth of the U.S. government military spending. Dataquest forecasts the military application market will decline 4.4 percent this year and decline at a negative CAGR of 0.4 percent CAGR from 1987 to 1991.

The military market continues to need state-of-the-art technology. The real opportunity for semiconductor manufacturers lies in retrofitting older equipment with new electronics. This is especially true in aircraft, where navigation systems are being revamped using 32-bit microprocessors and graphics displays. For these reasons, we expect semiconductor consumption by the military market to grow 13.9 percent this year and to continue to grow at a 5.4 percent CAGR from 1987 to 1991.

Transportation

Because automotive sales continued to be disappointing in the first half of 1987, economists for the Big Three U.S. automakers have cut their auto sales forecast. According to Automotive News, the average of the revised forecasts puts total auto and truck sales at about 14.8 million units in 1987, 9 percent less than 1986's 16.2 million.

Weaker than expected U.S. economic performance, 1987 sales stolen by 1986 incentives, and impending strikes by automotive workers were cited as the reason for poor auto sales this year.

With sales expected to be weak throughout 1987, motor vehicle production continues to be below 1986 levels. Table 5 shows automotive production statistics for 1986 and 1987 from January to September. Automobile production in 1987 is 8.4 percent less than production during the same period in 1986.

Some manufacturers continue to outshine the rest. Ford is the only one of the Big Three U.S. automakers to continue to increase production in 1987 over 1986. Japanese manufacturers' 1987 auto production in the United States increased dramatically against to the same period in 1986. Nissan and Honda have increased production in the first half of 1987 215 percent and 53 percent, respectively.

The increase in U.S. auto production by Japanese manufacturers does not translate into new sales for U.S. semiconductor manufacturers. Dataquest believes that Japanese companies building automobiles in the U.S. still buy a large majority of their components and subassemblies from Japan.

Although U.S. auto production is declining this year, Dataquest believes that semiconductor consumption by the automotive industry will grow 16 percent this year and at a 10.8 percent rate from 1987 to 1991.

How can there be growth in electronics when automobile production is declining? One reason is that the use of electronics is relatively new to the industry. The ever-increasing pervasiveness of electronics in automobiles provides room for growth in this market. These electronic possibilities are slowly making their way to consumers that buy high-end cars. Eventually, the use will trickle down to the midrange and low-end automobiles, so there is still plenty of room for new semiconductor technology in cars. Sensors, smart power devices, and microprocessors are products that are typically marketed to the automotive industry.

Table 5

North American Auto Production
(Units)

	January 1 to September 27, 1986	January 1 to September 26, 1987	% Change 1986-1987
American Motors Corp.	40,488	15,994	(60.5%)
Chrysler Motors	999,922	784,745	(21.5%)
Ford Motor Co.	1,318,899	1,348,645	2.3%
General Motors	3,121,103	2,523,324	(19.2%)
Honda	158,590	242,842	53.1%
Nissan	30,902	97,563	215.7%
Nummi	148,613	145,018	(2.4%)
Volkswagen	61,986	43,329	(30.1%)
Total U.S. Car	5,880,503	5,201,809	(11.5%)
Total Canadian Car	764,283	555,547	(27.3%)
North American Car	6,644,786	5,757,356	(13.4%)
North American Truck	3,309,230	3,364,748	1.7%
North American Car and Truck	9,954,016	9,122,104	(8.4%)

Source: Automotive News
Dataquest
October 1987

DATAQUEST CONCLUSIONS

The good news for North American semiconductor suppliers continues to be that the largest market segment semiconductor consumer, personal computers, has pulled out of its slump and is in a period of accelerating growth.

The bad news continues to be that historically, whenever the semiconductor industry goes into a period of accelerating growth, there has been subsequent decline. We expect this decline to occur in 1989, when we forecast semiconductor consumption to drop 2 percent after growing 23 percent in 1988. The only semiconductor application markets in which we forecast semiconductor consumption to grow in 1989 are military (3.7 percent) and transportation (8.7 percent).

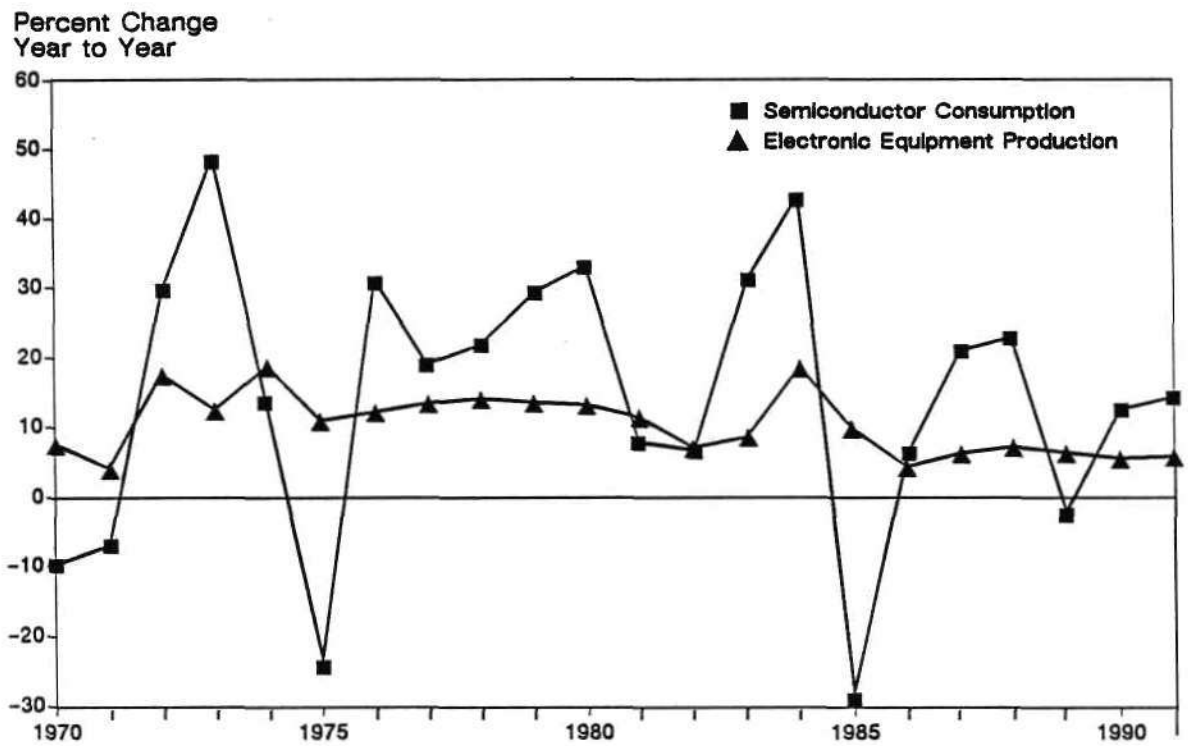
The point for semiconductor suppliers to remember is that to survive the downturn comfortably, it is a good idea to sell to more than one of the six application markets.

