Trends in Military Electronics

INTRODUCTION

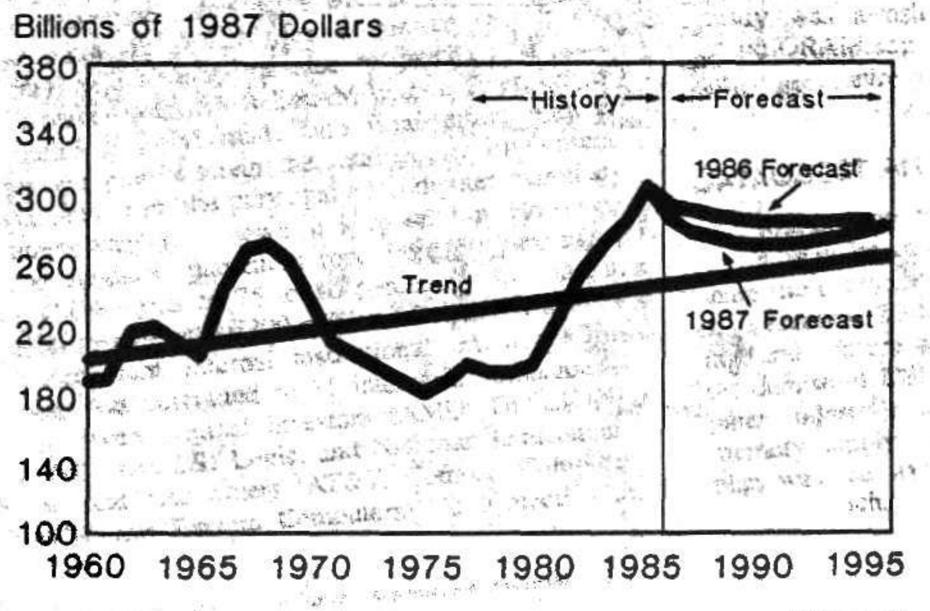
The U.S. military electronics industry has undergone much change in recent years. No longer are annual growth rates of 15 to 20 percent expected as the norm. As a result of continued upward trends in defense spending coupled with new tax legislation, poor performance or nonperformance on contracts, and other related incidents, both U.S. military electronics and IC suppliers will be affected.

Through efforts to reduce federal budget deficits, such as the Gramm-Rudman-Hollings bill, many military programs, although allowed to continue, are significantly cut in scope. Some programs are eliminated entirely. Those programs that continue are scrutinized more closely than before. Pressure is being brought upon military suppliers to become more price-competitive with the commercial world while delivering higher quality and performance products. Figure 1 shows historical and projected yearly changes in Department of Defense (DOD) budget authorizations through 1995.

It comes as no surprise then that in the semiconductor arena, military applications represent a decreasing share of North American IC consumption, expected to remain constant at 15 percent in 1986 and 1987 and to fall to 12 percent by 1991. Table 1 shows the total DOD electronic procurement and Research, Development, Test, and Evaluation (RDT&E) forecast for the next five years by equipment type. Figure 2 shows military semiconductor applications as a portion of total North American semiconductor consumption through 1990.

Figure 1

EIA DOD BUDGET AUTHORITY FORECASTS
(1986 versus 1987)



Source: EIA

Table 1

ELECTRONIC CONTENT SUMMARY
TOTAL PROCUREMENT AND RDT&E BY MAJOR PROGRAM*
(Billions of Dollars)

Program	1985	1986	1987	1988	1989	1990
Aircraft	$13.2	$11.7	$10.0	$10.0	$ 9.8	$ 9.8
Missiles	10.0	11.4	11.5	10.9	10.4	10.2
Space	5.1	5.6	6.0	6.3	6.7	6.9
Ships	5.0	4.4	3.7	3.6	3.5	3.4
Ordnance and Weapons	1.5	1.5	1.4	1.4	1.4	1.4
Vehicles	1.2	1.0	0.9	0.9	0.9	0.9
Electronics and Communications	12.0	12.9	12.8	12.6	12.4	12.3
All Other	1.3	1.2	1.2	1.2	1.2	1.2
Total	$49.4	$49.7	$47.5	$46.9	$46.3	$46.2
Percent Change	N/M	0.6%	(4.5%)	(1.3%)	(1.4%)	(0.1%)

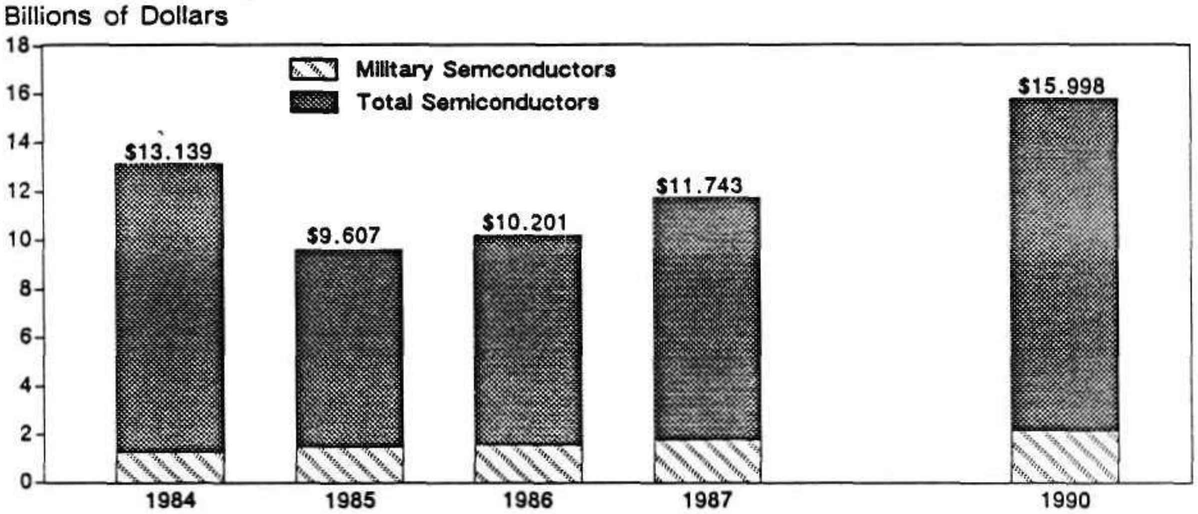
Program	1991	1992	1993	1994	1995	1996
Aircraft	$ 9.9	$10.0	$10.2	$10.4	$10.7	$10.9
Missiles	10.0	9.9	9.6	9.3	9.3	9.2
Space	7.3	7.6	7.9	8.4	8.9	9.2
Ships	3.4	3.4	3.5	3.5	3.5	3.5
Ordnance and Weapons	1.4	1.4	1.4	1.5	1.5	1.5
Vehicles	1.0	1.0	1.0	1.1	1.1	1.1
Electronics and Communications	12.5	12.7	12.9	13.3	13.6	13.8
All Other	1.2	1.2	1.2	1.2	1.2	1.3
Total	$46.7	$47.2	$47.6	$48.7	$49.8	$50.6
Percent Change	1.0%	1.1%	1.0%	2.1%	2.3%	1.6%

*In constant FY 1987 dollars
N/M = Not Meaningful
Note: Columns may not add to totals shown because of rounding.

Source: Electronics Industry Association
Dataquest
September 1987

Figure 2

MILITARY SEMICONDUCTOR CONSUMPTION AS A PORTION OF TOTAL
(Billions of Dollars)

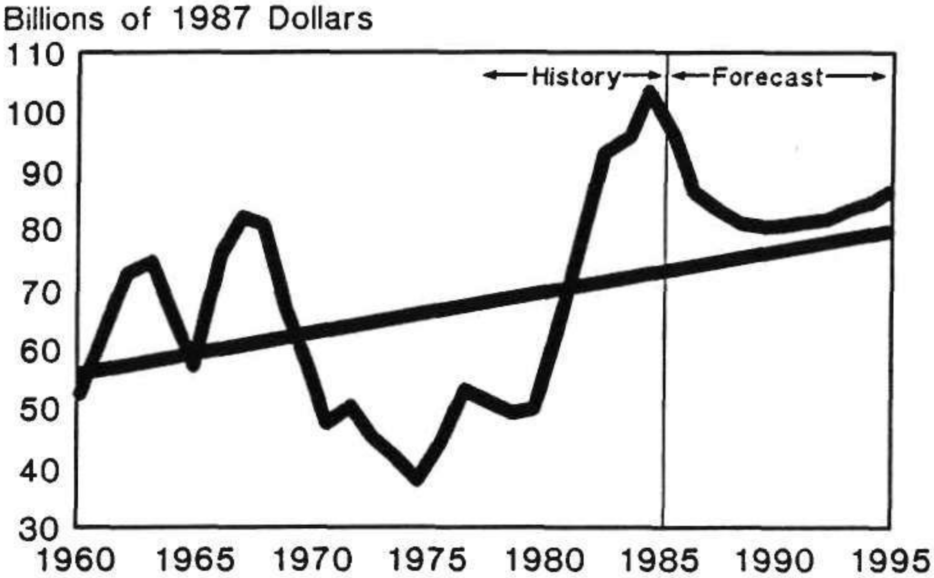


Source: Dataquest
September 1987

Despite this seemingly grim market portrayal, however, the DOD still remains the world's largest single customer for electronics, and thus the military market remains a strong segment of the North American semiconductor market. In addition, because DOD outlays still lag authorized expenditures, military electronics are expected to enjoy some continued growth in the near term. Figures 3 and 4 break out the total DOD procurement and RDT&E budget authority forecasts extended to 1995. Note that while the RDT&E budget is forecast to continue declining for the next decade, it remains well above the long-term trend throughout the period.

Figure 3

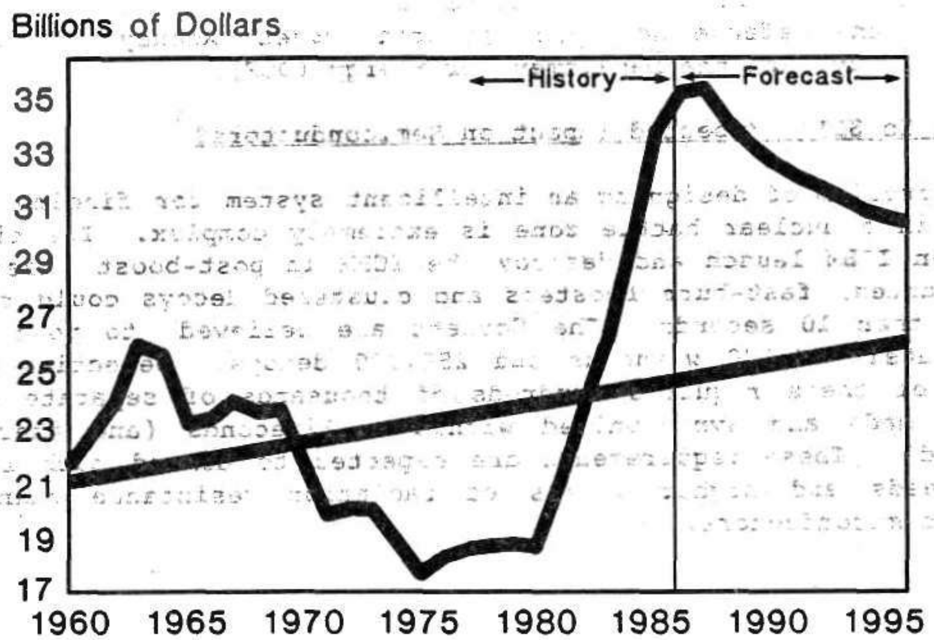
DOD PROCUREMENT BUDGET AUTHORITY FORECASTS



Source: EIA

Figure 4

DOD RDT&E BUDGET AUTHORITY FORECASTS



Source: EIA

MAJOR PROGRAMS

Major programs are under way in the United States, Western Europe, and Japan that will place large demands on suppliers that serve the military semiconductor marketplace. This section addresses the largest of these in each of the above regions.

U.S. Activities

Strategic Defense Initiative (SDI)

The U.S. defense electronics industry continues to be driven by major program requirements such as the Strategic Defense Initiative (SDI). SDI is a more than $25 billion dollar R&D effort intended to develop technology in space-based and ground-based antiballistic missile systems. The effort involves developing space-based lasers and related weapons intended to destroy enemy ballistic missiles in a layered defense deployment, with provisions for defense in the initial boost, midcourse, and reentry phases of enemy missile trajectory. Defensive measures will include directed-energy weapons, kinetic-energy weapons, surveillance-tracking and kill-assessment weapons, and analysis/battle-management systems. To be successful, unprecedented self-protection features are required. Some of the survivability enhancements under consideration are laser shields, orbital maneuvering, decoys, electronic countermeasures (ECM), stealth, radiation hardening, and active defense. A model of SDI is presented in Figure 5.

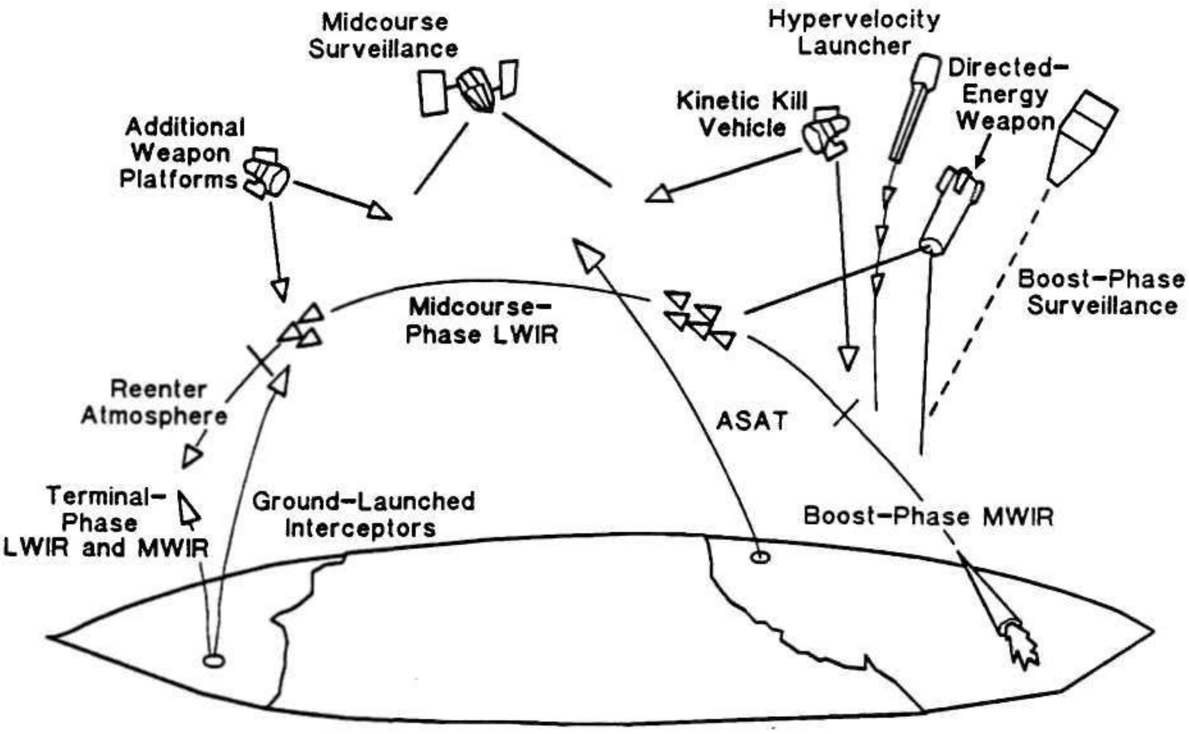
The Army and the Air Force are responsible for administering more than 75 percent of the SDI budget. The balance is believed to be administered by the Navy, the Defense Advanced Research Project Agency (DARPA), the Defense Nuclear Agency, and the Department of Energy (DOE).

What Is SDI's Expected Impact on Semiconductors?

The problem of designing an intelligent system for finding and destroying targets in a nuclear battle zone is extremely complex. The time required to detect an ICBM launch and destroy the ICBM in post-boost phase is estimated at 8 minutes; fast-burn boosters and clustered decoys could reduce the time to less than 10 seconds. The Soviets are believed to pose the threat of approximately 80,000 warheads and 250,000 decoys. Detection and countering any one of these requires hundreds of thousands of separate decisions that must be made and synchronized within milliseconds (and therefore must be automated). These requirements are expected to demand much faster computation speeds and higher levels of radiation resistance than available in today's semiconductors.

Figure 5

SDI MODEL



Source: Honeywell

The quantities of semiconductors required for SDI are driven by such factors as the number of battle stations required, detection resolution, and the complexities of calculations and communications. Estimates of the number of battle stations have ranged from less than 50 to more than 2,000.

A key element of SDI is a space-based radar system employing synthetic aperture radar (SAR). Radar processing requirements are expected to exceed those of the largest systems built to date. Dataquest believes one phased-array antenna or antenna array may require up to 1 million transceiver modules utilizing III-V compound semiconductor devices. Such demand would place a heavy burden on all existing GaAs suppliers.

In the area of electronic data processing (EDP), estimates of the number of lines of software code required to support SDI have ranged from 10 million to 100 million. Transaction rate requirements have been estimated to exceed the largest on-line transaction processing (OLTP) systems in operation today by a factor of 10. In addition, SDI communications requirements will place heretofore unrealized demands on semiconductor technology.

What Is SDIO?

The SDI Organization (SDIO) was formed in 1983, headed by Lieutenant General James A. Abramson, Jr. Under him and Chief SDI Scientist Gerold Yonas are program offices concerned with the areas of systems; sensors; survivability, lethality, and key technologies; kinetic-energy weapons; directed-energy weapons; innovative technology; resource management; and external affairs.