Figure 5 displays the historical relationship (1970 through 1986) between semiconductor consumption and electronic equipment production and includes our forecast through 1991.

David G. Norman

Figure 5

Comparison of Semiconductor Consumption and Electronic Equipment Production



Source: Dataquest
October 1987

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OCTOBER PROCUREMENT SURVEY: INVENTORY TRENDS EMERGE

Current actual inventories of semiconductors have now exceeded target levels for the fourth consecutive month. October procurement survey results indicate that since May and June, when inventory levels were in sync, there has been a steady excess. Table 1 reflects the relationship between target and actual inventory levels, measured in days. It is interesting to note that target levels have remained fairly constant over the survey period.

Table 1

Current Actual versus Target Inventory Levels
(Days)

	May	June	July	August	September	October
Target	33.7	35.0	31.8	28.8	31.3	31.3
Current Actual	33.2	34.6	39.7	33.1	36.1	38.0
Percent Over or Under	(0.01)	(0.01)	24.8	14.9	15.3	21.4

Source: Dataquest
October 1987

Another piece of information from this month's survey is that average lead times for new semiconductor orders have increased to 12.6 weeks against last month's average of 10.8 weeks. Lead times and availability continue to be major concerns cited by our survey respondents.

October billings are expected to be slightly up overall. To be specific, our respondents in the data processing community expected October billings to be up 6 percent over September's. New orders are also expected to increase slightly. Distribution purchases continue to remain flat over last month's, and prices are cited as also being stable. In fact, users have remarked that prices have been stable since the survey began.

Memory components still topped the list of parts most difficult to obtain in the required quantities. Discrete devices followed, with surface-mount discretes being mentioned also.

Electronics sales are still up over last year. Most users say that business is robust; however, FMVs, government involvement, and availability continue to affect the users' ability to operate smoothly.

Anthea C. Stratigos

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MACRO TRENDS IN THE RIGID DISK DRIVE INDUSTRY
A LOOK AT TRENDS FROM DATAQUEST'S NEW RIGID DISK FORECASTS

INTRODUCTION

Dataquest has recently completed its 1987 forecast update for the rigid disk drive industry. The forecast comprises a buildup from some 32 diameter and capacity segments, each of which includes forecasts for each of the three market channels (Resale, Captive, and PCM) as applicable and for each of four geographic regions (North America, Europe, Japan, and Rest of World). The details of these base-level forecasts are provided in the service binder section updates (mailed in August 1987).

Several consolidation cuts have been made across the base-level forecasts, yielding several different points of view of the industry at large and the macro trends in operation. This newsletter provides a summary of some of the more interesting of these top-level calculated trends.

TOTAL RIGID DRIVE SALES

Worldwide shipments in 1986 totaled 8.095 million drives, which yielded a total factory-level revenue of $9,298.80 million (at the end-user level $23,818.77 million.) Table 1 details the forecast totals to 1991. Growth is expected to remain strong for the overall market, but the growth rate is expected to slow, averaging a 14 percent compound annual growth rate (CAGR) between 1986 and 1991. This rate more closely reflects the general computer industry than the rampant growth during the first half of the 1980s.

Revenue growth is calculated to be 7 percent and 5 percent for the factory and the end-user levels respectively. This reflects the constantly improving cost-per-Mbyte performance of the rigid industry and also the increasing capacities of rigid drives. The calculated average capacity of drives in 1986 was 78 Mbytes. Drives are calculated to be increasing in capacity at a CAGR of 10 percent.

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Table 1

COMPUTER STORAGE INDUSTRY SERVICE
WORLDWIDE MARKET FORECASTS

REGION: World Wide
CHANNEL: Total
DQ CLASS: R0d0c0

SIZE: ALL
MEDIA: ALL
CAPACITY: ALL

		1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	CAGR (%) 86-91
New Shipments	(K)	688.36	888.64	1910.90	3590.15	4827.78	8095.34	9920.25	11974.76	14072.50	15065.12	15998.49	14
ASP Factory	($K)	5.02	4.27	2.56	1.81	1.53	1.15	1.07	0.96	0.93	0.92	0.86	(6)
Revenue Factory	($M)	3455.73	3793.74	4886.36	6500.63	7404.33	9298.80	10621.75	11463.83	13076.86	13923.31	13749.33	7
ASP End User	($K)	11.99	10.43	6.50	4.36	3.96	2.94	2.61	2.29	2.18	2.12	1.97	(8)
Revenue End User	($M)	8251.83	9264.20	12413.23	15653.88	19121.14	23818.77	25892.26	27364.85	30733.11	31949.17	31505.53	5
Retirements	(K)	40.42	53.68	69.35	93.76	134.74	214.81	353.06	711.95	1118.54	1660.36	2581.26	64
End Installed Base	(K)	2636.71	3471.67	5313.22	8809.61	13502.65	21383.18	30950.37	42213.18	55167.23	77640.44	78309.44	29
Average MB Per Drive		107.12	104.82	85.61	86.10	75.79	78.33	88.68	92.02	99.97	113.31	121.86	10
Cost Per MB Factory	($)	46.87	40.73	29.87	21.03	20.24	14.66	12.07	10.40	9.30	8.16	7.05	(14)
Cost Per MB End User	($)	111.91	99.46	75.88	50.64	52.26	37.56	29.43	24.83	21.85	18.72	16.16	(16)
Total GB Shipped	(K)	73.74	93.15	163.60	309.12	365.88	634.14	879.76	1101.91	1406.78	1706.95	1949.49	25

Source: Dataquest
October 1987

The total capacity of all rigid drives shipped in 1986 was 634,140 Gbytes. That is enough capacity to store about 50,730 copies of the Encyclopedia Britannica. Amazingly, this capacity is believed to be equivalent to the capacity of only five human brains. The industry's total capacity shipped is increasing at a 25 percent CAGR and is projected to reach 1,949,490 Gbytes (1,949.49 terabytes) in 1991. This reflects the continued increase of applications executed on computer systems, the increased sophistication of applications, the increased resolution of the data presented by computer systems, and the increased penetration of computers into the daily routines of industry, government, and also individuals.

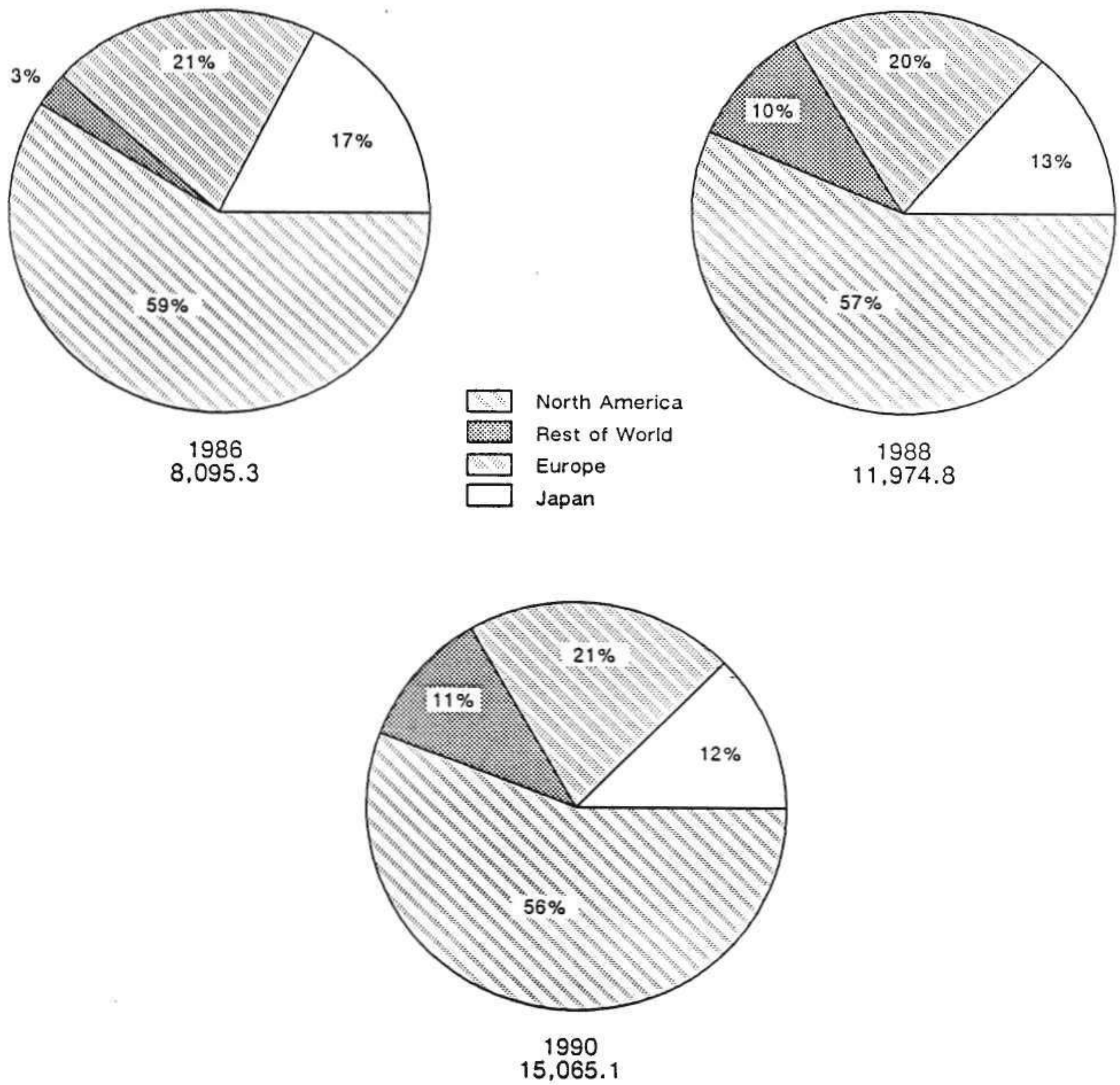
TRENDS BY GEOGRAPHIC DESTINATION

Figure 1 depicts the unit shipment distribution trends by geographic destination. The demand from North America is calculated to continue to hold its majority share of drive shipments over the next five years, but is gradually losing in market share. The largest area of market share growth is calculated to be the Rest of World region. Its growth is at the expense of North America and Japan. The fast growth by the Rest of World segment is reflective of the coming of age of computer literacy and the attendant demand for storage from countries outside the North American, European, and Asian regions.

Figure 2 shows the revenue distribution trends by geographic destination. The share distribution is similar to the unit distribution, however, the North American region commands a lower revenue share than unit shipment share. This is due to the slightly higher prices commanded outside the United States. For all three years displayed, the European region shows a higher revenue market share than it does unit share. This reflects the consistently higher selling prices in this second-to-largest market region.