Project Forecast II

The Air Force's Project Forecast II was designed to identify technologies and advanced system concepts intended to revolutionize the manner in which the Air Force fulfills its mission in the 21st century, assuring continued technological superiority over all potential adversaries. The team consisted of 18 panels composed of 175 military and civilian members. The effort spanned eight months and analyzed more than 2,000 concepts. One of the Forecast II categories is electronics and optics; another is information, computation, and displays. The technologies under the Forecast II Project are as follows:

- High-energy-density propellant
- Particle-bed nuclear propulsion
- High-performance turbine engine
- Combined-cycle engine
- Space power
- Advanced deception
- Rapidly reconfigurable crew station
- Acoustic charge transport
- Wafer-level union of devices
- Photonics

Trends in Military Electronics

- Full-spectrum, ultraresolution sensors
- Fail-safe, fault-tolerant electronics
- Survivable communications network
- Adaptive control of ultralarge arrays
- Smart skins
- High-temperature materials
- Broad-spectrum signature control
- Satellite protection
- Ultrastructured materials
- Cooling of hot structures
- Ultralight airframes
- STOL/STOVL/VSTOL technology
- Hypersonic aerothermodynamics
- Brilliant guidance
- Directed-energy technology
- Advanced manufacturing technology
- Unified life-cycle engineering
- Smart built-in test (BIT)
- Robotic telepresence
- Knowledge-based systems
- Virtual man-machine interaction
- Distributed information processing
- Antiproton technology
- Ultrahigh software quality and productivity

- Air-crew combat mission enhancement (ACME)
- Nonlinear optics
- Antiterrorism technology
- Plasma defense technology
- Low-cost, high-speed military computer technology

The systems concepts under the Forecast II project are as follows:

- Direct-ascent antisatellite system (ASAT)
- Manned space station
- Reusable orbit transfer vehicle
- Spacecraft defender
- Distributed sparse array of spacecraft
- Space-based surveillance system
- Multistatic surveillance system
- Airborne surveillance system
- Theater air warfare command, control, communications, intelligence (C^3I)
- Super cockpit
- Artificial ionospheric mirror
- Space object identification system
- Multirole conventional weapon
- Battle management processing and display system
- Imaging system
- Intratheater VSTOL transport aircraft
- Multirole global-range aircraft
- Supersonic VSTOL tactical aircraft

- High-altitude, long-endurance unmanned aircraft
- Hypersonic interceptor aircraft
- Special operations aircraft
- Autonomous antiarmor weapons
- Autonomous high-value target weapons
- Long-range air-to-air missile
- Hypervelocity weapons
- Long-range boost-glide vehicle
- Tactical low-cost drones
- Multimission remotely piloted vehicle (RPV)
- Hypervelocity vehicle
- Advanced heavy-lift space vehicle
- Advanced antisatellite system (ASAT)

Air Force Shuttle Program

As of December 9, 1985, the Air Force had plans to make 14 shuttle launches from Vandenberg Air Force Base in California between March 1986 and mid-1990. Some of the launches were to involve SDI research. The military's total space budget for 1986 was estimated at $15 billion, of which the Vandenberg space launch operation comprised $400 million. These plans were severely impacted by the 1986 shuttle disaster, which has caused the closing of a $100 million center in Colorado, affecting IBM and others adversely.

Next-Generation Spacecraft

As of early 1986, a next-generation spacecraft, intended to replace the NASA Space Shuttle, was being designed to take off from an airport rather than from a rocket pad. This effort has been designated National Aero Spaceplane Program (NASP). France, Japan, and other countries are believed to be working on similar projects.

ATF/ATA

The Air Force advanced tactical fighter (ATF) program is expected to result in the production of 750 aircraft. The Navy is evaluating the ATF as an eventual replacement for the F-14, which would require an additional 550 aircraft. The Navy may proceed to develop its own advanced plane, the ATA (advanced technology aircraft).

Avionics prototypes for the aircraft will consider such new technologies as the very high speed integrated circuit (VHSIC), incorporating common core architecture and distributed processing. In October 1986, the ATF program moved into flight test phase with the award of contracts to the Lockheed/Boeing/General Dynamics team and the Northrop/McDonnell Douglas team. Two prototype ATFs designated YF-22A and YF-23A are to be test-flown.

VHSIC

In order to assure advanced electronic capabilities in the future, very high speed ICs were developed in DOD's VHSIC program. DOD in 1986 took steps to accelerate incorporation of VHSIC Phase 1 ICs into systems in development as well as into existing hardware. The steps include:

- Guidelines delineating when to specify VHSIC Phase 1 on a program
- More than 20 brass-board hardware demonstrations of VHSIC benefits
- Increasing the number of VHSIC suppliers by allowing system qualification of company-funded VHSIC-like chips

About 30,000 operational VHSIC Phase I chips have reportedly been fabricated by the six Phase I teams.

VHSIC Phase I

The six VHSIC Phase I contractors are Honeywell, Hughes, IBM, TI, TRW, and Westinghouse. Of the 28 chip types originally proposed, 24 have been fabricated successfully, 3 have been dropped, and 1 is in development. TRW's family consists of 13 IC types; IBM has developed 1 Phase I chip. Approximately 12 others were developed by contractors with outside funding. Some results as of late 1986 are as follows:

- Honeywell sequencer chip with 136K components on chip--25 percent best yield versus a 13.6 percent goal
- TI 72K SRAM with 465K components--69 percent best yield versus a 12 percent goal

- TRW associative processor with 58K components--20.5 percent best yield versus a 5.7 percent goal

- Westinghouse 65K SRAM with 400K components--25 percent best yield versus a 10 percent goal

Other companies, such as Harris, Martin, Raytheon, and Rockwell, were in Phase Zero of VHSIC but did not win Phase I awards; they chose to develop Phase I-type chips on company funds.

Westinghouse claims that the Westinghouse/NSC team has shipped more than 30,000 VHSIC chips as of mid-October 1986.

<u>VHSIC Phase II</u>

The objective of VHSIC Phase II is to achieve a twentyfold increase in performance over Phase I chips. The three Phase II contractors--Honeywell, IBM, and TRW--are required to standardize on power supply voltages, a chip interface, and a data communications format. Chip feature sizes are to be reduced from 1.25u to 0.5u.

Honeywell's Phase II $60 million contract is managed by the Air Force. Honeywell is using a configurable gate array approach based on macro cells and four layers of metal interconnect. Honeywell claims that its Phase II chips have 8 to 11 times more density than its Phase I chips.

Under Phase II, Honeywell is to design and build three chips using CML bipolar technology: an array processor containing 30,000 gates plus 8K RAM, an array processor controller, and a system interface chip with a standard VHSIC I/O bus. The contract has an option for two additional ICs: one for a RISC-based high-speed computer and the other, an enhanced bus interface chip. The contract also requires two memory chips using Phase I feature sizes: an 18K SRAM with a 50-MHz I/O access rate over full military temperature range and a 144K ROM with the same constraints. Honeywell's Phase II package will be 3 x 3 or 4 x 4 inches, providing 420 I/Os.

IBM's $60 million Phase II contract is managed by the Army. Timothy P. Keenan is manager of process technology at IBM FSD Monanssas, where the VHSIC effort is located and Robert S. Estrada is IBM's VHSIC program manager. IBM is developing a CSP (common signal processor) for the Air Force. IBM met all its Phase I delivery schedules including the one for the sonar signal processor brass board. IBM used NMOS for Phase I and is using CMOS for Phase II. As an interim step, IBM is developing a library of scalable 1u standard cells.

Under Phase II, IBM is developing a systolic processor, a configurable SRAM, a bus interface unit, and an address generator. Initially, 1u feature sizes and 220 x 220 mil chip sizes using three-layer metal will be used for fabrication. Packaging will be similar to Honeywell's, with 16 chips mounted on a 2.5 x 2.5-inch substrate. In addition, IBM is developing eight more GP (general-purpose) devices for the Air Force CSP on 220 x 220-mil chips. The CSP chips will also migrate from 1u to 0.5u geometries over time.

TRW's $60 million Phase II contract is managed by the Navy. The company is funded to design and build three types of superchips with options for three more under its VHSIC program director, Thomas A. Zimmerman. TRW's approach is considered the highest-risk, highest-payoff strategy of the three. TRW started with a bipolar superchip approach, each approximately 1.4 x 1.4- to 1.4 x 1.8-inch die sizes, roughly 20 times the Honeywell and IBM chips. TRW's teammate, Motorola, is using CMOS. The TRW superchips contain redundant macro-cells, interconnected by software. A triply redundant data bus is incorporated on each chip. In late 1986, TRW reportedly dropped the bipolar approach and refocused on CMOS.

The three TRW chips are a 400-MOPS GP SP (general-purpose signal processor) using CMOS; a convolver correlator designed to perform 8 x 8 x 1,025 convolutions on 25 million data samples per second at a speed of 13 billion complex operations per second; a CMOS mass memory with 4 ports, 64K 32-bit words, 40ns I/O, and SECDED (secure data encoder/decoder). The optional chips are a 1,024-point FFT (fast fourier transform), capable of 1 billion complex operations per second; a CMOS 20-mips, GP, 32-bit data processor with 1 megabit RAM on board; and a 1,024 word-associative processor to operate at 10 billion operations per second. Also, TRW has designed a 700-Kbit DRAM using CMOS and 1.25u features.

DOD has approved three chips developed by Intel (without government funding) for VHSIC insertion. These are the 80386 32-bit microprocessor, the 80286 16-bit microprocessor, and the M51C98 64K SRAM. Prototypes became available in the fourth quarter of 1986, and completion of qualification is expected in 1987.

Intel Joins VHSIC Program

On June 1, 1987, Intel Corporation announced that it had become the first merchant semiconductor house approved by the VHSIC Program Office for VHSIC qualification on three products. The approval, for military versions of Intel's 80286 and 80386 16- and 32-bit microprocessors as well as its 51C98 35ns 16Kx4 SRAM, gives military equipment manufacturers the unique ability to build prototype designs well in advance of actual availability of the final military-version ICs.

Intel's ability to enter into the VHSIC program without participating in VHSIC-sponsored development is significant in its implication that doors may be opening for other new participants.

Advanced Fighter Contract Awards

In late October 1986, the Air Force awarded contracts to Lockheed and Northrop of approximately $698 million each to develop competitive prototypes of the advanced tactical fighter (ATF). The losers were Boeing, General Dynamics, Grumman, McDonnell Douglas, and Rockwell. McDonnell Douglas will team with Northrop and Boeing, and General Dynamics will team with Lockheed.

The Air Force awarded General Dynamics $633 million for F-16As. The loser was Northrop's F-20. A total of 20 F-16As will be modified by General Dynamics to satisfy the air defense fighter (ADF) requirement. The planes will carry Westinghouse AN/APG-68 long range radar and Hughes/Raytheon AMRAAM missiles and Sparrow missiles. New IFF (identification friend or foe), new long range communications, and a new expanded airborne computer will be used.

Foreign military investors are expected to buy F-16As and not F-20s because they are opposed to buying airplanes not inventoried by the United States. Furthermore, Japan is designing its own fighter and may not continue buying U.S.-manufactured military planes over the long term.

European Activities--EUREKA

EUREKA is a series of projects among the countries of Western Europe designed to help them catch up with U.S. and Japanese technology in many high-technology areas, including semiconductors and electronic systems. The programs, participating countries, expected duration and budget, and other details (expressed in 1986 dollars at fourth quarter 1986 conversion rates) are outlined in Table 2.

Table 2

EUREKA PROGRAMS SUMMARY

Program	Countries	Years	Budget ($M)	Comments
ES2	Belgium, France, Holland, Switzerland, Sweden, United Kingdom	3	$ 90.0	CAD/CAM for ASICs
GaAs	France, United Kingdom	3	$ 57.6	Development of GaAs
High-Power Semiconductors	Sweden, Switzerland	2	$ 4.8	

(Continued)

Table 2 (Continued)

EUREKA PROGRAMS SUMMARY

Program	Countries	Years	Budget ($M)	Comments
GTO Thyristors	France, United Kingdom	2	$ 19.2	Thyristors for railway systems
Desire	Belgium, United Kingdom	3	$ 3.8	Submicron lithography
Sub-0.1u Ion Projection	Austria, West Germany	5	$ 4.8	Lithography development
Integrated Sensors for LSI	France, Switzerland	5	$ 25.9	
Fast ASIC Prototyping	France, United Kingdom	5	$ 28.2	
High-Performance Signal Processing	Portugal, United Kingdom	2	$ 0.4	Development of A/Ds for nuclear applications
EUREKA Software	Denmark, Finland, France, Italy, United Kingdom	6	$135.0	Development of software for engineering factories
CAE	Spain, Switzerland	3	$ 16.3	Development of computerized engineering
European Software Factory	France, West Germany, Norway, Spain, Sweden	8	$314.0	
Prolog Tools	Belgium, West Germany, Switzerland	3	$ 1.9	Prolog for expert systems
Ada Real-Time Applications	France, United Kingdom	2	$ 4.1	
Moses	Belgium, France, United Kingdom	3	$ 72.0	Multimedia data base

(Continued)

Table 2 (Continued)

EUREKA PROGRAMS SUMMARY

Program	Countries	Years	Budget ($M)	Comments
Wideband Telecom System	France, Italy, United Kingdom	5	$154.0	Basis for future ISDN
Eurocim	France, Italy, Spain	5	$ 28.8	CAM for PCs
APEX	France, West Germany, Italy, United Kingdom	5	$ 28.8	Advanced programming for European information exchange
Paradi	Belgium, France, Holland, Switzerland	6	$ 57.6	AI-based automated production management system
Advanced Mobile Robots	Belgium, Denmark, Switzerland	6	$ 96.0	Public safety third-generation robots
Cerise	France, Luxembourg	5	$ 8.2	Imaging technology
Modular Image Processor	France, Sweden	4	$ 6.7	Produce 2 prototypes
Mentor	France, Norway	4	$ 28.8	Expert security system
Prometheus	France, West Germany, Sweden, Italy, United Kingdom	8	$ 14.9+	Traffic control
Color Display System	Finland, West Germany	3	$ 1.0	Modular system for process control
HDTV	France, West Germany, Holland, United Kingdom	4	$173.0	Development of 50Hz HDTV

(Continued)

Table 2 (Continued)

EUREKA PROGRAMS SUMMARY

Program	Countries	Years	Budget ($M)	Comments
Fieldbus	Finland, France, Italy, United Kingdom, Portugal	5	$ 24.5	LAN network for real-time control
BD 11	France, Spain	5	$ 19.2	Data base for expert systems
Mithra	France, Italy	4	$ 32.0	Mobile robots for telesurveillance
Transpolis Transpotel	Holland, Switzerland, United Kingdom	3	$ 38.4	Integrated data and communications distribution system
Europolis	Denmark, France, Italy, Spain	7	$122.8	Advanced metropolitan information control and monitoring
Hercule	France, United Kingdom	5	$ 21.1	Robotics applications for heavy construction
Chemical Destruction by Laser	France, Belgium, Holland	5	$ 8.6	Development of lasers for impurity destruction
E-beam welding	Spain, Sweden, United Kingdom	4	$ 2.3	Weld steel to 100mm thick
Composites	France, West Germany	4	$ 14.4	
Carmat 2000	France, West Germany, Holland, United Kingdom	4	$ 57.6	New materials for car structures

(Continued)

Table 2 (Continued)

EUREKA PROGRAMS SUMMARY

Program	Countries	Years	Budget ($M)	Comments
Vehicle Noise Identification	Belgium, West Germany	4	$ 1.5	Transport vehicle noise identification methods
Diane	France, Spain, West Germany	4	$ 14.4	Autointegrated system for neutronography
Ceramics for Gas Turbines	France, Italy, Sweden	5	$ 15.3	
New Materials for Car Engines	France, Italy	5	$ 14.4	Development of ceramics and new metals
Pan (N5)	Norway, United Kingdom	2	$ 1.9	Mass produce high-pressure subsea pipes
Bobins Supra Conductor	Austria, Switzerland	3	$ 7.7	High-power magnets
Gas Scintillation Counter	Portugal, United Kingdom	4	$ 3.8	Produce and market hardware
Construction Techniques	France, Italy, United Kingdom	5	$ 8.8	
Ceramics for Diesel Engines	France, West Germany	5	$ 13.4	Development of commercial vehicle ceramics
Stabine	Belgium, France	7	$ 45.1	Advanced power generation
PACA-Absorption Heat Pump	France, West Germany	5	$ 9.6	

(Continued)

Table 2 (Continued)

EUREKA PROGRAMS SUMMARY

Program	Countries	Years	Budget ($M)	Comments
High-Performance Ceramics	Austria, Belgium	3	$ 1.9	
Carminat	France, Holland	4	$ 49.9	Car driver information system
Oxidipene	France, Spain	8	$ 5.8	
Galeno 2000	Denmark, Spain	3	$ 57.6	Automatic non-evasive medical equipment

Source: Dataquest
September 1987

Japanese Activities

Japan to Make, Not Buy, New Jet Fighter

Mitsubishi Heavy Industries Ltd., designer and manufacturer of the Zero fighter of World War II, is expected to receive an order for about 100 FSX jet fighters for Japan's Defense Agency. R&D costs for the aircraft are believed to be $1.3 billion. The fighters will cost approximately $38 million each. Japan is seeking aircraft more advanced than the McDonnell Douglas F/A-18 and the General Dynamics F-16. Kawasaki Heavy Industries and Fuji Heavy Industries are expected to be subcontractors. Dataquest believes that this activity represents a demand for more than $700 million in military electronics hardware containing military-grade ICs and that Japanese IC manufacturers will supply the majority, if not all, of the requirements. The $5.1 billion will add to the already large U.S. trade deficit. Japan may attempt to reduce the trade impact by buying engines from one or more U.S. firms, if the U.S. government allows selling advanced jet engines into this application.

Japanese Space Activities

Dataquest expects Japan to increase emphasis on high-rel GaAs and Si ICs in support of its expanding space programs. While Japan claims to have a zero military budget, it has massed tremendous capabilities in aerospace hardware in recent years and has aggressive plans for the next decade. Japan's space activities include the following programs, which require military temperature range ruggedized and, in many cases, radiation-hardened semiconductors:

- Three new expendable boosters--H-I, M-3S-2, and H-II
- More than 10 advanced satellites
- Space platforms
- A space shuttle
- Participation in a U.S. shuttle mission
- Participation in the U.S./international space station
- Moon and Venus probes

Japan's space activities represent an increasing threat to Western leadership in satellites, platforms, and shuttles. Dataquest expects increased international interest in Japan's satellite launch capability to evolve as a result of recent NASA Shuttle, Ariane, and other launch failures.

Roles of NASDA, ISAS, and MITI

Japan has two space agencies, NASDA (National Space Development Agency) and ISAS (Institute of Space and Astronautical Science). These agencies have been responsible for launching about one satellite per year since 1970. MITI (Ministry of International Trade and Industry) serves to create competitive pressures by funding specific payloads.

Japan's space agencies are developing more than 10 satellites and space probes, many designed for geosynchronous orbit (approximately 22,000 miles altitude). These satellites require state-of-the-art GaAs and Si ICs to accomplish the intended functions within launch payload constraints. In addition, radiation-hardened requirements are expected to impact the IC designs.

Thirteen Japanese companies are studying the MITI/ISAS platform concept for launch by the U.S. shuttle and Japan's H-II booster (developed by Mitsubishi). The H-II booster will support manned launches by 1995. A summary of Japan's spacecraft, including launch dates, type of payload, and other pertinent data, are given in Table 3. These include four communications satellites and two meteorological satellites designed for geosynchronous orbit.