Figure 1

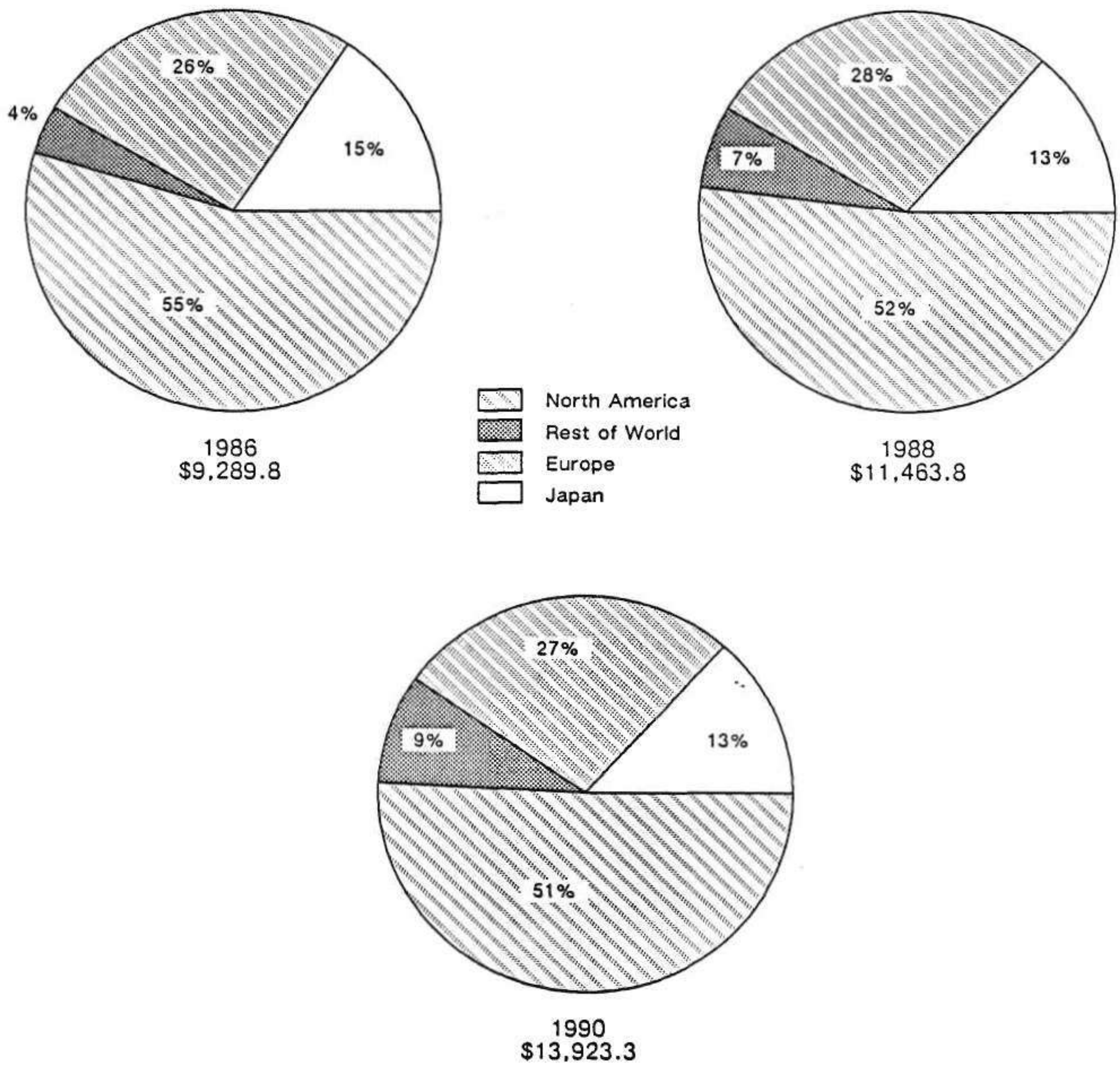
ESTIMATED WORLDWIDE RIGID MEDIA DRIVE
SHIPMENTS BY GEOGRAPHIC DESTINATION
(Thousands of Units)



Source: Dataquest
October 1987

Figure 2

ESTIMATED WORLDWIDE RIGID MEDIA DRIVE FACTORY-LEVEL REVENUE
BY GEOGRAPHIC DESTINATION
(Millions of Dollars)



Source: Dataquest
October 1987

TRENDS BY CAPACITY

The low-capacity end of the scale continues to harbor both the largest number of participating companies and the largest number of drive models. Table 2 shows the capacity and diameter composition of the total number of drive models that are currently announced and/or shipping. The largest number of drive models is in the 5.25-inch diameter category, with 298 drive models active. We expect this list to continue shrinking, however, with model terminations at the lower capacities offsetting new model introductions at the high end of the capacity scale. While 14-inch drives have the second largest number of drive models, the industry will see increasing numbers of model terminations, particularly of drives of less than 500 Mbytes.

Table 2

ACTIVE DRIVE MODELS BY CAPACITY AND DIAMETER--JUNE 1987

Capacities	14-inch	8- to 10.5-inch	5.25-inch	Sub-4-inch
0-30 Mbytes	9	4	83	61
31-100 Mbytes	17	25	113	39
101-200 Mbytes	11	15	71	3
201-500 Mbytes	36	35	30	-
501-1,000 Mbytes	29	23	1	-
1,001+ Mbytes	31	8	-	-
Total by diameter	133	110	298	103