Table 3

JAPANESE SPACECRAFT

Launch Date	Type	Name	Company	Payload (Lbs.)	Orbit Height	Comments
8/1/86	EGP	Experimental Geodetic Payload	Kawasaki	1,500	900 miles	Laser target, first H-I payload
Mid-1987	ETS-5	Engineering Test Satellite #5	Mitsubishi	N/A	Geosync.	Mobile Satcom with ships, planes
1/87	MOS-1	Marine Observation Satellite	NEC	1,650	545 miles	Carrying CCDs and other multispectral detectors
Early 1988	CS-3A	Communications Satellite #3A	Mitsubishi	N/A	Geosync.	Third generation, 6,000 voice channels plus K- and C-band transponders
Mid-1988	CS-3B	Communications Satellite #3B	Mitsubishi	N/A	Geosync.	Sister to CS-3A
Mid-1989	GMS-4	Geosync. Meterological Sat.	NEC	N/A	Geosync.	Weather spacecraft; H-I launch vehicle
Mid-1989	GMS-5	Geosync. Meterological Sat.	NEC	N/A	Geosync.	$185 million development cost; 3-axis stabilized; H-I launch vehicle
Mid-1990	BS-3A	Broadcast Satellite	NEC	N/A	Geosync.	Color TV--3 channels

(Continued)

Table 3 (Continued)

JAPANESE SPACECRAFT

Launch Date	Type	Name	Company	Payload (Lbs.)	Orbit Height	Comments
Mid-1991	BS-3B	Broadcast Satellite	NEC	N/A	Geosync.	Sister to BS-3A
N/A	ERS-1	Earth Resources Satellite #1	NEC/ Mitsubishi	3,000	N/A	Will carry synthetic aperture radar, visible and IR sensors
1/92	ETS-6	Engineering Test Satellite #6	Mitsubishi	N/A	N/A	First H-II payload
1994	N/A	Moon Probe	N/A	N/A	Inapplic.	H-II payload; seismic detection
Mid-1990s		Venus Probe	N/A	N/A	Inapplic.	H-II payload; magnetosphere probe

Geosync. = Geosynchronous orbit (approximately 22,700 miles above Earth's surface)
N/A = Not available at press time
Inapplic. = Inapplicable

Source: AZTEK Associates

Japan is developing a demand for low volumes of domestically produced high-reliability, radiation-hardened ICs. To achieve better economies of scale, the next logical step is to take these ICs to the international marketplace. Western suppliers of military range ICs may experience increased market pressure as a result of Japan's space efforts.

Japan's investment in its space efforts is resulting in far greater capacities in high-reliability semiconductors, satellite systems, and launch hardware than required to support the programs listed in Table 3. In view of recent Western launch failures, Japan will likely experience increasing difficulty in attempting to keep a low profile regarding its space programs.

MARKET SHARE

The following section contains Dataquest's estimates of military semiconductor sales by major companies. Although this list is neither all-inclusive nor exact, it provides an overview of the major players and their respective product emphasis in the military market. Table 4 summarizes the total estimated military semiconductor sales for each company, followed by Tables 5 through 21, which provide a breakdown of each company's military revenue by product type.

Table 4

ESTIMATED 1986 TOTAL MILITARY SEMICONDUCTOR REVENUE
(Millions of Dollars)

Advanced Micro Devices	$135
Analog Devices	$ 33
Fairchild	$148
GE/Intersil/RCA	$102
Harris	$166
Intel	$ 65
LSI Logic	$ 40
Monolithic Memories, Inc.	$ 32
Motorola	$110
National Semiconductor	$133
Precision Monolithics, Inc.	$ 10
Raytheon	$ 49
Signetics	$ 53
Sprague	$ 27
Thomson-Mostek	$ 23
Texas Instruments	$204
Zilog	$ 11

Source: Dataquest
September 1987

Table 5

ESTIMATED MILITARY MARKET SHARE FOR SELECTED PRODUCT LINES--AMD
(Millions of Dollars)

	1982	1983	1984	1985	1986
Total Semiconductor	$ 60	$ 75	$ 80	$132	$135
Total Integrated Circuit	$ 60	$ 75	$ 80	$132	$135
Bipolar Digital	$ 48	$ 60	$ 64	$105	$107
Bipolar Logic	30	36	38	63	64
Bipolar Memory	18	24	26	42	43
MOS	$ 12	$ 15	$ 16	$ 27	$ 28
MOS Logic	3	4	4	6	7
MOS Memory	6	7	7	14	14
MOS MPU	3	4	5	7	7
Linear	0	0	0	0	0
Total Discrete	0	0	0	0	0
Total Optoelectronic	0	0	0	0	0

Table 6

ESTIMATED MILITARY MARKET SHARE FOR SELECTED PRODUCT LINES--ANALOG DEVICES
(Millions of Dollars)

	1982	1983	1984	1985	1986
Total Semiconductor	$ 17	$ 21	$ 26	$ 29	$ 33
Total Integrated Circuit	$ 17	$ 21	$ 26	$ 29	$ 33
Bipolar Digital	0	0	0	0	0
Bipolar Logic	0	0	0	0	0
Bipolar Memory	0	0	0	0	0
MOS	0	0	0	0	2
MOS Logic	0	0	0	0	2
MOS Memory	0	0	0	0	0
MOS MPU	0	0	0	0	0
Linear	$ 17	$ 21	$ 26	$ 29	$ 31
Total Discrete	0	0	0	0	0
Total Optoelectronic	0	0	0	0	0

Source: Dataquest
September 1987

Table 7

ESTIMATED MILITARY MARKET SHARE FOR SELECTED PRODUCT LINES--FAIRCHILD
(Millions of Dollars)

	1982	1983	1984	1985	1986
Total Semiconductor	$ 62	$ 78	$120	$160	$148
Total Integrated Circuit	$ 54	$ 67	$109	$149	$138
Bipolar Digital	$ 34	$ 45	$ 71	$ 89	$ 86
Bipolar Logic	20	25	42	50	48
Bipolar Memory	14	20	29	39	38
MOS	$ 3	$ 4	$ 5	$ 6	$ 6
MOS Logic	1	1	1	2	3
MOS Memory	1	2	3	1	1
MOS MPU	1	1	1	3	2
Linear	$ 17	$ 18	$ 33	$ 55	$ 46
Total Discrete	$ 8	$ 11	$ 11	$ 11	$ 10
Total Optoelectronic	0	0	0	0	0

Table 8

ESTIMATED MILITARY MARKET SHARE FOR SELECTED PRODUCT LINES--
GE/INTERSIL/RCA
(Millions of Dollars)

	1982	1983	1984	1985	1986
Total Semiconductor	$ 71	$ 77	$ 85	$ 90	$102
Total Integrated Circuit	$ 59	$ 65	$ 71	$ 76	$ 87
Bipolar Digital	0	0	0	0	0
Bipolar Logic	0	0	0	0	0
Bipolar Memory	0	0	0	0	0
MOS	$ 48	$ 52	$ 57	$ 62	$ 72
MOS Logic	38	40	44	47	55
MOS Memory	8	9	10	11	13
MOS MPU	2	3	3	4	4
Linear	$ 11	$ 13	$ 14	$ 14	$ 15
Total Discrete	$ 9	$ 9	$ 10	$ 10	$ 11
Total Optoelectronic	$ 3	$ 3	$ 4	$ 4	$ 4

Source: Dataquest
September 1987

Table 9

ESTIMATED MILITARY MARKET SHARE FOR SELECTED PRODUCT LINES--
HARRIS CORPORATION
(Millions of Dollars)

	1982	1983	1984	1985	1986
Total Semiconductor	$ 69	$ 80	$128	$131	$166
Total Integrated Circuit	$ 69	$ 80	$128	$131	$166
Bipolar Digital	$ 30	$ 25	$ 30	$ 33	$ 48
Bipolar Logic	18	15	18	20	28
Bipolar Memory	12	10	12	13	20
MOS	$ 26	$ 33	$ 55	$ 58	$ 63
MOS Logic	12	15	30	34	41
MOS Memory	11	15	22	22	20
MOS MPU	3	3	3	2	2
Linear	$ 21	$ 22	$ 43	$ 40	$ 55
Total Discrete	0	0	0	0	0
Total Optoelectronic	0	0	0	0	0

Table 10

ESTIMATED MILITARY MARKET SHARE FOR SELECTED PRODUCT LINES--INTEL
(Millions of Dollars)

	1982	1983	1984	1985	1986
Total Semiconductor	$ 25	$ 29	$ 60	$ 60	$ 65
Total Integrated Circuit	$ 25	$ 29	$ 60	$ 60	$ 65
Bipolar Digital	0	0	0	0	0
Bipolar Logic	0	0	0	0	0
Bipolar Memory	0	0	0	0	0
MOS	$ 25	$ 29	$ 60	$ 60	$ 65
MOS Logic	5	6	0	0	0
MOS Memory	15	17	30	30	33
MOS MPU	5	6	30	30	32
Linear	0	0	0	0	0
Total Discrete	0	0	0	0	0
Total Optoelectronic	0	0	0	0	0

Source: Dataquest
September 1987

Table 11

ESTIMATED MILITARY MARKET SHARE FOR SELECTED PRODUCT LINES--LSI LOGIC
(Millions of Dollars)

	1982	1983	1984	1985	1986
Total Semiconductor	0	0	$ 1	$ 15	$ 40
Total Integrated Circuit	0	0	$ 1	$ 15	$ 40
Bipolar Digital	0	0	0	0	0
Bipolar Logic	0	0	0	0	0
Bipolar Memory	0	0	0	0	0
MOS	0	0	$ 1	$ 15	$ 40
MOS Logic	0	0	1	15	40
MOS Memory	0	0	0	0	0
MOS MPU	0	0	0	0	0
Linear	0	0	0	0	0
Total Discrete	0	0	0	0	0
Total Optoelectronic	0	0	0	0	0

Table 12

ESTIMATED MILITARY MARKET SHARE FOR SELECTED PRODUCT LINES--MMI
(Millions of Dollars)

	1982	1983	1984	1985	1986
Total Semiconductor	$ 12	$ 22	$ 30	$ 34	$ 32
Total Integrated Circuit	$ 12	$ 22	$ 30	$ 34	$ 32
Bipolar Digital	$ 12	$ 22	$ 30	$ 34	$ 32
Bipolar Logic	9	18	24	29	27
Bipolar Memory	3	4	6	5	5
MOS	0	0	0	0	0
MOS Logic	0	0	0	0	0
MOS Memory	0	0	0	0	0
MOS MPU	0	0	0	0	0
Linear	0	0	0	0	0
Total Discrete	0	0	0	0	0
Total Optoelectronic	0	0	0	0	0

Source: Dataquest
September 1987

Table 13

ESTIMATED MILITARY MARKET SHARE FOR SELECTED PRODUCT LINES--MOTOROLA
(Millions of Dollars)

	1982	1983	1984	1985	1986
Total Semiconductor	$102	$124	$134	$117	$110
Total Integrated Circuit	$ 82	$103	$112	$ 94	$ 87
Bipolar Digital	$ 57	$ 75	$ 81	$ 67	$ 62
Bipolar Logic	55	73	79	65	60
Bipolar Memory	2	2	2	2	2
MOS	$ 19	$ 22	$ 22	$ 21	$ 19
MOS Logic	8	9	9	9	6
MOS Memory	8	9	9	5	5
MOS MPU	3	4	4	7	8
Linear	$ 6	$ 8	$ 9	$ 6	$ 6
Total Discrete	$ 17	$ 17	$ 18	$ 18	$ 18
Total Optoelectronic	$ 3	$ 4	$ 4	$ 5	$ 5

Table 14

ESTIMATED MILITARY MARKET SHARE FOR SELECTED PRODUCT LINES--
NATIONAL SEMICONDUCTOR CORPORATION
(Millions of Dollars)

	1982	1983	1984	1985	1986
Total Semiconductor	$ 94	$106	$103	$132	$133
Total Integrated Circuit	$ 83	$ 95	$ 93	$122	$123
Bipolar Digital	$ 33	$ 42	$ 45	$ 56	$ 53
Bipolar Logic	30	37	38	48	44
Bipolar Memory	3	5	7	8	9
MOS	$ 22	$ 24	$ 26	$ 36	$ 38
MOS Logic	5	7	11	16	20
MOS Memory	9	9	9	11	14
MOS MPU	8	8	6	9	4
Linear	$ 28	$ 31	$ 27	$ 30	$ 32
Total Discrete	$ 11	$ 11	$ 10	$ 10	$ 10
Total Optoelectronic	0	0	0	0	0

Source: Dataquest
September 1987

Table 15

ESTIMATED MILITARY MARKET SHARE FOR SELECTED PRODUCT LINES--
PRECISION MONOLITHICS
(Millions of Dollars)

	1982	1983	1984	1985	1986
Total Semiconductor	$ 6	$ 7	$ 8	$ 8	$ 10
Total Integrated Circuit	$ 5	$ 6	$ 7	$ 7	$ 9
Bipolar Digital	0	0	0	0	0
Bipolar Logic	0	0	0	0	0
Bipolar Memory	0	0	0	0	0
MOS	0	0	0	0	0
MOS Logic	0	0	0	0	0
MOS Memory	0	0	0	0	0
MOS MPU	0	0	0	0	0
Linear	$ 5	$ 6	$ 7	$ 7	$ 9
Total Discrete	$ 1	$ 1	$ 1	$ 1	$ 1
Total Optoelectronic	0	0	0	0	0

Table 16

ESTIMATED MILITARY MARKET SHARE FOR SELECTED PRODUCT LINES--RAYTHEON
(Millions of Dollars)

	1982	1983	1984	1985	1986
Total Semiconductor	$ 45	$ 46	$ 49	$ 46	$ 49
Total Integrated Circuit	$ 43	$ 44	$ 46	$ 43	$ 45
Bipolar Digital	$ 26	$ 27	$ 28	$ 24	$ 26
Bipolar Logic	20	21	22	20	22
Bipolar Memory	6	6	6	4	4
MOS	0	0	0	0	0
MOS Logic	0	0	0	0	0
MOS Memory	0	0	0	0	0
MOS MPU	0	0	0	0	0
Linear	$ 17	$ 17	$ 18	$ 19	$ 19
Total Discrete	$ 2	$ 2	$ 3	$ 3	$ 4
Total Optoelectronic	0	0	0	0	0

Source: Dataquest
September 1987

Table 17

ESTIMATED MILITARY MARKET SHARE FOR SELECTED PRODUCT LINES--SIGNETICS
(Millions of Dollars)

	1982	1983	1984	1985	1986
Total Semiconductor	$ 51	$ 53	$ 57	$ 55	$ 53
Total Integrated Circuit	$ 51	$ 53	$ 57	$ 55	$ 53
Bipolar Digital	$ 46	$ 48	$ 52	$ 51	$ 49
Bipolar Logic	34	35	38	41	35
Bipolar Memory	12	13	14	10	14
MOS	0	0	0	0	0
MOS Logic	0	0	0	0	0
MOS Memory	0	0	0	0	0
MOS MPU	0	0	0	0	0
Linear	$ 5	$ 5	$ 5	$ 4	$ 4
Total Discrete	0	0	0	0	0
Total Optoelectronic	0	0	0	0	0

Table 18

ESTIMATED MILITARY MARKET SHARE FOR SELECTED PRODUCT LINES--SPRAGUE
(Millions of Dollars)

	1982	1983	1984	1985	1986
Total Semiconductor	N/A	N/A	N/A	$ 27	$ 27
Total Integrated Circuit	N/A	N/A	N/A	$ 25	$ 25
Bipolar Digital	0	0	0	0	0
Bipolar Logic	0	0	0	0	0
Bipolar Memory	0	0	0	0	0
MOS	N/A	N/A	N/A	$ 19	$ 18
MOS Logic	N/A	N/A	N/A	19	18
MOS Memory	0	0	0	0	0
MOS MPU	0	0	0	0	0
Linear	N/A	N/A	N/A	$ 6	$ 7
Total Discrete	0	0	0	$ 1	$ 1
Total Optoelectronic	0	0	0	$ 1	$ 1

N/A = Not Applicable

Source: Dataquest
September 1987

Table 19

ESTIMATED MILITARY MARKET SHARE FOR SELECTED PRODUCT LINES--THOMSON-MOSTEK
(Millions of Dollars)

	1982	1983	1984	1985	1986
Total Semiconductor	$ 15	$ 18	$ 24	$ 25	$ 23
Total Integrated Circuit	$ 15	$ 18	$ 24	$ 25	$ 23
Bipolar Digital	0	0	0	0	0
Bipolar Logic	0	0	0	0	0
Bipolar Memory	0	0	0	0	0
MOS	$ 15	$ 18	$ 24	$ 25	$ 23
MOS Logic	0	0	0	1	1
MOS Memory	15	18	23	23	21
MOS MPU	0	0	1	1	1
Linear	0	0	0	0	0
Total Discrete	0	0	0	0	0
Total Optoelectronic	0	0	0	0	0

Table 20

ESTIMATED MILITARY MARKET SHARE FOR SELECTED PRODUCT LINES--
TEXAS INSTRUMENTS
(Millions of Dollars)

	1982	1983	1984	1985	1986
Total Semiconductor	$108	$119	$149	$194	$204
Total Integrated Circuit	$ 87	$ 96	$122	$165	$170
Bipolar Digital	$ 65	$ 70	$ 92	$130	$126
Bipolar Logic	60	64	78	106	87
Bipolar Memory	2	3	4	5	6
Bipolar MPU	6	8	10	13	22
MOS	$ 6	$ 8	$ 10	$ 13	$ 22
MOS Logic	2	3	3	4	12
MOS Memory	3	4	6	7	8
MOS MPU	1	1	1	2	2
Linear	$ 16	$ 18	$ 20	$ 22	$ 22
Total Discrete	$ 14	$ 15	$ 17	$ 18	$ 21
Total Optoelectronic	$ 7	$ 8	$ 10	$ 11	$ 13

Source: Dataquest
September 1987

Table 21

ESTIMATED MILITARY MARKET SHARE FOR SELECTED PRODUCT LINES--ZILOG
(Millions of Dollars)

	1982	1983	1984	1985	1986
Total Semiconductor	$ 6	$ 7	$ 8	$ 9	$ 11
Total Integrated Circuit	$ 6	$ 7	$ 8	$ 9	$ 11
Bipolar Digital	0	0	0	0	0
Bipolar Logic	0	0	0	0	0
Bipolar Memory	0	0	0	0	0
MOS	$ 6	$ 7	$ 8	$ 9	$ 11
MOS Logic	0	0	0	0	0
MOS Memory	0	0	0	0	0
MOS MPU	6	7	8	9	11
Linear	0	0	0	0	0
Total Discrete	0	0	0	0	0
Total Optoelectronic	0	0	0	0	0

Source: Dataquest
September 1987

MILITARY SEMICONDUCTOR PRICE TRENDS

This section describes some of the factors that affect military semiconductor pricing. Forecasts through 1991 are provided in Tables 22 through 31 to illustrate price trends for major IC products and product families.

The price trend data shown herein are for quantity levels of 100,000 pieces for SSI/MSI devices, 25,000 for LSI devices, and 5,000 for VLSI devices. Prices are in 1987 constant dollars unless noted. Obviously, these quantities reflect unusually high volumes for military programs and would only be seen in multiyear contracts with major OEMs.

Standard Logic Devices

Prices for standard logic have suffered severe erosion during the last two years, attributed in part to repositioning among high-speed TTL families and in part to CMOS competition with TTL. The situation was aggravated by U.S. IC distributors and suppliers, which both increased emphasis on obtaining higher-ASP military business to replace lost commodity IC revenue. This tendency has been a factor in previous recessions and downturns. In 1985 to 1986, the situation was intensified by Japanese price pressure on memories for commercial applications, giving added impetus to the "niche-market mania" that has become prevalent as the U.S. suppliers' typical marketing strategy.

As shown in Table 22, the 54F and 54ALS price levels are expected to continue declining as each family moves to displace the more mature TTL over the next two to three years. The same is true for HC (CMOS) logic. The emergence of a single standard to replace LS is now dependent on consolidation among or withdrawal of suppliers.

Table 22

PRICE TRENDS FORECAST
(Prices in U.S. Dollars)

Product/Family	1987	1988	1989	1990	1991
Logic					
54LS00					
883B	$0.60	$0.58	$0.57	$0.60	$0.65
38510	$1.10	$1.07	$1.05	$1.05	$1.05
54LS74					
883B	$0.86	$0.84	$0.82	$0.85	$0.85
38510	$1.35	$1.31	$1.26	$1.25	$1.25
54LS245					
883B	$1.78	$1.75	$1.75	$1.78	$1.80
38510	$2.75	$2.70	$2.65	$2.65	$2.65
54F00					
883B	$1.17	$0.92	$0.75	$0.59	$0.59
38510	$1.95	$1.75	$1.62	$1.49	$1.40
54F74					
883B	$1.40	$1.13	$0.91	$0.81	$0.80
38510	$2.25	$2.07	$1.95	$1.86	$1.78
54F138					
883B	$2.65	$2.25	$1.87	$1.55	$1.52
38510	$3.90	$3.45	$3.10	$2.82	$2.60

(Continued)

Table 22 (Continued)

PRICE TRENDS FORECAST
(Prices in U.S. Dollars)

Product/Family	1987	1988	1989	1990	1991
Logic					
54HC00					
883B	$0.90	$0.80	$0.70	$0.60	$0.55
38510	$1.60	$1.44	$1.23	$1.14	$1.10
54HC74					
883B	$1.10	$0.99	$0.88	$0.85	$0.82
38510	$1.95	$1.72	$1.45	$1.33	$1.28
54HC244					
883B	$2.45	$2.20	$1.92	$1.74	$1.63
38510	$4.30	$3.95	$3.65	$3.38	$3.17
54ALS00					
883B	$0.74	$0.66	$0.58	$0.58	$0.58
38510	$1.45	$1.20	$1.05	$1.05	$1.05
54ALS74					
883B	$1.05	$0.94	$0.84	$0.83	$0.82
38510	$1.95	$1.82	$1.73	$1.71	$1.69
54ALS373					
883B	$1.97	$1.85	$1.76	$1.72	$1.70
38510	$3.65	$3.40	$3.24	$3.18	$3.13

Source: Dataquest
September 1987

Microprocessors

The 8-bit microprocessors are maturing and the 16-bit devices will mature over the next two to three years. Significant price declines are expected through 1990 in the standard 32-bit 68020 and 80386 devices as production experience builds.

MIL-STD-1750A, pioneered by the U.S. Air Force, is a digital processor system architecture standard. The specification delineates:

- Requirements for real-time operation
- Use of Ada, the DOD standard high-level language
- A set of 288 instructions
- Acceptable word formats and types of data
- A uniform set of internal registers
- 16 interrupts and service details

- Multiprocessing requirements
- Graceful recovery from faults

The 1750A specification does not state a processing speed, process technology, number of chips, or power requirements. It leaves these aspects of implementation of a particular controller to the discretion of the contractor.

Fairchild Semiconductor is currently the leading supplier of MIL-STD-1750A microprocessors with its bipolar 9450 product, a single-chip 1750A implementation. The U.S. defense community is under increasing pressure to standardize on the 1750A wherever possible. As a result, the 9450 and similar 1750A-type microprocessors are gaining popularity.

This increasing demand is driving continued evolution of 1750A-type chips, as well as the emergence of new suppliers such as Performance Semiconductor and LSI Logic, which have both introduced versions in CMOS. Table 23 presents an overview of the suppliers and of the products currently offered that meet 1750A specifications. Table 24 reflects military microdevice pricing. This influx of new products and higher quantity orders is expected to result in price declines on the order of 30 percent per year through 1989, with another 30 percent decline by 1991.

Table 23

MIL-STD 1750A PROCESSORS

Company	ID Number	Chip(s)	Board	Subsystem	Comments
Delco	Magic 5		x	x	7.5-10 mips
Elisra				x	
FSC	F9450/51/52	x	x		
IBM FSD	AP101/102			x	
LSI Logic	L64500/550	x			1.5 mips
McDonnell Douglas	MDC281				3-chip hybrid
Mikros	MKS1750/SM	x	x	x	0.25 mips
Performance Semi	PACE 1750A	x			1.3-5 mips
ROLM	7750		x	x	
Sanders				x	
Sperry	1630			x	
Teledyne	TD1750			x	
TI		x			VHSIC, 3+ mips
Tracor			x		
TRW		x	x		VHSIC, 3+ mips
UTMC	1750AR	x			0.75 mips
Westinghouse		x	x		VHSIC, 3+ mips

Source: Dataquest
September 1987

Table 24

ESTIMATED MILITARY MICRODEVICE PRICING

Product/Family	1987	1988	1989	1990	1991
MPU					
9450					
883B	$600.00	$450.00	$355.00	$310.00	$280.00
38510	N/A	Intro			
8085					
883B	$ 28.50	$ 28.00	$ 28.00	$ 29.00	$ 31.00
38510	$ 48.00	$ 45.00	$ 45.00	$ 45.00	$ 45.00
8086					
883B	$105.00	$ 95.00	$ 85.00	$ 80.00	$ 80.00
38510	$170.00	$140.00	$125.00	$115.00	$115.00
8086 (8 MHz)					
883B	$135.00	$125.00	$115.00	$105.00	$105.00
38510	$210.00	$185.00	$170.00	$160.00	$160.00
68000 (8 MHz)					
883B	$130.00	$121.00	$112.00	$102.00	$102.00
38510	$205.00	$180.00	$166.00	$157.00	$155.00
8087					
883B	$130.00	$125.00	$115.00	$105.00	$105.00
38510	$175.00	$170.00	$155.00	$145.00	$145.00
8087 (8 MHz)					
883B	$150.00	$135.00	$125.00	$120.00	$120.00
38510	$210.00	$185.00	$170.00	$160.00	$160.00
80186					
883B	$190.00	$170.00	$150.00	$135.00	$125.00
38510	$275.00	$230.00	$210.00	$190.00	$175.00
80186 (8 MHz)					
883B	$220.00	$195.00	$180.00	$165.00	$160.00
38510	$355.00	$290.00	$245.00	$225.00	$215.00

(Continued)

Table 24 (Continued)

ESTIMATED MILITARY MICRODEVICE PRICING

Product/Family	1987	1988	1989	1990	1991
MPU					
80186 (10 MHz)					
883B	Intro				
38510	N/A	Intro			
80286 (8 MHz)					
883B	$275.00	$225.00	$200.00	$180.00	$180.00
38510	$360.00	$295.00	$255.00	$235.00	$220.00
Z80					
883B					
38510					
68020 (16 MHz)					
883B	$550.00	$370.00	$280.00	$230.00	$190.00
38510	N/A	Intro			
80386 (16 MHz)					
883B	$650.00	$485.00	$390.00	$330.00	$295.00
38510	N/A	Intro			

N/A = Not Available

Source: Dataquest
September 1987

Static RAMs (SRAMs)

CMOS static RAMs in standard-speed and 55ns versions are now available from a large supplier base and are displacing NMOS devices in new designs at 64K density. Pricing of this device is expected to decline on the order of 20 to 25 percent per year into 1990 as volumes develop. The 16K SRAMs will mature over the next two years, with some further decline in 38510 version pricing from 1989 through 1990. Dataquest believes that long lead-time programs should consider designing with the 256K devices, which will mature in the early 1990s. Table 25 shows estimated military static RAM pricing for 1987 through 1991.

Table 25

ESTIMATED MILITARY STATIC RAM PRICING

Product/Family	1987	1988	1989	1990	1991
SRAMs					
16K (70+ns)					
883B	$ 35.00	$25.00	$24.00	$ 22.00	$ 21.00
38510	$100.00	$70.00	$55.00	$ 40.00	$ 35.00
16K (55ns)					
883B	$ 43.00	$29.00	$27.00	$ 26.00	$ 25.00
38510	$125.00	$80.00	$60.00	$ 50.00	$ 45.00
64K					
883B	$ 65.00	$55.00	$45.00	$ 50.00	$ 55.00
38510	$105.00	$90.00	$90.00	$105.00	$125.00
256K					
883B	Intro				
38510	N/A	Intro			
CMOS 64K (55ns)					
883B	$ 48.00	$32.00	$27.00	$ 22.00	$ 18.00
38510	Intro				

N/A = Not Available

Source: Dataquest
September 1987

Dynamic RAMs (DRAMs)

Availability of 256K and 1Mb DRAMs at negotiable pricing is dependent upon reentry of U.S. suppliers to this market. Otherwise, DOD programs are dependent upon availability of parts manufactured offshore. Table 26 shows estimated military dynamic RAM pricing for 1987 through 1991.

Table 26

ESTIMATED MILITARY DYNAMIC RAM PRICING

Product/Family	1987	1988	1989	1990	1991
DRAMs					
64K					
883B	$ 30.00	$ 40.00	$ 40.00	$ 40.00	$ 40.00
38510	$100.00	$100.00	$110.00	$125.00	$125.00
256K					
883B	Intro				
38510	N/A	Intro			
1024K*					
883B					
38510					

*Availability depends on U.S. suppliers reentering the mainstream DRAM market.
N/A = Not Available

Source: Dataquest
September 1987

Programmable Read-Only Memories (PROMs)

Bipolar PROMs have matured at the 16K density level. The 64K is expected to be bit cost-effective before 1990. Pricing of the 16K 883B version may decline approximately 15 percent per year through 1989; the 38510 pricing is believed to be nearing stability in 1987. Commercial products have experienced a recent increase in demand, which may stretch lead times for some military TTL PROMs on a spot basis into 1988. Table 27 shows estimated military memory pricing for 1987 through 1991.

Table 27

ESTIMATED MILITARY MEMORY PRICING

Product/Family	1987	1988	1989	1990	1991
Programmable ROM					
16K TTL PROM					
883B	$ 18.00	$ 15.00	$ 13.00	$ 12.00	$ 12.00
38510	$ 26.00	$ 25.00	$ 24.00	$ 24.00	$ 24.00
64K TTL PROM					
883B	$108.00	$ 74.00	$ 52.00	$ 36.00	$ 32.00
38510	N/A	Intro			
UV EPROM					
64K					
883B	$ 30.00	$ 30.00	$ 35.00	$ 35.00	$ 38.00
38510	$ 42.00	$ 40.00	$ 45.00	$ 50.00	$ 50.00
128K					
883B	$ 46.00	$ 42.00	$ 42.00	$ 45.00	$ 45.00
38510	$ 75.00	$ 70.00	$ 70.00	$ 75.00	$ 75.00
256K					
883B	$ 83.00	$ 75.00	$ 70.00	$ 65.00	$ 65.00
38510	$115.00	$105.00	$105.00	$105.00	$105.00
512K					
883B	$190.00	$170.00	$150.00	$135.00	$125.00
38510	$275.00	$230.00	$210.00	$190.00	$175.00
1024K					
883B	Intro				
38510	N/A	Intro			
EEPROM					
64K					
883B	$ 45.00	$ 35.00	$ 30.00	$ 30.00	$ 30.00
38510	$ 80.00	$ 60.00	$ 45.00	$ 45.00	$ 45.00
256K					
883B	$390.00	$340.00	$190.00	$135.00	$110.00
38510	N/A	Intro			

N/A = Not Available

Source: Dataquest
September 1987

EPROMs and EEPROMs

UV EPROM prices have reached relatively stable levels at 64K density. The 256K is expected to decline at 7 to 10 percent through 1990. The 1024 is expected to be introduced in the 883B version later this year, followed by the 38510 version 8 to 12 months later.

In applications for which density is not the most critical factor, 64K CMOS EEPROMs are becoming available at below 0.1 cents per bit (38510 version) in 1988. The 883B version of the 256K CMOS EEPROM, priced below 0.15 cents per bit, is expected in the same time frame.

Gate Arrays

Prices for 1.5u process CMOS gate arrays vary from 0.5 cents per gate at 1,000 to 2,000 density downward to 0.3 cents per gate at 5,000 to 10,000 gates per chip, then upward to 1.5 cents per gate at 20,000 plus gates per chip. The expected price decline is approximately 10 percent per year as the 1.5u process matures. Table 28 shows estimated military gate array pricing for 1987 through 1991.

Table 28

ESTIMATED MILITARY GATE ARRAY PRICING

Product/Family	1987	1988	1989	1990	1991
1.5u CMOS Gate Array (per gate die prices)					
1K-2K gates	$0.0050	$0.0045	$0.0041	$0.0037	$0.0034
2K-5K gates	$0.0040	$0.0036	$0.0032	$0.0029	$0.0026
5K-10K gates	$0.0030	$0.0027	$0.0024	$0.0021	$0.0019
10K-20K gates	$0.0080	$0.0072	$0.0065	$0.0059	$0.0054
20K+ gates	$0.0150	$0.0135	$0.0121	$0.0110	$0.0099
1.5u CMOS Gate Array NRE ($K)					
1K-2K gates	$50				
2K-5K gates	$55				
5K-10K gates	$60				
10K-20K gates	$65				
20K+ gates	$70				

Source: Dataquest
September 1987

Nonrecurring engineering (NRE) charges, lower than for standard cell designs, range from approximately $50,000 for smaller arrays to $70,000 to $75,000 for arrays exceeding 20,000 gates per chip. These charges are not expected to vary significantly over time, as the effects of inflation tend to be offset by improvements in CAD/CAE tools and other efficiencies of scale as gate array technology advances.

Standard Cell Devices

Prices for CMOS standard cell devices based on a 1.5u process range from 0.4 cents per gate for smaller arrays downward to 0.25 cents at 5,000 to 10,000 density, then upward to 1.3 cents per gate at 20,000 plus gates. The trend in price is an expected decline of 8 to 12 percent per year as this process matures. NRE charges range from $60,000 for small standard cell arrays to more than $200,000 as density approaches 20,000 gates per chip and above. Table 29 shows estimated military cell-based IC pricing for 1987 through 1991.

Table 29

ESTIMATED MILITARY CELL-BASED IC PRICING

Product/Family	1987	1988	1989	1990	1991
1.5u CMOS Cell-Based IC Device (per gate die prices)					
1K-2K gates	$0.0040	$0.0036	$0.0032	$0.0029	$0.0026
2K-5K gates	$0.0033	$0.0030	$0.0027	$0.0024	$0.0022
5K-10K gates	$0.0025	$0.0022	$0.0020	$0.0018	$0.0016
10K-20K gates	$0.0072	$0.0065	$0.0058	$0.0052	$0.0047
20K+ gates	$0.0130	$0.0117	$0.0105	$0.0094	$0.0085
1.5u CMOS Cell-Based IC Device NRE ($K)					
1K-2K gates	$ 60				
2K-5K gates	$ 80				
5K-10K gates	$120				
10K-20K gates	$170				
20K+ gates	$220				

Source: Dataquest
September 1987

NRE charges will vary over time primarily as a function of inflation and changes in overhead rates as business fluctuates (these factors are not accounted for in this analysis). As standard cell technology matures, some savings in NRE may result from the continuing development of macro-cells. However, this situation is driven primarily by the commercial market and may not result in macros that are worst-case optimized for full military temperature range operation.

TTL Programmable Logic Devices (PLDs)

Pricing of TTL PLDs is expected to decline at an annual rate of 15 percent for smaller devices and at approximately 20 percent for larger devices into 1988. Pricing of the smaller devices will approach stability within two years, whereas larger TTL PLDs will continue to decline at approximately 20 percent per year through 1990. Table 30 shows estimated military PLD pricing for 1987 through 1991.

CMOS EEPLDs

CMOS EEPLD prices are experiencing rapid decline from new market entrants pushing to displace lower-performance TTL devices. Competition is increasing as the major IC houses respond to the new players. Price parity with a 30 percent performance penalty may be achieved across the board by late 1988.

Table 30

ESTIMATED MILITARY PLD PRICING

Product/Family	1987	1988	1989	1990	1991
TTL Fuse Link PLDs					
16, 18, 20 pins, under 15ns	$13.20	$11.30	$10.25	$ 9.45	$ 9.00
16, 18, 20 pins, under 30ns	$11.25	$ 8.90	$ 8.00	$ 7.65	$ 7.65
22, 24 pins, under 15ns	$55.00	$39.50	$31.25	$25.60	$19.80
22, 24 pins, under 30ns	$39.80	$31.30	$24.40	$19.20	$15.70
CMOS EE Reprogrammable PLDs under 50ns					
16, 18, 20 pins	$14.55	$ 9.50	$ 8.00	$ 7.50	$ 7.50
22, 24 pins	$37.50	$27.00	$18.50	$16.00	$14.50
28 or more pins	$44.00	$31.00	$24.00	$19.00	$16.50

Source: Dataquest
September 1987

Analog/Linear Circuits

The prices of regulators, comparators, op amps and other single-function linear chips are relatively stable after severe pressure in the 1985 to 1986 time frame. These mature products may experience slight price increases over the next three years as some suppliers reassess their product portfolios. This situation could change if the current merger activity among IC houses becomes a trend. Table 31 shows estimated military linear IC pricing for 1987 through 1991.