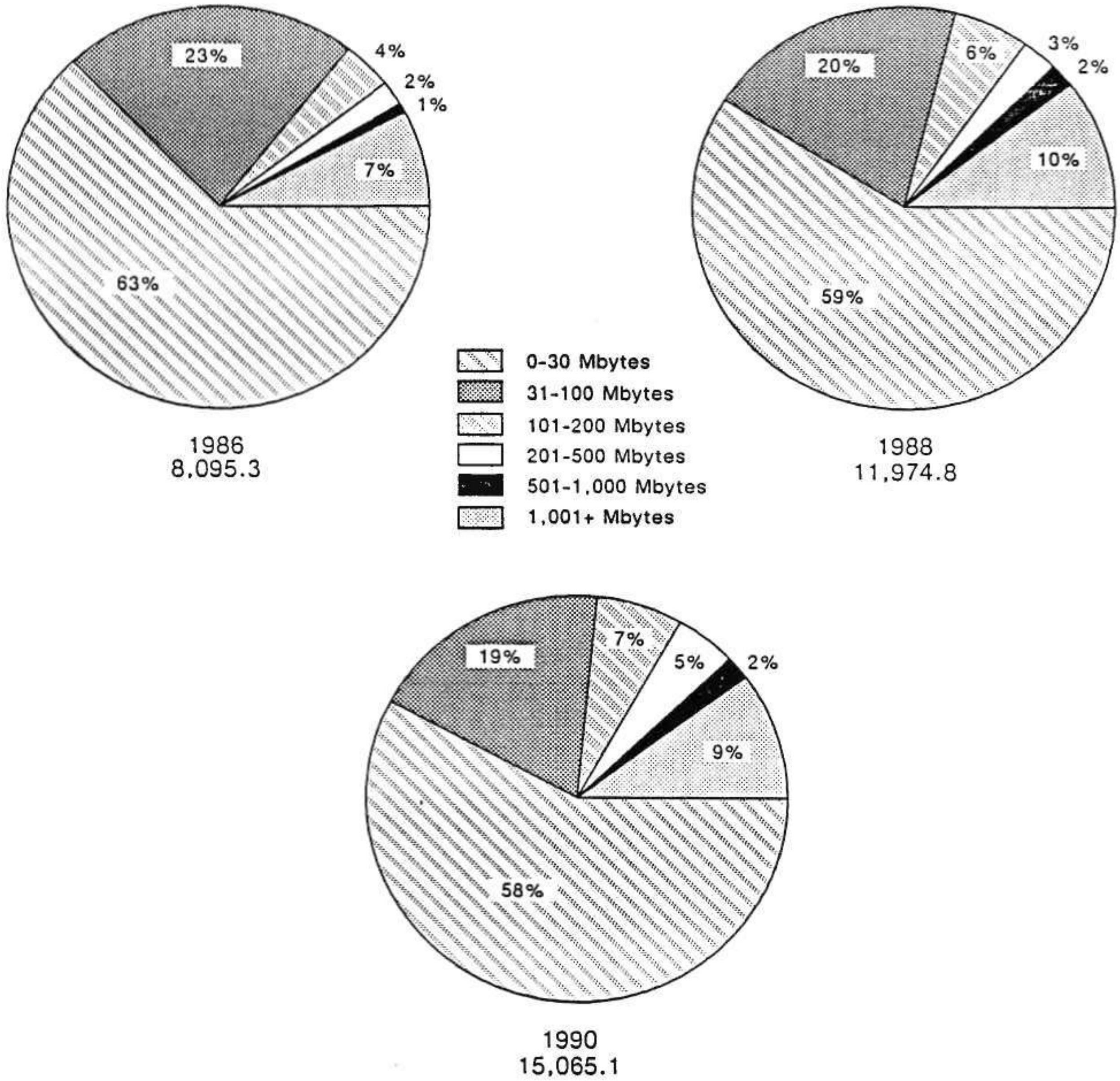
Total models in the industry: 644

Source: Dataquest
October 1987

Figure 3 shows the unit shipment market share of rigid drives by capacity range for the years 1986, 1988, and 1990. The calculated capacity trends for the total market indicates a gradual shift to drives of higher capacities, which reflects primarily the shift upward to higher-capacity 3.5- and 5.25-inch drives.

Figure 3

ESTIMATED WORLDWIDE RIGID MEDIA DRIVE SHIPMENTS
DISTRIBUTION BY CAPACITY
(Thousands of Units)



Source: Dataquest
October 1987

TRENDS BY DIAMETER

The calculated growth rates for the various characteristics of rigid drives by diameter are listed in Table 3. In terms of unit shipments, both the 5.25-inch and the 8- to 10.5-inch ranges exhibit decreasing unit shipments over the next five-year period, reflecting erosion of their respective market shares to drives of the next smaller diameters. Drives of 3.5-inch diameter are expected to displace 5.25-inch drives at the lowest capacity ranges, and 5.25-inch drives are expected to push 8- to 10.5-inch drives into the capacities greater than 500 Mbytes. Riding on its large shipment growth, the 3.5-inch segment will display the highest revenue growth (55 percent CAGR). The industry as a whole is exhibiting a decreasing cost per Mbyte, at a negative 14 percent. The three smaller diameters will yield the best improvements in this parameter, with price decreases of about 18 percent.

Table 3

ESTIMATED WORLDWIDE MARKET CHARACTERISTIC GROWTH RATES BY DIAMETER

	Compound Annual Growth Rate				
	Total	Sub-4-Inch	5.25-Inch	8- to 10.5-Inch	14-Inch
Units	14%	55%	(7%)	(4%)	1%
Factory-Level ASP	(6%)	(10%)	11%	3%	6%
Factory-Level Revenue	7%	39%	4%	(1%)	7%
Mbyte per Drive	10%	10%	35%	27%	15%
Cost per Mbyte	(14%)	(18%)	(18%)	(19%)	(8%)