Table 31

ESTIMATED MILITARY LINEAR IC PRICING

Product/Family	1987	1988	1989	1990	1991
Linear/Analog					
7800 Regulator 883B	$2.70	$2.70	$2.75	$2.85	$2.95
7800 Regulator 38510	$3.25	$3.25	$3.30	$3.35	$3.35
139 Quad Comp. 883B/38510	$2.10	$2.10	$2.15	$2.30	$2.50
1741 Op Amp 883B/38510	$1.90	$1.90	$1.95	$2.05	$2.10
1488 Bus IC 883B/38510	$1.65	$1.65	$1.75	$1.90	$1.90

Source: Dataquest
September 1987

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Semiconductor Application Markets

Research Topics Scheduled for Q2 1990

Newsletter Topics

- Semiconductor trends in PC design
- Equipment breakdown
- OEM monthly: April, May, June
- Worldwide semiconductor industry quarterly forecast
- Q2 electronics industry update
- Application market review
- SAMonitor: April, May, June
- Semiconductor content trends

Binder Updates

- Trends in manufacturing automation
- Semiconductor consumption—military
- Semiconductor consumption—transportation
- Semiconductor consumption—data processing
- Semiconductor consumption—communications
- Semiconductor consumption—industrial
- Trends in consumer electronics

Tentative Research Topics for Q3 1990 through Q1 1991

Newsletter Topics

Q3 1990

- OEM monthly: July, August, September
- Worldwide semiconductor industry quarterly forecast
- Final 1989 worldwide market share
- Q3 electronic industry update
- SAMonitor: July, August, September
- Equipment breakdown
- Semiconductor content trends

Q4 1990

- OEM monthly: October, November, December
- Q4 electronics industry update
- Worldwide semiconductor industry quarterly forecast
- SAMonitor: October, November, December
- Semiconductor content trends
- Equipment breakdown

Q1 1991

- OEM monthly: January, February, March
- The Dun & Bradstreet Corporation's economic outlook
- Worldwide semiconductor industry quarterly forecast
- Preliminary 1991 worldwide market share
- Q1 electronics industry update
- SAMonitor: January, February, March
- User/application conference

Binder Updates

Q3 1990

- Trends in communications
- Electronic equipment overview
- Application market revenue

Q4 1990

- Trends in technical workstations
- Trends in disk drives

Q1 1991

- Trends in consumer
- Trends in transportation
- Application market overview
- Application market review
- Electronic equipment forecast

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Semiconductor Application Markets

Research Topics Scheduled for Q3 1990

Newsletter Topics

- *OEM Monthly:* July, August, September
- Worldwide semiconductor industry quarterly forecast
- Final 1989 worldwide market shares
- Q3 electronic industry update
- *SAMonitor:* July, August, September
- Equipment breakdown
- Semiconductor content trends

Binder Updates

- Trends in communications
- Electronic equipment overview
- Application market revenue

Tentative Research Topics for Q4 1990 through Q2 1991

Newsletter Topics

Q4 1990

- *OEM Monthly:* October, November, December
- Q4 electronics industry update
- Worldwide semiconductor industry quarterly forecast
- *SAMonitor:* October, November, December
- Semiconductor content trends
- Equipment breakdown

Q1 1991

- *OEM Monthly:* January, February, March
- The Dun & Bradstreet Corporation's economic outlook
- Worldwide semiconductor industry quarterly forecast
- Preliminary 1991 worldwide market shares
- Q1 electronics industry update
- *SAMonitor:* January, February, March
- User/application conference

Q2 1991

- *OEM Monthly:* April, May, June
- Worldwide semiconductor industry quarterly forecast
- Q2 electronics industry update
- *SAMonitor:* April, May, June

Binder Updates

Q4 1990

- Trends in technical workstations
- Trends in disk drives

Q1 1991

- Trends in military electronics
- Trends in auto electronics
- Application market overview—North America
- Overview—electronic equipment forecast
- Electronic equipment forecast
- Trends in PCs
- Consumption by application market
- Semiconductor shipments

Q2 1991

- Application overview—worldwide
- Semiconductor consumption—data processing
- Trends in electronic printers
- Semiconductor consumption—communications
- Semiconductor consumption—industrial
- Semiconductor consumption—consumer
- Trends in consumer electronics
- Semiconductor consumption—military
- Semiconductor consumption—transportation

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Research Topics Scheduled for Q3 1990

Newsletter Topics

- *OEM Monthly:* July, August, September
- Worldwide semiconductor industry quarterly forecast
- Final 1989 worldwide market shares
- Q3 electronic industry update
- *SAMonitor:* July, August, September
- Equipment breakdown
- Semiconductor content trends

Binder Updates

- Trends in communications
- Electronic equipment overview
- Application market revenue

Tentative Research Topics for Q4 1990 through Q2 1991

Newsletter Topics

Q4 1990

- *OEM Monthly:* October, November, December
- Q4 electronics industry update
- Worldwide semiconductor industry quarterly forecast
- *SAMonitor:* October, November, December
- Semiconductor content trends
- Equipment breakdown

Q1 1991

- *OEM Monthly:* January, February, March
- The Dun & Bradstreet Corporation's economic outlook
- Worldwide semiconductor industry quarterly forecast
- Preliminary 1991 worldwide market shares
- Q1 electronics industry update
- *SAMonitor:* January, February, March
- User/application conference

Q2 1991

- *OEM Monthly:* April, May, June
- Worldwide semiconductor industry quarterly forecast
- Q2 electronics industry update
- *SAMonitor:* April, May, June

Binder Updates

Q4 1990

- Trends in technical workstations
- Trends in disk drives

Q1 1991

- Trends in military electronics
- Trends in auto electronics
- Application market overview—North America
- Overview—electronic equipment forecast
- Electronic equipment forecast
- Trends in PCs
- Consumption by application market
- Semiconductor shipments

Q2 1991

- Application overview—worldwide
- Semiconductor consumption—data processing
- Trends in electronic printers
- Semiconductor consumption—communications
- Semiconductor consumption—industrial
- Semiconductor consumption—consumer
- Trends in consumer electronics
- Semiconductor consumption—military
- Semiconductor consumption—transportation

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Semiconductor Application Markets

For strategic planners, market analysts, and marketing and product managers in semiconductor companies

Dataquest's Semiconductor Application Markets (SAM) service provides a comprehensive analysis of semiconductor consumption by end-use applications. SAM has been designed and organized to provide decision support to those involved in:

- Strategic planning
- Tactical marketing
- Product planning
- Sales planning
- Competitive analysis

SAM presents clients with an applications or demand view of the semiconductor industry. It provides information on equipment manufacturers and their semiconductor procurement and captive production, electronic equipment market forecasts, detailed analyses on key fast-growing equipment segments, and a thorough forecast and analysis of semiconductor consumption by application market.

SAM tracks more than 200 markets in the following major areas:

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

SAM clients receive information and analyses that are broken down as follows:

- The dynamics of specific electronic equipment markets, including:
  - Forecasts in dollars
  - Forecasts in units
  - Major manufacturers
  - Key trends
- Electronic equipment company profiles and semiconductor procurement data
- System analyses—the semiconductor content of particular types of electronic equipment

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Small Dept. ($25K–$75K)
Work Group (<$25K)
Single-User Enhanced (<$75K)

Data Storage Subsystems
Rigid Disk
Flexible Disk Drives
Tape Drives (¼", ½")
Optical

Terminals
Alphanumeric (CRT)
Graphics Terminals

Input/Output
Remote Batch, Job-Entry and Output
Key Entry Equipment
Media-to-Media Data Conversion
Magnetic Ink Recognition
Optical Scanning Equipment
Computer Plotters
Serial Printers
Line Printers
Page Printers

Dedicated Systems
Office Automation
— Copiers and Duplicators
— Electronic Calculators
— Dictating, Transcribing
— Electronic Typewriters
— Word Processors
Banking Systems
Point-of-Sale Terminals
Cash Registers
Mailing, Letter Handling, Addressing
Other Specialized Terminals
Smart Cards

Communications

Customer Premises
Terminal Equipment
— Single-Line Telephones
— Integrated Voice/Data Workstation
— Teleprinter
Facsimile
Data Communications Equipment
— Modems
— Statistical Multiplexers
— T-1 Multiplexers
— Front-End Processors
Local Area Networks
Data PBX
Data Network Control Systems
Business Communication Systems
— Key Telephone Systems
— PBX
— Centrex
Automatic Call Distributors
Attached Network Functions
— Protocol Converters
— Voice Messaging
Call Accounting
Videoteleconferencing

Public Telecommunications
Transmission Equipment
— Multiplex
— Carrier Systems
— Microwave Radio
— Satellite Communications
Switching Equipment
— Central Office
— Other Common Carrier
— Private Packet Data Network

Radio
Mobile Radio Systems
Mobile Base Stations
Mobile Vehicular
Cellular Radio/Telephone
— Base Station
— Radio Telephones
Broadcast Receivers, Transmitters
Amateur Radio
Citizen's Band: Mobile and Base
Portable Receivers, Transmitters
Checkout, Monitor, Evaluation
Communications Antenna <890 MHz
Microwave Antenna >890 MHz

Broadcast and Studio
Audio Equipment
Video Equipment
Transmitters, RF Power Amplifier
Studio Transmitter Links
Cable TV Broadcast Equipment CCTV
Broadcast Transmitter Antenna
Other (Studio, Theater)

Misc. Equipment
Intercommunication Equipment
Light Communications Systems
— Fiber Optic
— Other
Telemetering Systems

Industrial

Security/Energy Management
Alarm Systems
Discrete Devices
MPU Load Programmers
Computerized Energy Control System

Manufacturing Systems
Semiconductor Production
Test Equipment
Process Control Systems
Programmable Machine Tools
Mechanical Assembly Equipment
Plastic Processing Machinery
Robot Systems
— Assembly
— Material Handling/Loading
— Painting
— Spot Welding
— Arc Welding
— Machining—Other
Automated Material Handling
— Guided Vehicles
— Programmable Conveyors
— Storage/Retrieval Systems
— Programmable Monorails
— Warehousing

Instrumentation
Integrating and Totalizing Meters for Gas and Liquids
Counting Devices
Panel Meters
Elapsed-Time Meters
Portable Measuring Instruments
Recording Instruments
Physical Property Test, Inspection and Measurement
Commercial Meteorological and General-Purpose Instruments
Nuclear Radiation Detection and Monitoring Instruments
Surveying and Drafting Instruments
Ultrasonic Cleaners, Drills
Meteorological
Geophysical
Analytical and Scientific Instruments

Medical Equipment
Diagnostic
Patient-Monitoring
Prosthetic
Surgical Support
Therapeutic
Medical Lasers

Misc. Equipment
Vending Machines
Laser Systems (Excluding Communications and Medical)
Power Supplies
Traffic Control
Particle Accelerator Electronics
Trainers and Simulators
Teaching Machines and Aids
Laboratory and Scientific Apparatus
Industrial and Scientific X-Ray
Scientific Not Elsewhere Classified

Consumer

Audio
Audio Amplifiers
Compact Disc Players
Radio
Stereo Sets
Stereo Headphones
Musical Instruments
Tape Recorders

Video
Videocameras
VTRs (VCRs)
Videodisc Players
Color TVs
B&W TVs
LCD TVs
Cable TV Decoding Boxes

Personal Electronics
Games
Cameras
Watches
Clocks

Appliances
Air Conditioners
Microwave Ovens
Washers and Dryers
Refrigerators
Dishwashers, Disposals
Ranges and Ovens
Rice Cookers

Other
Antennas (TV, CB, Radio)
Automatic Garage Door Openers
Consumer Electronic Equipment Not Elsewhere Classified

Military

Defense
— Space
— Avionics
— Shipboard
— Missiles/Weapons
— Detection/Tracking
— Electronic Warfare
— Communication
— Simulation/Training
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San Jose, California 95131-2398
(408) 437-8000
Telex: 171973
Fax: (408) 437-0292

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Dataquest's Semiconductor Application Markets services are comprehensive market research services providing thorough forecasts and analyses of semiconductor consumption by end-use application markets. These services provide information on equipment manufacturers, electronic equipment markets, and detailed analyses on key fast-growing equipment segments. Through these services, Dataquest's analysts become an extension of your sales, product, strategic planning, and marketing teams by delivering concise information and analysis on the issues that affect your strategic and tactical business plans.

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Semiconductors *Asia*

This service provides a demand-side view of the semiconductor industry by looking at the electronic equipment markets in Asia. This service also focuses on the products, markets, companies, trends, and technologies of the Asian semiconductor industry. Coverage is provided for the five tigers: Hong Kong, Singapore, Taiwan, Korea, and China.

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This service provides clients with an applications view of Japanese electronic equipment production. Quantitative data are supplemented by qualitative analyses of the underlying trends and issues affecting both the Japanese semiconductor market and the Japanese semiconductor industry.

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- *Source: Dataquest*
- On-Line Access
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Dataquest Perspective

Dataquest Perspective is a multitopic publication that contains timely Dataquest analysis of our databases and market forecasts, discussions of the major players and their market shares, technology and product assessments, and our views of industry trends and issues.

These publications are filed chronologically in a binder and include a quarterly index that is cross-referenced by company name and major topic. Articles contained in the *Dataquest Perspective* fall under the following headings:

- Market Analysis
- Product Analysis
- Company Analysis
- Technology Analysis
- End-User Analysis
- Conferences and Exhibitions
- News and Views

Source: Dataquest

This is an annually updated collection of publications that are the base documents and reference materials for the Semiconductor Application Markets services. The publications are:

Market Statistics Several publications are provided on key industry market statistics; worldwide and regional semiconductor five-year history and five-year forecast of revenue; electronic equipment forecasts; and semiconductor consumption by application market forecasts. Additional market statistics are provided for each of the detailed market segments.

Company Backgrounders by Dataquest A set of company backgrounders on the top companies in the industry. Each backgrounder includes financial, product-line, and other useful information on companies including sales and manufacturing locations, joint ventures, and mergers and acquisitions.

How to Use Dataquest Provides detailed information about subscriptions, inquiry privileges, phone contacts, library use, and other industry services offered by Dataquest.

Dataquest Research and Methodology Details the research methodology and assumptions used to gather data and information.

Dataquest High-Technology Guide—Segmentation and Glossary Describes in detail the segmentation and terms used by all Dataquest industry services to define the markets Dataquest tracks. It includes definitions for products, applications, regions, technologies, and environments. It also includes standard definitions of terms such as retirements, average selling price, and compound annual growth rate.

On-Line Access

With the touch of a button, clients throughout the world receive direct on-line access to the most recent semiconductor service publications, forecasts, and analyses at any time of the day or night. Designed to complement and enhance your subscription, *Dataquest On-Line* brings you the facts you need when you need them.

In addition, *Dataquest On-Line* features an electronic inquiry service. Questions, clarifications, and correspondence can be handled with the accuracy and convenience of E-mail.

The DQ Monday Report

The DQ Monday Report offers weekly online, comprehensive, worldwide market intelligence and biweekly pricing data for the semiconductor industry. The report is accessible 24 hours a day via your computer terminal. *The DQ Monday Report* gives subscribers up-to-the-minute snapshots of the latest product, corporate, and governmental activities affecting the semiconductor industry worldwide.

The DQ Monday Report provides complete pricing and lead time information for 25 products for three volume levels and six regions worldwide. Source information comes directly from Dataquest industry analysts located in San Jose, Tokyo, Denham, Taipei, Hong Kong, and Seoul.

Information Resource Centers

Located in Framingham, Denham (England), San Jose, and Tokyo, Dataquest's Information Resource Centers are a valuable component of the information delivered through the Semiconductor Application Markets services. The centers maintain a wide selection of industry directories and trade press periodicals, financial reports from most of the publicly held companies followed by Dataquest industry services, government reports, and on-line and other information services.

Key Service Applications and Uses

As multifaceted industry intelligence services, the Semiconductor Application Markets services define, examine, and interpret the many variables critical to your success in the world's markets. As such, they are particularly useful in helping clients in the following areas:

Business Planning A complete picture of the electronic equipment markets with five-year market forecasts of semiconductor consumption by end-use market provides you with the essential information to support your tactical and strategic planning needs.

Business Development Assessment of semiconductor product opportunities and threats helps you identify where to invest current and future resources.

Market Analysis Logically segmented five-year histories and forecasts provide information on market size while indicating saturation points and industry evolution. Additionally, information on and analysis of user preferences, buying capabilities, and overall absorption potential, as well as demand-side analysis of the market's characteristics and potential provide a thorough assessment of the market.

Company Analysis Analysis of the relative strengths and weaknesses of key equipment manufacturers and their products paints a scenario of overall competitive strategies.

System Content Analysis Analysis of the semiconductor content of particular types of electronic equipment provides insight into changing semiconductor consumption trends.

Technology Assessment Analysis and forecasts of technology trends and developments help you to understand the evolution of enabling and competitive technologies and better plan for their implementation and adoption.

Product Coverage

The Semiconductor Application Markets services provide clients with a unique cross-industry perspective by drawing information from Dataquest's other industry research groups. This information is carefully analyzed and combined with research conducted by Dataquest's semiconductor analysts. The following represents some of the areas that are covered by the Semiconductor Application Markets services.

Data Processing Market

Computers
- Personal Computers
- Personal Workstations

Data Storage Subsystems
- Rigid/Flexible Drives
- Optical Drives

Terminals

Input/Output Devices
- Printers
- Scanners

Dedicated Systems

Communications Market

Customer Premises
- Facsimile
- Local Area Networks
- Video Teleconferencing

Public Telecommunications

Radio
- Cellular Telephones

Broadcast and Studio

Industrial Market

Security/Energy Management
Manufacturing Systems
Medical Equipment
Instrumentation

Consumer Market

Audio
Video
Personal Electronics
Appliances

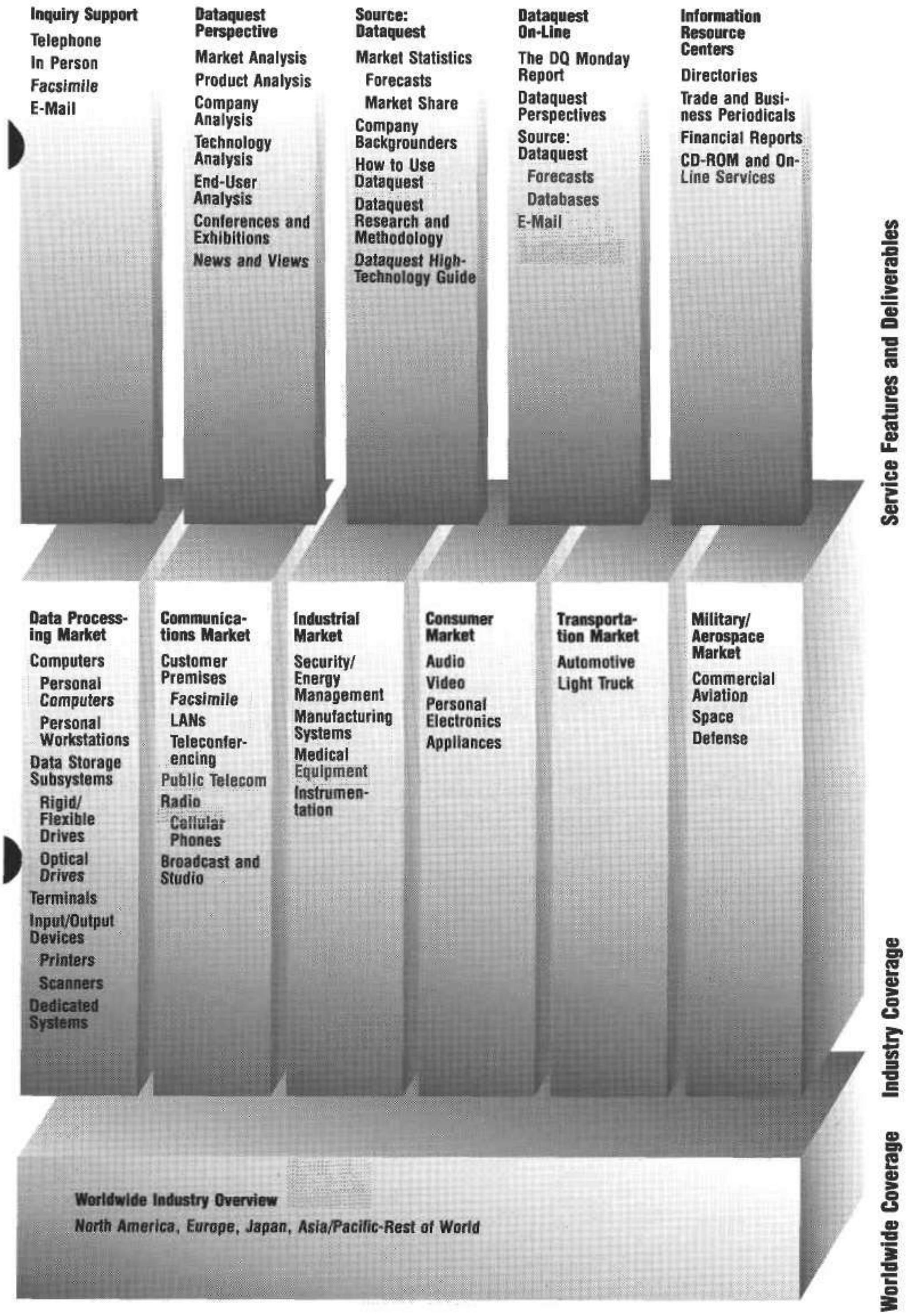
Transportation Market

Automotive
Light Truck

Military/Aerospace Market

Commercial Aviation
Space
Defense

About Dataquest



The Semiconductor Application Markets services deliver information and analysis in a format designed to help you make well-informed strategic, product, and marketing decisions.

Dataquest has tracked the semiconductor industry since 1974. The Semiconductor Group develops, maintains, and updates databases that cover the total spectrum of semiconductor products and markets. In addition to their knowledge of revenue, shipments, market share, competitive influences, product specifications, and other hard facts, Dataquest's analysts provide insight into the relevance of these factors to the market and your business.

Dataquest covers more than 25 high-technology industry markets in five broad areas: Semiconductors; Systems; Peripherals; Telecommunications; and Service/Support and Professional Services. Data and trends from these industries are available for analysis by the Semiconductor Group. Dataquest maintains major research operations worldwide in cities that include San Jose, Framingham, Denham (England), Paris, and Tokyo.

Additional Products and Services of Interest

Custom Research and Consulting As an important adjunct to its industry service program, Dataquest also performs custom research and consulting when a client's needs extend beyond the scope of the service. Dataquest's custom research and consulting program offers you a truly individualized and proprietary approach to meeting your information requirements. Each project is treated with the strictest confidence and conducted under the highest standards of business ethics to ensure client confidentiality.

Primary Research A survey service that employs skilled statisticians and survey analysts who work with you to meet your specific primary research objectives. Dataquest provides methodology alternatives, questionnaire development, data collection, data tabulation and analysis, and the presentation of results. This service also has extensive experience in conducting Focus Groups.

Semiconductors A family of Dataquest industry services providing research and analyses on the markets, products, companies, technologies, and legal and geopolitical trends of the semiconductor industry. These services provide a broad look at all relevant aspects of the Asian, European, North American, and Japanese regional semiconductor industries. Detailed product segments covering analog and mixed-signal ICs, ASICs, gallium arsenide, memories, and microcomponents are also available.

Semiconductor Equipment, Manufacturing, and Materials A Dataquest industry service providing global strategic insight and analysis emphasizing an integrated perspective of the interdependence of wafer fabrication equipment technology, semiconductor materials applications, and IC process technology as they relate to the broader issues of semiconductor manufacturing.

Semiconductor Procurement A Dataquest industry service providing component engineers, procurement managers, and buyers with information and analysis in a format that is designed to help the semiconductor user make well-informed tactical and strategic pricing and product procurement decisions.

Semiconductor Application Markets

Dataquest

a company of
The Dun & Bradstreet Corporation

1290 Ridder Park Drive
San Jose, California 95131-2398
(408) 437-8000
Telex: 171973
Fax: (408) 437-0292

Sales/Service Offices:

UNITED KINGDOM
Dataquest UK Limited
Roussel House,
Broadwater Park
Denham, Uxbridge, Middx UB9 5HP
England
0895-835050
Telex: 266195
Fax: 0895 835260-1-2

FRANCE
Dataquest SARL
Tour Gallieni 2
36, avenue Gallieni
93175 Bagnolet Cedex
France
(1)48 97 31 00
Telex: 233 263
Fax: (1)48 97 34 00

EASTERN U.S.
Dataquest Boston
1740 Massachusetts Ave.
Boxborough, MA 01719-2209
(508) 264-4373
Telex: 171973
Fax: (508) 635-0183

GERMANY
Dataquest GmbH
Rosenkavalierplatz 17
D-8000 Munich 81
West Germany
(089)91 10 64
Telex: 5218070
Fax: (089)91 21 89

JAPAN
Dataquest Japan, Ltd.
Taiyo Ginza Building/2nd Floor
7-14-16 Ginza, Chuo-ku
Tokyo 104 Japan
(03)546-3191
Telex: 32768
Fax: (03)546-3198

KOREA
Dataquest Korea
Daeheung Bldg. 505
648-23 Yeoksam-dong
Kangnam-gu, Seoul 135 Korea
011-82-2-552-2332
Fax: 011-82-2-552-2661

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**SEMICONDUCTOR APPLICATION MARKETS
REFERENCE BINDER**

TABLE OF CONTENTS

Table of Contents

Introduction

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

NOTE: The arrow symbol indicates the latest document(s) correct location behind this subject tab.

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

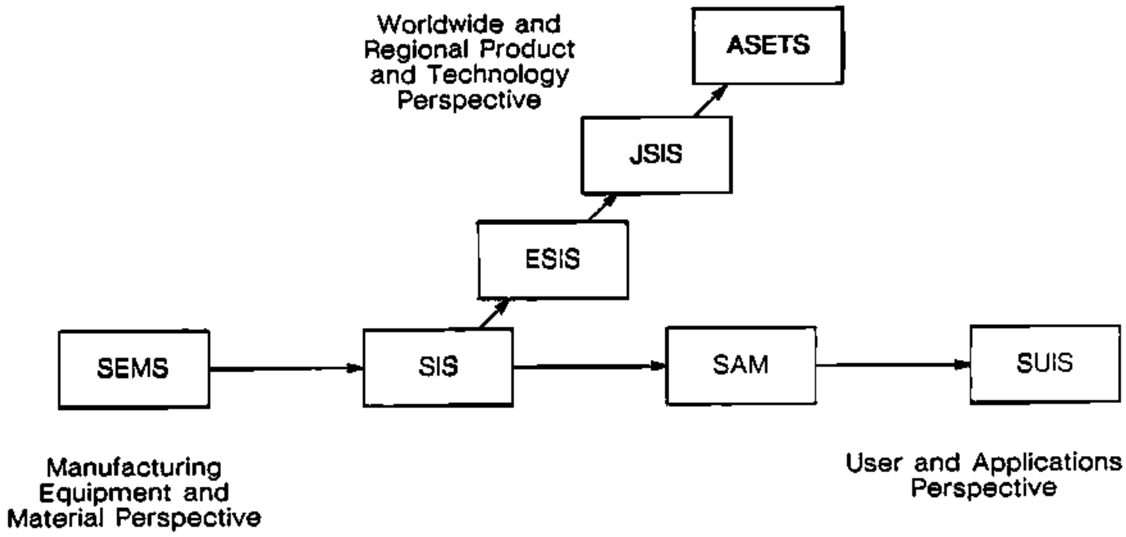
SAM's position is unique in that it provides a third dimension with which to view the regional and product data that come from adjoining analysts and services. The six component division services listed below work in alignment with SAM:

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

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

Figure 1

Dataquest Component Services Perspectives



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Source: Dataquest June 1989

ELEMENTS OF THE SERVICE

The service has the following 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.

Clients often are 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

Introduction to the Service

- Laser printer forecast
- Historical I/O ratios
- Graphics terminals market size
- ASIC alliances in automotive industry
- Procurement survey results
- LAN forecast
- Home computer market
- Electronic equipment forecast
- Ten biggest buyers of PC chip sets
- Top PC chip set 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

Introduction to the Service

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 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.

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:

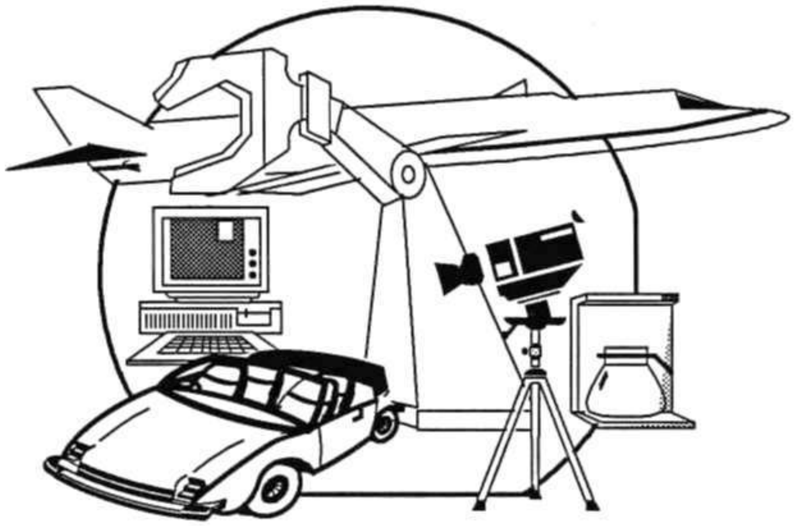
- Semiconductor users from all industries that both make and buy devices
- Dataquest's other technology services, providing an ongoing view of their quickly changing industries from both regional and equipment market product viewpoints

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

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Source: Dataquest
June 1989

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Methodology

INTRODUCTION

The remainder of information behind the Introduction 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 the following 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 with the primary purpose of processing information. 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 with the primary function of 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," because 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 currently is 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 "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 the current year, 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. The information set begins with 1983 and forecasts estimated equipment shipments. 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 "Consumption by Application Market" 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.

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 resulting from 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-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
June 1989

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.

Input/Output Ratios

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 because of 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 because of 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
June 1989

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 come 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 distinguish 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 <u>not</u> 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

- Segment 1
  - 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

- Segment 2
  - 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

- <u>Segment 3</u>
  - 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

- <u>Segment 4</u>
  - 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

- <u>Segment 5</u>
  - 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 and Compact ETs)—Segment 1 electronic typewriters typically are considered portable typewriters and compact typewriters. Calculation functions, as in a pocket calculator, are usually available for portable typewriters. Portable typewriters currently utilize thermal or daisywheel technology print mechanisms. Compact electronic typewriters are typically physically between the size of a portable and a full-size unit. Print mechanisms typically are daisywheel technology.

- Segment 2 (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 3 (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 4 (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 5 (Display and Modular Displays)—Display typewriters 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. Modular displays 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.

TELECOMMUNICATIONS

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

Definitions

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 radio/telephone 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.

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 transmission speed, expressed in bits per second (bps), and by data terminal modems or personal computer modems.

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.

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

- 300/1,200-bps data terminal and personal computer modems
- 2,400-bps data terminal and personal computer modems
- 4,800-bps data terminal and personal computer modems
- 9,600-bps data terminal and personal computer modems
- High-speed modems include modems that fall into the following transmission speeds:
  - 14.4 Kbps
  - 16.8 Kbps
  - 19.2 Kbps

Definitions

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.

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.

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.

Business Communications Systems

Business communications systems include 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.

Definitions

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

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 include the following segments: protocol converters and data service units (DSUs) and channel service units (CSUs).

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).

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

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.

Definitions

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 and other common carrier switching equipment/tandem switches.

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

Definitions

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 Networks

Private packet data networks include the following segments: private packet data network nodes, private packet data network packet assemblers/disassemblers (PADs), and switch concentrators.

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 radio/telephone market.

Cellular Radio/Telephone

Cellular radio/telephone 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 radio/telephone equipment is the equipment used in cellular radio/telephone systems. This segment includes radio/telephones and base station equipment.

Radio/Telephones

Radio/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.

Definitions

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.

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

Definitions

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.

AUTOMATED MATERIAL HANDLING

Automated 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.

CIVIL AEROSPACE

Radar

Radar equipment includes airborne and ground-based systems.

Space

Space systems include satellites and ground control equipment for civil (i.e., commercial) purposes only.

Definitions

Navigation/Communication

Navigation/communication includes flight and navigation sensors, transmitters and displays, gyroscopes, airframe control equipment, and voice and data equipment.

Aircraft Flight Systems

Aircraft flight systems (AFSs) include sensors, transmitters, and displays specific to flight and engine functions.

Simulation and Training

Simulation and training equipment includes flight and situation simulators, equipment operations, and maintenance 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.

Definitions

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.

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.

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.

Data Processing

Input/Output

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

Definitions

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 include 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.

Definitions

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.

Executive Summary

The following is a list of material in this section:

- ➡ Application Market Overview North America
- Application Market Overview Japan
- Application Market Overview Europe

NOTE: The arrow symbol indicates the latest document(s) correct location behind this subject tab.

Application Market Overview—North America

DERIVING SEMICONDUCTOR CONSUMPTION BY APPLICATION MARKET

As mentioned throughout this notebook, semiconductor consumption by application market is estimated by applying input/output (I/O) ratios to the equipment forecast. A summary of this portion of the model is presented in Tables 1 through 8.

The SAM service estimates total North American semiconductor consumption using I/O ratios that account for both the merchant and captive content of the equipment market. In a two-step procedure, SAM analysts calculate these ratios by including both the captive and merchant consumption of a given application market, system group, and/or key electronic system. The captive portion for each application market is subsequently removed. This two-step procedure enables SAM to do *demand-side*, merchant-market semiconductor consumption analysis by application market at the same level of the semiconductor product analysis used by other Dataquest semiconductor services.

Captive production typically can be tracked at only a total semiconductor level; specific product detail is unavailable. Thus, to break out semiconductor product markets further by each application market, SAM "adjusts" for the captive portion of consumption (at the total semiconductor level) and then analyzes consumption at the merchant market detail tracked by our product analysts.

SAM tracks the captive market separately; this information is available to our clients on an inquiry basis. Each year, Dataquest's Components Group conducts a very detailed semiconductor consumption analysis of key and influential electronic systems. These analyses have helped SAM derive detailed I/O ratios that have been used in our database analysis and that now directly "close" to the Components Group's semiannual long-range semiconductor industry forecast. These merchant data are reflected in the product breakouts on consumption by application market. The breakouts are presented in the remaining sections of this notebook.

Index of Tables

Table 1

North American Electronic Equipment Production History
Segment Overview
(Millions of Dollars)

Equipment Type	1983	1984	1985	1986	1987	1988
Data Processing						
Computers	37,365	49,449	55,563	56,479	62,788	68,769
Data Storage/Subsystems (Total)	5,711	7,388	9,598	11,792	11,882	16,120
Data Storage/Subsystems (Net)	5,711	7,338	9,598	11,792	11,082	13,200
Terminals	3,247	3,662	6,781	3,607	3,448	3,110
Input/Output	7,112	7,649	7,348	7,543	9,216	10,541
Dedicated Systems	4,836	5,546	5,829	5,404	5,315	5,375
Total	58,271	73,644	85,119	84,825	91,849	100,995
Communications						
Premise Telecom Equipment	6,513	7,681	8,623	9,124	9,940	11,046
Public Telecommunications	4,511	5,117	5,886	6,144	6,336	6,887
Mobile Communications Equipment	3,118	4,073	4,399	4,712	5,392	5,985
Broadcast and Studio	1,415	1,436	1,467	1,492	1,780	1,965
Other Telecom	892	1,174	1,544	1,442	1,541	1,600
Total	16,449	19,481	21,919	22,914	24,989	27,483
Industrial						
Security/Energy Management	1,997	1,960	1,967	2,069	2,211	2,393
Manufacturing Systems	10,027	12,712	13,182	12,781	13,380	15,200
Instrumentation	5,607	6,461	6,571	6,570	7,180	7,774
Medical Equipment	4,740	4,880	4,759	5,002	5,345	5,785
Civil Aerospace	1,764	5,763	6,454	6,906	6,930	7,116
Other Industrial	3,456	3,889	4,102	4,364	4,777	5,356
Total	27,591	35,665	37,035	37,692	39,823	43,624
Consumer						
Audio	270	246	252	269	269	279
Video	4,969	5,308	5,284	5,232	5,522	5,628
Personal Electronics	1,048	473	331	235	249	241
Appliances	8,942	10,172	10,889	11,673	12,672	12,830
Other Consumer	509	647	810	897	945	992
Total	15,738	16,846	17,566	18,306	19,657	19,970
Military	NA	NA	47,300	49,370	50,932	51,063
Transportation	5,547	7,441	8,480	9,580	10,199	10,744
Total	123,596	153,077	217,419	222,687	237,449	253,879

NA = Not available
Source: Dataquest (July 1990)

Table 2

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

Equipment Type	1989	1990	1991	1992	1993	1994	CAGR 1989-1990	CAGR 1989-1994
Data Processing								
Computers	74,757	80,892	88,073	96,980	105,998	115,910	8.2%	9.2%
Data Storage/Subsystems (Total)	17,998	19,736	20,254	21,262	23,077	24,144	9.7%	6.1%
Data Storage/Subsystems (Net)	14,940	16,410	16,545	16,913	17,979	18,273	9.8%	4.1%
Terminals	2,584	2,081	1,712	1,446	1,238	1,173	(19.5%)	(14.6%)
Input/Output	11,336	12,281	13,287	14,339	15,560	17,034	8.3%	8.5%
Dedicated Systems	5,324	5,333	5,481	5,194	5,137	5,159	0.2%	(0.6%)
Total	108,941	116,997	125,098	134,872	145,912	157,549	7.4%	7.7%
Communications								
Premise Telecom Equipment	12,517	13,866	15,102	16,116	17,137	19,530	10.8%	9.3%
Public Telecommunications	7,175	7,590	8,019	8,870	9,666	10,328	5.8%	7.6%
Mobile Communications Equipment	6,418	6,748	7,083	7,400	7,746	8,092	5.1%	4.7%
Broadcast and Studio	2,145	2,315	2,465	2,615	2,765	2,915	7.9%	6.3%
Other Telecom	1,660	1,720	1,790	1,860	1,930	2,000	3.6%	3.8%
Total	29,915	32,239	34,459	36,861	39,244	42,865	7.8%	7.5%
Industrial								
Security/Energy Management	2,506	2,639	2,822	3,020	3,203	3,397	5.3%	6.3%
Manufacturing Systems	16,286	16,965	18,538	20,106	21,484	22,976	4.2%	7.1%
Instrumentation	8,122	8,436	9,142	9,683	10,136	10,614	3.9%	5.5%
Medical Equipment	6,117	6,485	6,896	7,171	7,530	7,916	6.0%	5.3%
Civil Aerospace	8,149	9,411	10,807	12,228	13,694	15,347	15.5%	13.5%
Other Industrial	5,719	6,053	6,537	6,991	7,467	7,980	5.8%	6.9%
Total	46,899	49,989	54,742	59,199	63,514	68,230	6.6%	7.8%
Consumer								
Audio	285	292	299	306	311	318	2.5%	2.2%
Video	5,749	5,864	6,014	6,206	6,432	6,708	2.0%	3.1%
Personal Electronics	239	240	241	239	239	239	0.4%	0
Appliances	13,147	13,512	13,918	14,317	14,650	14,950	2.8%	2.6%
Other Consumer	1,037	1,078	1,126	1,171	1,157	1,157	4.0%	2.2%
Total	20,457	20,986	21,598	22,239	22,789	23,372	2.6%	2.7%
Military	51,727	52,918	54,263	55,845	57,866	59,998	2.3%	3.0%
Transportation	11,292	11,828	12,897	13,952	14,836	15,449	4.7%	6.5%
Total	269,231	284,957	303,057	322,968	344,161	367,463	5.8%	6.4%

Source: Dataquest (July 1990)

Table 3

North American Electronic Equipment Production Segment Overview (Percentage of Total)