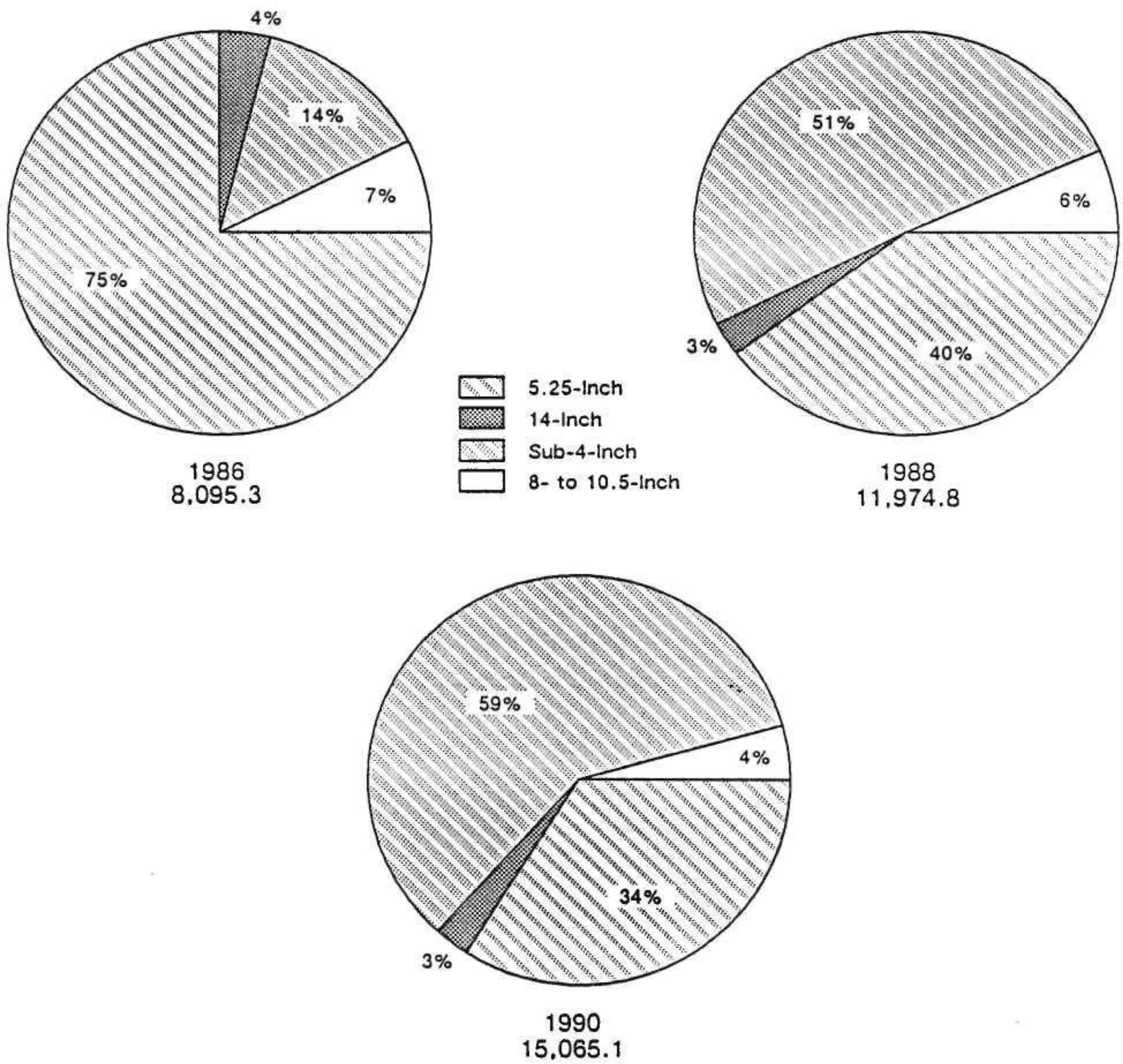
Source: Dataquest
October 1987

Figures 4 and 5 show respectively the unit shipment distribution and the revenue distribution by diameter. The basic trend in unit shipments is toward the smaller drives. The two smallest diameters together accounted for 89 percent of the 1986 unit shipments, which is shown to grow to 93 percent by 1990. This reflects the continued growth and penetration into the low-end systems arenas by 3.5- and 5.25-inch rigid drives. The major dynamic of the unit shipment picture is the gain in 3.5-inch shipments at the expense of 5.25-inch shipments.

The revenue distribution by diameter displays a much more uniform picture than the unit shipment distribution. While the 14-inch segment continues to have the smallest number of unit shipments, because of their higher performance and capacities, these drives command the largest revenue. Like the unit shipment picture, the 3.5-inch segment shows the largest gain of market share due to its youth and rapid growth rate at the low-capacity end of the scale.

Figure 4

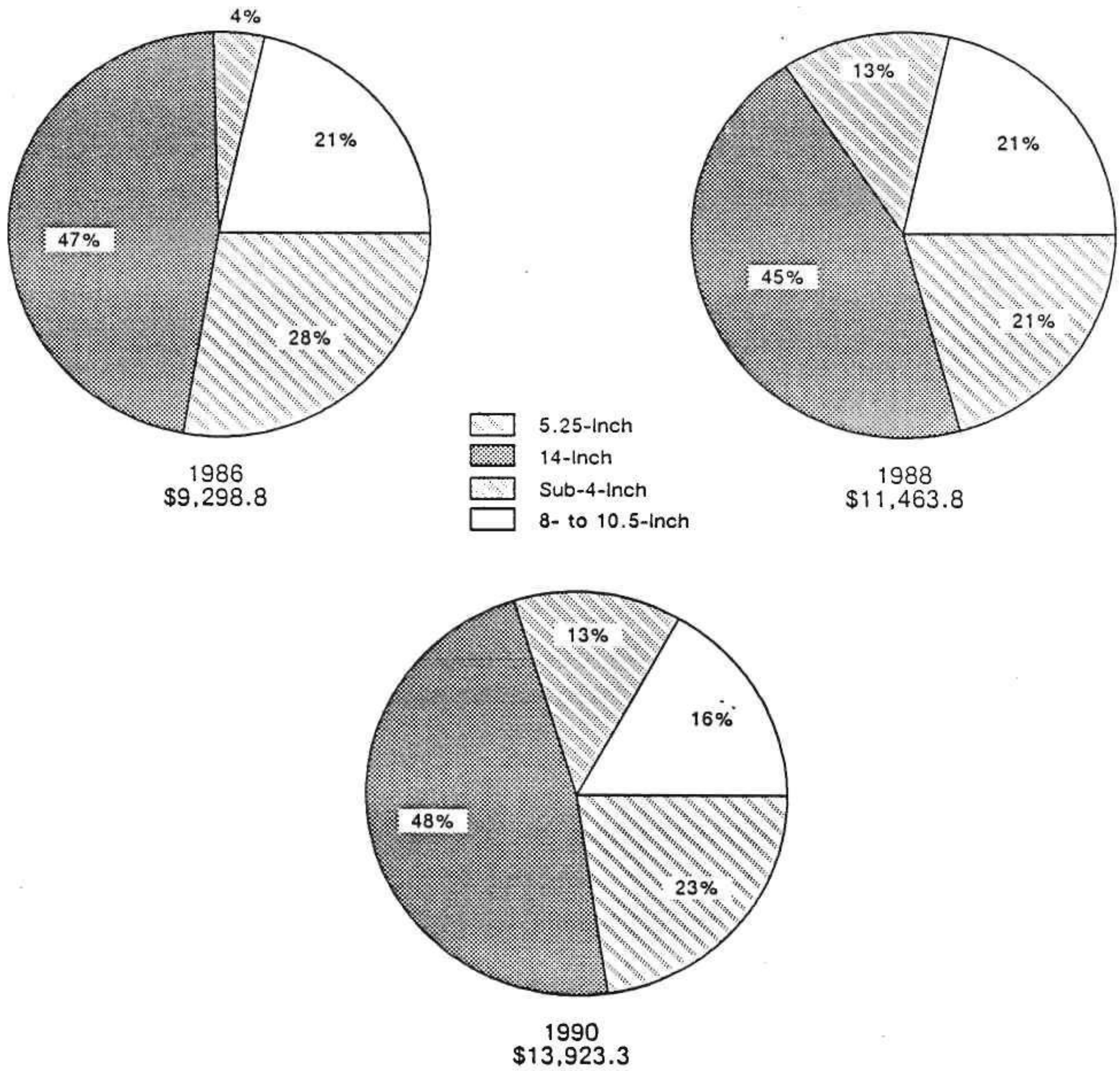
ESTIMATED WORLDWIDE RIGID MEDIA DRIVE SHIPMENTS
DISTRIBUTION BY DIAMETER
(Thousands of Units)



Source: Dataquest
October 1987

Figure 5

ESTIMATED WORLDWIDE RIGID MEDIA DRIVE FACTORY-LEVEL REVENUE
DISTRIBUTION BY DIAMETER
(Millions of Dollars)



Source: Dataquest
October 1987

TRENDS BY MARKET CHANNEL

Table 4 displays the estimated growth rates for various market characteristics by market channel (Captive, PCM, and Resale). (The resale channel sometimes is also referred to as the OEM channel.) Captive drives show the fastest unit shipment growth, illustrating the anticipated increasing level of participation in the 3.5- and 5.25-inch drive markets by some of the largest systems companies. The PCM channel is also expected to show healthy growth, based on 3380E clone shipments in the near term and next-generation clones beginning at the end of the forecast period (1991). All channels exhibit improving costs per Mbyte, with the resale channel leading with a negative 17 percent. This reflects the resale channel's more competitive environment and the increasing capacities of drives shipped via the channel.