Equipment Type	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Data Processing												
Computers	30.2	32.3	25.6	25.4	26.4	27.1	27.8	28.4	29.1	30.0	30.8	31.5
Data Storage/Subsystems (Total)	4.6	4.8	4.4	5.3	5.0	6.3	6.7	6.9	6.7	6.6	6.7	6.6
Data Storage/Subsystems (Net)	4.6	4.8	4.4	5.3	4.7	5.2	5.5	5.8	5.5	5.2	5.2	5.0
Terminals	2.6	2.4	3.1	1.6	1.5	1.2	1.0	0.7	0.6	0.4	0.4	0.3
Input/Output	5.8	5.0	3.4	3.4	3.9	4.2	4.2	4.3	4.4	4.4	4.5	4.6
Dedicated Systems	3.9	3.6	2.7	2.4	2.2	2.1	2.0	1.9	1.8	1.6	1.5	1.4
Total	47.1	48.1	39.1	38.1	38.7	39.8	40.5	41.1	41.3	41.8	42.4	42.9
Communications												
Premise Telecom Equipment	5.3	5.0	4.0	4.1	4.2	4.4	4.6	4.9	5.0	5.0	5.0	5.3
Public Telecommunications	3.6	3.3	2.7	2.8	2.7	2.7	2.7	2.7	2.6	2.7	2.8	2.8
Mobile Communications Equipment	2.5	2.7	2.0	2.1	2.3	2.4	2.4	2.4	2.3	2.3	2.3	2.2
Broadcast and Studio	1.1	0.9	0.7	0.7	0.7	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Other Telecom	0.7	0.8	0.7	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.5
Total	13.3	12.7	10.1	10.3	10.5	10.8	11.1	11.3	11.4	11.4	11.4	11.7
Industrial												
Security/Energy Management	1.6	1.3	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Manufacturing Systems	8.1	8.3	6.1	5.7	5.6	6.0	6.0	6.0	6.1	6.2	6.2	6.3
Instrumentation	4.5	4.2	3.0	3.0	3.0	3.1	3.0	3.0	3.0	3.0	2.9	2.9
Medical Equipment	3.8	3.2	2.2	2.2	2.3	2.3	2.3	2.3	2.3	2.2	2.2	2.2
Civil Aerospace	1.4	3.8	3.0	3.1	2.9	2.8	3.0	3.3	3.6	3.8	4.0	4.2
Other Industrial	2.8	2.5	1.9	2.0	2.0	2.1	2.1	2.1	2.2	2.2	2.2	2.2
Total	22.3	23.3	17.0	16.9	16.8	17.2	17.4	17.5	18.1	18.3	18.5	18.6
Consumer												
Audio	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Video	4.0	3.5	2.4	2.3	2.3	2.2	2.1	2.1	2.0	1.9	1.9	1.8
Personal Electronics	0.8	0.3	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Appliances	7.2	6.6	5.0	5.2	5.3	5.1	4.9	4.7	4.6	4.4	4.3	4.1
Other Consumer	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.3	0.3
Total	12.7	11.0	8.1	8.2	8.3	7.9	7.6	7.4	7.1	6.9	6.6	6.4
Military	NA	NA	21.8	22.2	21.4	20.1	19.2	18.6	17.9	17.3	16.8	16.3
Transportation	4.5	4.9	3.9	4.3	4.3	4.2	4.2	4.2	4.3	4.3	4.3	4.2
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

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

Table 4

North American Electronic Equipment Production Segment Overview (Annual Growth, Percentage Change)

Equipment Type	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Data Processing											
Computers	32.3	12.4	1.6	11.2	9.5	8.7	8.2	8.9	10.1	9.3	9.4
Data Storage/Subsystems (Total)	29.4	29.9	22.9	0.8	35.7	11.7	9.7	2.6	5.0	8.5	4.6
Data Storage/Subsystems (Net)	28.5	30.8	22.9	(6.0)	19.1	13.2	9.8	0.8	2.2	6.3	1.6
Terminals	12.8	85.2	(46.8)	(4.4)	(9.8)	(16.9)	(19.5)	(17.7)	(15.5)	(14.4)	(5.3)
Input/Output	7.6	(3.9)	2.7	22.2	14.4	7.5	8.3	8.2	7.9	8.5	9.5
Dedicated Systems	14.7	5.1	(7.3)	(1.6)	1.1	(0.9)	0.2	2.8	(5.2)	(1.1)	0.4
Total	26.4	15.6	(0.3)	8.3	10.0	7.9	7.4	6.9	7.8	8.2	8.0
Communications											
Premise Telecom Equipment	17.9	12.3	5.8	8.9	11.1	13.3	10.8	8.9	6.7	6.3	14.0
Public Telecommunications	13.4	15.0	4.4	3.1	8.7	4.2	5.8	5.7	10.6	9.0	6.8
Mobile Communications Equipment	30.6	8.0	7.1	14.4	11.0	7.2	5.1	5.0	4.5	4.7	4.5
Broadcast and Studio	1.5	2.2	1.7	19.3	10.4	9.2	7.9	6.5	6.1	5.7	5.4
Other Telecom	31.6	31.5	(6.6)	6.9	3.8	3.8	3.6	4.1	3.9	3.8	3.6
Total	18.4	12.5	4.5	9.1	10.0	8.8	7.8	6.9	7.0	6.5	9.2
Industrial											
Security/Energy Management	(1.9)	0.4	5.2	6.9	8.2	4.7	5.3	6.9	7.0	6.1	6.1
Manufacturing Systems	26.8	3.7	(3.0)	4.7	13.6	7.1	4.2	9.3	8.5	6.9	6.9
Instrumentation	15.2	1.7	0	9.3	8.3	4.5	3.9	8.4	5.9	4.7	4.7
Medical Equipment	3.0	(2.5)	5.1	6.9	8.2	5.7	6.0	6.3	4.0	5.0	5.1
Civil Aerospace	226.7	12.0	7.0	0.3	2.7	14.5	15.5	14.8	13.1	12.0	12.1
Other Industrial	12.5	5.5	6.4	9.5	12.1	6.8	5.8	8.0	6.9	6.8	6.9
Total	29.3	3.8	1.8	5.7	9.5	7.5	6.6	9.5	8.1	7.3	7.4
Consumer											
Audio	(8.9)	2.4	6.7	0.0	3.7	2.2	2.5	2.4	2.3	1.6	2.3
Video	6.8	(0.5)	(1.0)	5.5	1.9	2.1	2.0	2.6	3.2	3.6	4.3
Personal Electronics	(54.9)	(30.0)	(29.0)	6.0	(3.2)	(0.8)	0.4	0.4	(0.8)	0	0
Appliances	13.8	7.0	7.2	8.6	1.2	2.5	2.8	3.0	2.9	2.3	2.0
Other Consumer	27.1	25.2	10.7	5.4	5.0	4.5	4.0	4.5	4.0	(1.2)	0
Total	7.0	4.3	4.2	7.4	1.6	2.4	2.6	2.9	3.0	2.5	2.6
Military	NA	NA	4.4	3.2	0.3	1.3	2.3	2.5	2.9	3.6	3.7
Transportation	34.1	14.0	13.0	6.5	5.3	5.1	4.7	9.0	8.2	6.3	4.1
Total	23.9	42.0	2.4	6.6	6.9	6.0	5.8	6.4	6.6	6.6	6.8

NA = Not available
Source: Dataquest (July 1990)

Table 5

North American Input/Output Ratios Segment Overview (Percentage)

Equipment Type	1988	1989	1990	1991	1992	1993	1994
Data Processing							
Computers	8.0	8.7	7.7	8.5	9.7	11.9	11.9
Data Storage/Subsystems (Total)	7.0	8.0	7.3	9.0	11.2	14.4	16.2
Data Storage/Subsystems (Net)	NM	NM	NM	NM	NM	NM	NM
Terminals	6.0	6.3	5.6	6.1	6.6	7.4	6.4
Input/Output	5.5	6.2	5.6	6.4	7.7	9.9	10.4
Dedicated Systems	4.9	5.3	4.4	4.5	5.3	6.3	6.0
Total	7.6	8.4	7.4	8.4	9.8	12.3	12.6
Communications							
Premise Telecom Equipment	11.3	11.0	9.4	10.0	11.0	12.8	12.0
Public Telecommunications	6.3	6.7	5.9	6.3	6.6	7.2	7.0
Mobile Communications Equipment	5.9	5.9	5.2	5.5	6.1	6.9	6.9
Broadcast and Studio	5.5	5.5	4.7	4.9	5.3	6.0	5.9
Other Telecom	6.9	7.4	6.8	7.5	8.5	10.0	10.3
Total	8.2	8.3	7.2	7.7	8.4	9.6	9.4
Industrial							
Security/Energy Management	5.6	5.9	5.9	6.7	7.7	9.3	10.0
Manufacturing Systems	5.5	5.4	5.3	5.6	6.3	7.5	7.9
Instrumentation	4.2	4.4	4.3	4.6	5.3	6.2	6.5
Medical Equipment	5.3	5.6	5.4	6.0	7.0	8.3	8.8
Civil Aerospace	3.4	3.1	2.7	2.7	2.8	3.0	3.0
Other Industrial	5.0	5.3	5.3	5.9	6.7	7.6	8.1
Total	4.8	4.9	4.7	5.0	5.6	6.5	6.8
Consumer							
Audio	5.4	5.3	5.1	5.4	5.9	6.4	6.6
Video	6.1	6.2	5.8	6.2	6.7	7.3	7.4
Personal Electronics	5.0	5.0	4.6	5.0	5.0	5.9	5.9
Appliances	5.6	5.7	5.2	5.6	6.0	6.7	6.8
Other Consumer	7.4	7.4	6.7	7.0	7.5	8.7	9.1
Total	5.8	5.9	5.4	5.8	6.2	7.0	7.1
Military	3.3	3.2	3.2	3.3	3.3	3.4	3.4
Transportation	8.8	8.5	8.2	8.1	8.0	8.0	8.0
Total	6.2	6.6	6.0	6.6	7.4	8.9	9.1

NM = Not meaningful
Source: Dataquest (July 1990)

Table 6

North American Merchant Semiconductor Shipments Segment Overview (Millions of Dollars)

Equipment Type	1988	1989	1990	1991	1992	1993	1994	CAGR 1989-1990	CAGR 1989-1994
Data Processing									
Computers	5,532	6,505	6,189	7,459	9,413	12,600	13,831	(4.9%)	16.3%
Data Storage/Subsystems (Total)	1,135	1,441	1,439	1,828	2,391	3,329	3,910	(0.1%)	22.1%
Data Storage/Subsystems (Net)	NM	NM	NM	NM	NM	NM	NM	NM	NM
Terminals	187	164	117	104	95	92	75	(28.7%)	(14.5%)
Input/Output	584	708	684	847	1,106	1,545	1,780	(3.4%)	20.2%
Dedicated Systems	264	280	234	249	276	324	312	(16.4%)	2.2%
Total	7,702	9,098	8,663	10,487	13,281	17,890	19,908	(4.8%)	17.0%
Communications									
Premise Telecom Equipment	1,243	1,377	1,310	1,503	1,770	2,186	2,340	(4.9%)	11.2%
Public Telecommunications	437	479	447	503	581	696	728	(6.7%)	8.7%
Mobile Communications Equipment	351	380	351	393	451	538	562	(7.6%)	8.1%
Broadcast and Studio	109	118	109	121	139	166	173	(7.6%)	8.0%
Other Telecom	111	123	117	134	158	193	206	(4.9%)	10.9%
Total	2,251	2,477	2,334	2,654	3,099	3,779	4,009	(5.8%)	10.1%
Industrial									
Security/Energy Management	134	148	157	189	232	297	341	6.1%	18.2%
Manufacturing Systems	838	882	894	1,040	1,268	1,615	1,809	1.4%	15.5%
Instrumentation	328	359	364	423	510	631	692	1.4%	14.0%
Medical Equipment	305	341	351	415	501	623	697	2.9%	15.4%
Civil Aerospace	241	255	253	292	342	417	453	(0.8%)	12.2%
Other Industrial	269	303	321	385	465	569	645	5.9%	16.3%
Total	2,115	2,288	2,340	2,744	3,318	4,152	4,637	2.3%	15.2%
Consumer									
Audio	15	15	15	16	18	20	21	0	7.0%
Video	346	359	340	374	415	472	494	(5.3%)	6.6%
Personal Electronics	12	12	11	12	12	14	14	(8.3%)	3.1%
Appliances	715	749	700	773	854	980	1,023	(6.5%)	6.4%
Other Consumer	73	77	72	79	88	101	105	(6.5%)	6.4%
Total	1,161	1,212	1,138	1,254	1,387	1,587	1,657	(6.1%)	6.5%
Military	1,669	1,679	1,716	1,766	1,843	1,946	2,069	2.2%	4.3%
Transportation	946	957	971	1,045	1,114	1,184	1,239	1.5%	5.3%
Total	15,844	17,711	17,162	19,950	24,042	30,538	33,519	(3.1%)	13.6%

NM = Not meaningful
Source: Dataquest (July 1990)

Table 7

North American Merchant Semiconductor Shipments
Segment Overview
(Percentage of Total)

Equipment Type	1988	1989	1990	1991	1992	1993	1994
Data Processing							
Computers	34.9	36.7	36.1	37.4	39.2	41.3	41.3
Data Storage/Subsystems (Total)	7.2	8.1	8.4	9.2	9.9	10.9	11.7
Data Storage/Subsystems (Net)	NM	NM	NM	NM	NM	NM	NM
Terminals	1.2	0.9	0.7	0.5	0.4	0.3	0.2
Input/Output	3.7	4.0	4.0	4.2	4.6	5.1	5.3
Dedicated Systems	1.7	1.6	1.4	1.2	1.1	1.1	0.9
Total	48.6	51.4	50.5	52.6	55.2	58.6	59.4
Communications							
Premise Telecom Equipment	7.8	7.8	7.6	7.5	7.4	7.2	7.0
Public Telecommunications	2.8	2.7	2.6	2.5	2.4	2.3	2.2
Mobile Communications Equipment	2.2	2.1	2.0	2.0	1.9	1.8	1.7
Broadcast and Studio	0.7	0.7	0.6	0.6	0.6	0.5	0.5
Other Telecom	0.7	0.7	0.7	0.7	0.7	0.6	0.6
Total	14.2	14.0	13.6	13.3	12.9	12.4	12.0
Industrial							
Security/Energy Management	0.8	0.8	0.9	0.9	1.0	1.0	1.0
Manufacturing Systems	5.3	5.0	5.2	5.2	5.3	5.3	5.4
Instrumentation	2.1	2.0	2.1	2.1	2.1	2.1	2.1
Medical Equipment	1.9	1.9	2.0	2.1	2.1	2.0	2.1
Civil Aerospace	1.5	1.4	1.5	1.5	1.4	1.4	1.4
Other Industrial	1.7	1.7	1.9	1.9	1.9	1.9	1.9
Total	13.3	12.9	13.6	13.8	13.8	13.6	13.8
Consumer							
Audio	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Video	2.2	2.0	2.0	1.9	1.7	1.5	1.5
Personal Electronics	0.1	0.1	0.1	0.1	0.0	0.0	0.0
Appliances	4.5	4.2	4.1	3.9	3.6	3.2	3.1
Other Consumer	0.5	0.4	0.4	0.4	0.4	0.3	0.3
Total	7.3	6.8	6.6	6.3	5.8	5.2	4.9
Military	10.5	9.5	10.0	8.9	7.7	6.4	6.2
Transportation	6.0	5.4	5.7	5.2	4.6	3.9	3.7
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0

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

Table 8

North American Merchant Semiconductor Shipments
Segment Overview
(Annual Growth, Percentage Change)

Equipment Type	1989	1990	1991	1992	1993	1994
Data Processing						
Computers	17.6	(4.9)	20.5	26.2	33.9	9.8
Data Storage/Subsystems (Total)	27.0	(0.1)	27.0	30.8	39.2	17.5
Data Storage/Subsystems (Net)	NM	NM	NM	NM	NM	NM
Terminals	(12.3)	(28.7)	(11.1)	(8.7)	(3.2)	(18.5)
Input/Output	21.2	(3.4)	23.8	30.6	39.7	15.2
Dedicated Systems	6.1	(16.4)	6.4	10.8	17.4	(3.7)
Total	18.1	(4.8)	21.1	26.6	34.7	11.3
Communications						
Premise Telecom Equipment	10.8	(4.9)	14.7	17.8	23.5	7.0
Public Telecommunications	9.6	(6.7)	12.5	15.5	19.8	4.6
Mobile Communications Equipment	8.3	(7.6)	12.0	14.8	19.3	4.5
Broadcast and Studio	8.3	(7.6)	11.0	14.9	19.4	4.2
Other Telecom	10.8	(4.9)	14.5	17.9	22.2	6.7
Total	10.0	(5.8)	13.7	16.8	21.9	6.1
Industrial						
Security/Energy Management	10.4	6.1	20.4	22.8	28.0	14.8
Manufacturing Systems	5.3	1.4	16.3	21.9	27.4	12.0
Instrumentation	9.5	1.4	16.2	20.6	23.7	9.7
Medical Equipment	11.8	2.9	18.2	20.7	24.4	11.9
Civil Aerospace	5.8	(0.8)	15.4	17.1	21.9	8.6
Other Industrial	12.6	5.9	19.9	20.8	22.4	13.4
Total	8.2	2.3	17.3	20.9	25.1	11.7
Consumer						
Audio	0	0	6.7	12.5	11.1	5.0
Video	3.8	(5.3)	10.0	11.0	13.7	4.7
Personal Electronics	0.0	(8.3)	9.1	0	16.7	0
Appliances	4.8	(6.5)	10.4	10.5	14.8	4.4
Other Consumer	5.5	(6.5)	9.7	11.4	14.8	4.0
Total	4.4	(6.1)	10.2	10.6	14.4	4.4
Military	0.6	2.2	2.9	4.4	5.6	6.3
Transportation	1.2	1.5	7.6	6.6	6.3	4.6
Total	11.8	(3.1)	16.2	20.5	27.0	9.8

NM = Not meaningful
Source: Dataquest (July 1990)

Application Market Overview--Japan

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 details for Western Europe and Japan will be left to their respective services--namely, European Semiconductor Application Markets service (ESAM) and Japanese Semiconductor Application Markets service (JSAM).

The methodology for compiling these data, as well as the organizational structure, is similar to that used in the North American section. This section includes electronic equipment overview tables, an input/output (I/O) ratio overview table, and semiconductor consumption overview tables. It also profiles fast-growing equipment markets.

The vast majority of the data used has been collected by Dataquest's Japanese Components Group, located in Tokyo. Because the information was compiled in Japan, the following 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 I/O ratio for equipment manufactured in Japan appears substantially larger than the ratio for North America-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
1983	235
1984	237
1985	238
1986	167
1987	144
1988	135*

*Assumed at this rate for 1988-1992.

Source: Wall Street Journal
International Monetary Fund
Dataquest
February 1989

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 been deleted also. It can be assumed that their small totals have been included elsewhere in the production statistics.

Application Market Overview--Japan

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.

ELECTRONIC EQUIPMENT OVERVIEW TABLES

This section presents the overview tables in both yen and dollars for Japanese electronic equipment (Tables 2 and 3, respectively), input/output ratios (Table 4), and Japanese semiconductor consumption in yen and dollars (Tables 5 and 6, respectively) by end market.