Table 4

ESTIMATED WORLDWIDE MARKET CHARACTERISTIC GROWTH RATES BY MARKET CHANNEL

	Compound Annual Growth Rate			
	Total	Captive	PCM	Resale
Units	14%	19%	16%	12%
Factory-Level ASP	(6%)	(10%)	1%	(5%)
Factory-Level Revenue	7%	8%	16%	6%
Mbyte per Drive	10%	3%	8%	14%
Cost per Mbyte	(14%)	(12%)	(7%)	(17%)

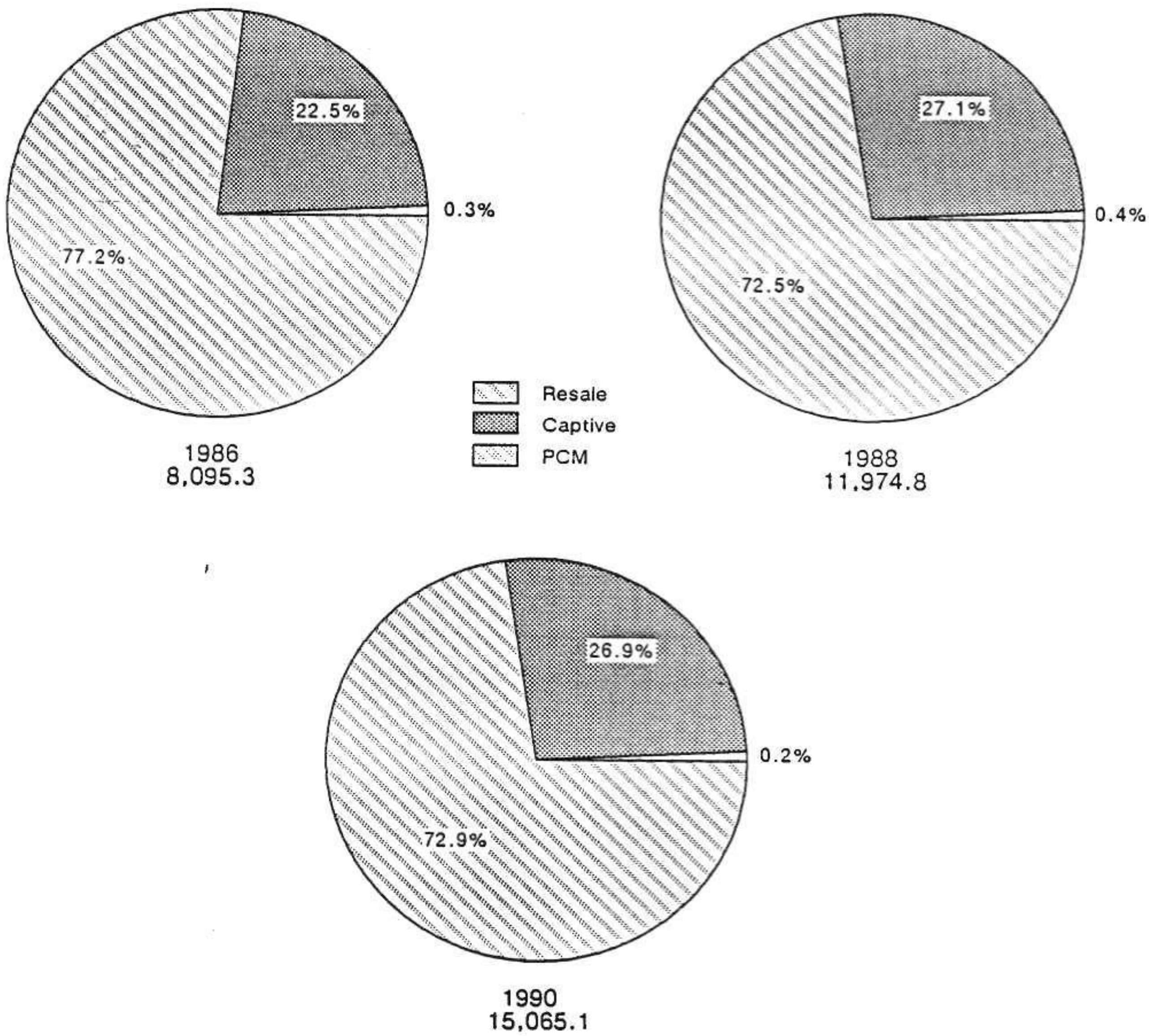
Source: Dataquest
October 1987

The unit shipment scenario is shown in Figure 6. The largest change in shipment market share is in the captive market channel. The captive channel will win an increasing market share due primarily to increased production by captive manufacturers of 3.5- and 5.25-inch drives.

The equivalent revenue picture, based on market channel distribution, is shown in Figure 7. The captive channel is king, riding on the higher-capacity, higher-performance, and higher-priced drives produced by the captive manufacturers. The captive channel revenue picture also benefits from increased low-end participation.

Figure 6

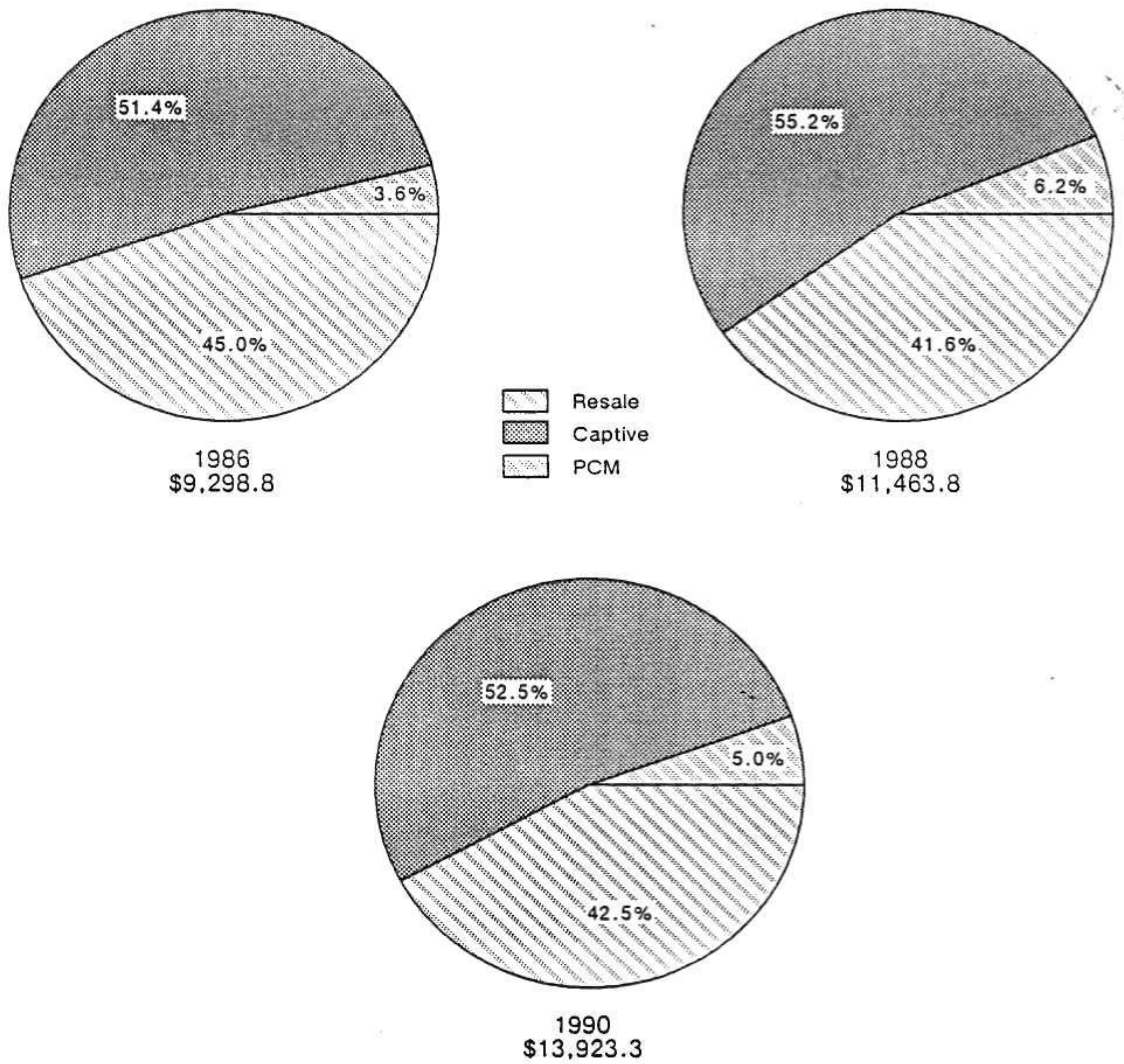
ESTIMATED WORLDWIDE RIGID MEDIA DRIVE SHIPMENTS
DISTRIBUTION BY MARKET CHANNEL
(Thousands of Units)



Source: Dataquest
October 1987

Figure 7

ESTIMATED WORLDWIDE RIGID MEDIA DRIVE FACTORY-LEVEL REVENUE DISTRIBUTION BY MARKET CHANNEL
(Millions of Dollars)



Source: Dataquest
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SUMMARY

Taken in the aggregate, the rigid disk picture yields an optimistic picture for the future. While overall shipment and revenue growth rates are slowing, the demand for increasing rotating magnetic storage is reflected in the industry's 25 percent CAGR of total capacities shipped between 1986 and 1991.

In terms of diameters, the most dynamic segments are the 5.25-inch and the 3.5-inch segments. These diameters are continuing on a path established at the beginning of the industry, and that is to push the next larger diameter up into a higher capacity range if it is to survive. The result is that by the end of the forecast period (1991), 5.25-inch drives will be pushed above the 100-Mbyte level by the 3.5-inch drives, and the 5.25-inch drives will nudge the 8- to 10.5-inch drives to the greater than 500-Mbyte range. Drives of 14-inch diameter are already up against the wall, and with the possible exception of one more density increase from IBM (and the clone manufacturers) in its 3380 product line, we expect to see few new 14-inch developments. Both the 8- to 10.5-inch and 14-inch drive ranges will start to lose out on market share by the end of the forecast period.

Market share by market channel remains relatively stable, with the captive channel slightly increasing both its unit shipment and its revenue share as manufacturers increase the numbers of 3.5- and 5.25-inch drives they build internally.

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OCTOBER PROCUREMENT SURVEY: INVENTORY TRENDS EMERGE

Current actual inventories of semiconductors have now exceeded target levels for the fourth consecutive month. October procurement survey results indicate that since May and June, when inventory levels were in sync, there has been a steady excess. Table 1 reflects the relationship between target and actual inventory levels, measured in days. It is interesting to note that target levels have remained fairly constant over the survey period.

Table 1

Current Actual versus Target Inventory Levels
(Days)

	May	June	July	August	September	October
Target	33.7	35.0	31.8	28.8	31.3	31.3
Current Actual	33.2	34.6	39.7	33.1	36.1	38.0
Percent Over or Under	(0.01)	(0.01)	24.8	14.9	15.3	21.4

Source: Dataquest
October 1987

Another piece of information from this month's survey is that average lead times for new semiconductor orders have increased to 12.6 weeks against last month's average of 10.8 weeks. Lead times and availability continue to be major concerns cited by our survey respondents.

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October billings are expected to be slightly up overall. To be specific, our respondents in the data processing community expected October billings to be up 6 percent over September's. New orders are also expected to increase slightly. Distribution purchases continue to remain flat over last month's, and prices are cited as also being stable. In fact, users have remarked that prices have been stable since the survey began.

Memory components still topped the list of parts most difficult to obtain in the required quantities. Discrete devices followed, with surface-mount discretes being mentioned also.

Electronics sales are still up over last year. Most users say that business is robust; however, FMVs, government involvement, and availability continue to affect the users' ability to operate smoothly.

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