As discussed in the introduction, the segmentation is the same as for the North American section, allowing SAM to provide a global and consistent perspective on electronic equipment production.

Table 2

Japanese Electronic Equipment Forecast
(Billions of Yen)

Segment	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	CAGR 1986-1987	CAGR 1987-1992
Data Processing												
Computers	¥ 990	¥ 1,106	¥ 1,367	¥ 1,551	¥ 1,682	¥ 1,941	¥ 2,041	¥ 2,412	¥ 2,867	¥ 3,361	8.5%	14.8%
Data Storage	432	634	788	956	1,011	1,204	1,205	1,502	1,713	2,016	5.8%	14.8%
Terminals	628	802	864	931	1,050	1,187	1,250	1,386	1,574	1,776	12.8%	11.1%
Input/Output	290	541	569	630	674	741	776	876	989	1,107	7.0%	10.4%
Dedicated Systems	872	1,070	1,167	981	957	1,017	1,036	1,085	1,174	1,264	(2.5%)	5.7%
Subtotal	¥ 3,212	¥ 4,153	¥ 4,755	¥ 5,049	¥ 5,374	¥ 6,090	¥ 6,388	¥ 7,261	¥ 8,317	¥ 9,524	6.4%	12.1%
Communications												
Customer Premises	¥ 461	¥ 622	¥ 806	¥ 799	¥ 826	¥ 934	¥ 960	¥ 1,064	¥ 1,194	¥ 1,367	3.3%	10.6%
Public Telecommunications	388	457	505	482	592	635	689	790	868	955	22.8%	10.0%
Radio	475	536	565	597	633	690	723	762	831	910	6.0%	7.5%
Broadcast and Studio	62	63	74	67	61	64	66	68	70	74	(8.6%)	3.9%
Subtotal	¥ 1,386	¥ 1,679	¥ 1,949	¥ 1,945	¥ 2,112	¥ 2,323	¥ 2,438	¥ 2,684	¥ 2,963	¥ 3,306	8.6%	9.4%
Industrial												
Instrumentation	¥ 462	¥ 555	¥ 622	¥ 525	¥ 493	¥ 543	¥ 586	¥ 663	¥ 772	¥ 868	(6.1%)	12.0%
Manufacturing Systems	484	719	847	735	604	663	706	774	852	944	(17.8%)	9.3%
Medical	321	341	389	441	475	514	548	591	706	800	7.7%	11.0%
Others	135	170	170	172	209	239	263	301	342	394	21.5%	13.5%
Subtotal	¥ 1,403	¥ 1,785	¥ 2,029	¥ 1,873	¥ 1,781	¥ 1,959	¥ 2,103	¥ 2,329	¥ 2,672	¥ 3,006	(4.9%)	11.0%
Consumer												
Audio	¥ 936	¥ 1,038	¥ 1,004	¥ 898	¥ 784	¥ 833	¥ 800	¥ 861	¥ 944	¥ 1,123	(12.8%)	7.5%
Video	2,332	3,069	3,209	2,891	2,724	3,002	3,109	3,391	3,785	4,225	(5.8%)	9.2%
Personal Electronics	808	868	906	853	708	726	726	776	833	913	(17.0%)	5.2%
Appliances	1,336	1,687	1,902	1,831	1,715	1,820	1,859	1,935	1,998	2,110	(6.3%)	4.2%
Subtotal	¥ 5,412	¥ 6,662	¥ 7,021	¥ 6,472	¥ 5,930	¥ 6,381	¥ 6,494	¥ 6,963	¥ 7,560	¥ 8,371	(8.4%)	7.1%
Transportation	¥ 706	¥ 863	¥ 946	¥ 989	¥ 990	¥ 1,079	¥ 1,133	¥ 1,188	¥ 1,238	¥ 1,369	0.1%	6.7%
Total	¥12,119	¥15,142	¥16,700	¥16,329	¥16,187	¥17,832	¥18,557	¥20,425	¥22,750	¥25,576	(0.9%)	9.6%

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

Source: Dataquest
February 1989

Table 3

Japanese Electronic Equipment Forecast (Millions of Dollars)

Segment	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	CAGR 1986-1987	CAGR 1987-1992
Data Processing												
Computers	$ 4,212	$ 4,668	$ 5,743	$ 9,285	$ 11,681	$ 14,378	$ 15,119	$ 17,867	$ 21,237	$ 24,896	25.8%	16.3%
Data Storage	1,838	2,675	3,311	5,725	7,021	8,919	9,519	11,126	12,689	14,933	22.6%	16.3%
Terminals	2,672	3,385	3,629	5,575	7,292	8,793	9,259	10,267	11,659	13,156	30.8%	12.5%
Input/Output	1,234	2,283	2,391	3,772	4,681	5,489	5,748	6,489	7,326	8,200	24.1%	11.9%
Dedicated Systems	3,713	4,514	4,904	5,876	6,646	7,533	7,674	8,037	8,696	9,363	13.1%	7.1%
Subtotal	$13,669	$17,525	$19,978	$30,234	$ 37,319	$ 45,111	$ 47,319	$ 53,785	$ 61,607	$ 70,548	23.4%	13.6%
Communications												
Customer Premises	$ 1,960	$ 2,626	$ 3,386	$ 4,787	$ 5,736	$ 6,919	$ 7,111	$ 7,881	$ 8,844	$ 10,126	19.8%	12.0%
Public Telecommunications	1,651	1,930	2,122	2,886	4,111	4,704	5,104	5,852	6,430	7,074	42.4%	11.5%
Radio	2,023	2,264	2,374	3,574	4,396	5,111	5,356	5,644	6,156	6,741	23.0%	8.9%
Broadcast and Studio	263	264	310	400	424	474	489	504	519	548	6.0%	5.3%
Subtotal	$ 5,897	$ 7,083	$ 8,191	$11,647	$ 14,667	$ 17,207	$ 18,059	$ 19,881	$ 21,948	$ 24,489	25.9%	10.8%
Industrial												
Instrumentation	$ 1,967	$ 2,343	$ 2,613	$ 3,143	$ 3,424	$ 4,022	$ 4,341	$ 4,911	$ 5,719	$ 6,430	8.9%	13.4%
Manufacturing Systems	2,060	3,033	3,560	4,402	4,194	4,911	5,230	5,733	6,311	6,993	(4.7%)	10.8%
Medical	1,368	1,439	1,634	2,640	3,298	3,807	4,059	4,378	5,230	5,926	24.9%	12.4%
Others	574	719	716	1,030	1,451	1,770	1,948	2,230	2,533	2,919	40.9%	15.0%
Subtotal	$ 5,969	$ 7,533	$ 8,523	$11,215	$ 12,368	$ 14,511	$ 15,578	$ 17,252	$ 19,793	$ 22,267	10.3%	12.5%
Consumer												
Audio	$ 3,985	$ 4,379	$ 4,218	$ 5,380	$ 5,442	$ 6,170	$ 5,926	$ 6,378	$ 6,993	$ 8,319	1.2%	8.9%
Video	9,923	12,950	13,484	17,310	18,917	22,237	23,030	25,119	28,037	31,296	9.3%	10.6%
Personal Electronics	3,438	3,664	3,806	5,105	4,917	5,378	5,378	5,748	6,170	6,763	(3.7%)	6.6%
Appliances	5,684	7,117	7,992	10,963	11,907	13,481	13,771	14,335	14,800	15,630	8.6%	5.6%
Subtotal	$23,030	$28,109	$29,500	$38,757	$ 41,182	$ 47,267	$ 48,104	$ 51,580	$ 56,000	$ 62,007	6.3%	8.5%
Transportation	$ 3,004	$ 3,641	$ 3,977	$ 5,923	$ 6,873	$ 7,996	$ 8,396	$ 8,797	$ 9,171	$ 10,141	16.1%	8.1%
Total	$51,569	$63,891	$70,168	$97,776	$112,409	$132,092	$137,456	$151,295	$168,519	$189,452	15.0%	11.0%

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

Source: Dataquest
February 1989

Table 4

Estimated Input/Output Ratio by Application Market (Percentage)

Segment	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Data Processing										
Computers	22.8%	29.2%	23.4%	23.5%	23.9%	24.4%	23.1%	23.2%	24.2%	25.3%
Data Storage	11.7%	14.6%	12.3%	12.6%	12.8%	12.7%	12.1%	12.1%	12.5%	13.1%
Terminals	12.7%	15.9%	14.0%	14.2%	14.6%	14.8%	14.3%	14.3%	14.7%	15.7%
Input/Output	15.7%	18.2%	16.9%	16.9%	17.1%	17.4%	16.6%	16.8%	17.1%	18.1%
Dedicated Systems	8.5%	11.9%	10.7%	10.9%	11.0%	11.4%	10.8%	10.9%	11.0%	11.7%
Average I/O Ratio	14.8%	18.5%	16.0%	16.4%	16.8%	17.2%	16.4%	16.6%	17.3%	18.3%
Communications										
Customer Premises	12.6%	15.8%	14.0%	14.3%	14.5%	14.9%	14.0%	14.6%	15.1%	16.5%
Public Telecommunications	8.1%	11.0%	8.9%	9.0%	9.3%	9.6%	9.0%	9.2%	9.5%	10.3%
Radio	13.0%	16.3%	14.6%	14.7%	14.9%	15.3%	14.5%	14.7%	15.1%	15.9%
Broadcast and Studio	8.5%	10.6%	9.2%	9.2%	9.4%	9.7%	9.2%	9.3%	9.7%	10.0%
Average I/O Ratio	11.3%	14.5%	12.7%	12.9%	13.0%	13.4%	12.6%	12.9%	13.3%	14.4%
Industrial										
Instrumentation	16.1%	20.1%	18.1%	18.1%	18.3%	18.9%	17.7%	18.1%	18.9%	19.8%
Manufacturing Systems	4.2%	6.4%	5.3%	5.4%	5.7%	5.9%	5.2%	5.5%	5.8%	6.6%
Medical	5.1%	7.1%	6.0%	6.1%	6.2%	6.4%	5.9%	6.0%	6.2%	7.0%
Others	6.4%	9.4%	8.3%	8.4%	8.5%	8.6%	8.3%	8.4%	8.5%	8.9%
Average I/O Ratio	8.5%	11.1%	9.6%	9.4%	9.7%	10.0%	9.2%	9.6%	10.0%	10.8%
Consumer										
Audio	14.1%	16.6%	16.3%	17.5%	17.4%	17.7%	17.2%	17.4%	17.6%	18.2%
Video	13.1%	16.5%	15.0%	15.2%	16.0%	16.0%	15.2%	15.5%	15.9%	16.5%
Personal Electronics	6.3%	7.9%	7.8%	8.2%	8.5%	8.9%	9.0%	9.1%	9.5%	9.8%
Appliances	2.5%	3.3%	2.9%	3.1%	3.2%	3.2%	3.0%	3.0%	3.2%	3.4%
Average I/O Ratio	9.7%	12.1%	11.0%	11.2%	11.6%	11.8%	11.3%	11.6%	12.1%	12.7%
Transportation	7.7%	9.5%	8.2%	8.5%	9.2%	9.8%	9.6%	9.9%	10.4%	10.8%
Average I/O Ratio	11.0%	13.8%	12.3%	12.6%	13.2%	13.5%	12.9%	13.2%	13.8%	14.7%

Source: Dataquest
February 1989

Table 5

Japanese Semiconductor Consumption Forecast (Billions of Yen)

Segment	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	CAGR 1986-1987	CAGR 1987-1992
Data Processing												
Computers	¥ 225	¥ 323	¥ 320	¥ 365	¥ 401	¥ 472	¥ 472	¥ 559	¥ 695	¥ 851	10.3%	16.2%
Data Storage	51	92	97	120	129	153	156	182	215	264	7.5%	15.3%
Terminals	79	128	121	132	154	177	179	198	231	279	16.3%	12.7%
Input/Output	46	99	96	106	115	129	129	147	169	201	8.2%	11.8%
Dedicated Systems	74	128	125	107	105	116	112	118	129	147	(1.8%)	7.0%
Subtotal	¥ 475	¥ 769	¥ 759	¥ 831	¥ 904	¥1,051	¥1,048	¥1,203	¥1,439	¥1,742	9.0%	14.0%
Communications												
Customer Premises	¥ 58	¥ 99	¥ 113	¥ 114	¥ 120	¥ 140	¥ 134	¥ 155	¥ 180	¥ 226	5.0%	13.5%
Public Telecommunications	31	50	45	43	55	61	62	73	83	98	27.0%	12.3%
Radio	62	87	82	88	95	106	105	112	126	145	7.8%	8.9%
Broadcast and Studio	5	7	7	6	6	6	6	6	7	7	(6.6%)	5.2%
Subtotal	¥ 156	¥ 243	¥ 247	¥ 251	¥ 275	¥ 312	¥ 307	¥ 346	¥ 395	¥ 477	9.5%	11.6%
Industrial												
Instrumentation	¥ 74	¥ 112	¥ 112	¥ 95	¥ 90	¥ 103	¥ 104	¥ 120	¥ 146	¥ 172	(4.7%)	13.8%
Manufacturing Systems	20	46	45	40	34	39	37	42	49	62	(13.5%)	12.5%
Medical	16	24	23	27	30	33	32	36	44	56	9.4%	13.5%
Others	9	16	14	14	18	21	22	25	29	35	23.1%	14.6%
Subtotal	¥ 120	¥ 198	¥ 195	¥ 176	¥ 172	¥ 195	¥ 194	¥ 223	¥ 268	¥ 325	(2.2%)	13.6%
Consumer												
Audio	¥ 132	¥ 172	¥ 163	¥ 157	¥ 137	¥ 148	¥ 137	¥ 150	¥ 166	¥ 204	(13.0%)	8.3%
Video	306	507	480	443	436	481	473	527	603	696	(2.1%)	9.8%
Personal Electronics	51	69	71	70	60	65	65	71	79	90	(13.3%)	8.2%
Appliances	33	56	56	57	54	58	57	59	63	71	(4.8%)	5.6%
Subtotal	¥ 522	¥ 804	¥ 770	¥ 726	¥ 687	¥ 751	¥ 732	¥ 807	¥ 911	¥1,061	(5.8%)	9.3%
Transportation	¥ 54	¥ 82	¥ 78	¥ 84	¥ 91	¥ 106	¥ 109	¥ 117	¥ 129	¥ 147	8.2%	10.1%
Total	¥1,328	¥2,096	¥2,049	¥2,069	¥2,131	¥2,412	¥2,391	¥2,696	¥3,141	¥3,752	2.9%	12.0%

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

Source: Dataquest
February 1989

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Table 6

Japanese Semiconductor Consumption Forecast (Millions of Dollars)

Segment	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	CAGR 1986-1987	CAGR 1987-1992
Data Processing												
Computers	$ 959	$1,363	$1,346	$ 2,178	$ 2,786	$ 3,503	$ 3,498	$ 4,141	$ 5,150	$ 6,304	27.9%	17.7%
Data Storage	215	390	408	718	897	1,133	1,154	1,345	1,591	1,954	24.7%	16.8%
Terminals	338	538	507	789	1,067	1,300	1,323	1,464	1,711	2,067	34.9%	14.1%
Input/Output	194	416	404	635	799	953	956	1,089	1,252	1,486	25.5%	13.2%
Dedicated Systems	316	539	526	640	731	861	831	873	955	1,092	13.9%	8.4%
Subtotal	$2,023	$3,246	$3,190	$ 4,959	$ 6,281	$ 7,789	$ 7,762	$ 8,912	$10,658	$12,903	26.4%	15.5%
Communications												
Customer Premises	$ 247	$ 416	$ 475	$ 682	$ 832	$ 1,034	$ 994	$ 1,147	$ 1,333	$ 1,675	21.8%	15.0%
Public Telecommunications	133	212	189	259	383	452	462	540	611	729	47.3%	13.8%
Radio	263	369	346	524	657	782	776	829	930	1,074	25.0%	10.3%
Broadcast and Studio	22	28	29	37	40	46	45	47	50	55	8.3%	6.6%
Subtotal	$ 665	$1,024	$1,038	$ 1,502	$ 1,912	$ 2,314	$ 2,277	$ 2,564	$ 2,924	$ 3,533	27.0%	13.1%
Industrial												
Instrumentation	$ 316	$ 471	$ 472	$ 566	$ 628	$ 760	$ 767	$ 887	$ 1,080	$ 1,276	10.6%	15.2%
Manufacturing Systems	87	195	189	238	239	289	273	315	364	459	0.3%	13.9%
Medical	70	102	99	161	205	243	239	264	325	413	26.9%	15.0%
Others	37	67	60	86	123	152	161	187	215	259	42.8%	16.1%
Subtotal	$ 509	$ 835	$ 820	$ 1,051	$ 1,196	$ 1,444	$ 1,440	$ 1,652	$ 1,984	$ 2,408	13.4%	15.0%
Consumer												
Audio	$ 564	$ 726	$ 687	$ 938	$ 949	$ 1,093	$ 1,016	$ 1,111	$ 1,231	$ 1,511	0.9%	9.7%
Video	1,302	2,138	2,017	2,644	3,028	3,562	3,505	3,905	4,464	5,158	13.5%	11.2%
Personal Electronics	217	291	296	417	420	481	484	524	585	665	0.5%	9.6%
Appliances	140	237	235	339	376	428	419	435	469	525	10.4%	7.0%
Subtotal	$2,223	$3,392	$3,235	$ 4,337	$ 4,773	$ 5,564	$ 5,425	$ 5,975	$ 6,749	$ 7,859	9.3%	10.7%
Transportation	$ 231	$ 346	$ 326	$ 503	$ 633	$ 785	$ 804	$ 867	$ 954	$ 1,090	25.5%	11.5%
Total	$5,651	$8,843	$8,610	$12,352	$14,793	$17,859	$17,708	$19,970	$23,269	$27,794	19.3%	13.5%

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

Source: Dataquest
February 1989

Application Market Overview--Japan

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 compound annual growth rate (CAGR) of 14.8 percent through 1992, 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.

Communications Segment

Facsimile Machines

Facsimile machines represent another rapidly growing market for semiconductors, consuming approximately 2.4 percent of all chips consumed in Japan.

The leading manufacturers of facsimile equipment, by rank, are Ricoh, Matsushita, Canon, and NEC.

In 1987, facsimile production reached $2.53 billion. In 1992, Dataquest expects facsimile production to grow to $6.16 billion.

Industrial Segment

Robotics

Fanuc, Yaskawa, Kawasaki Heavy Industries, and Hitachi are the leading manufacturers of robots in Japan. Dataquest believes that Japanese production of robots will recover from its 1987 slump and grow at an 11.2 percent CAGR to $1.22 billion in 1992.

Consumer Segment

VCRs

VCRs are the most prevalent application for semiconductors, consuming 11.3 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.

Video Cameras

Video cameras are forecast to be the fastest-growing consumer product produced in Japan through 1992 (CAGR 18 percent). Increased miniaturization, quality enhancements, and cost reduction are expected to drive the growth of video cameras.

The major manufacturers of video cameras in Japan are: Hitachi, JVC, Matsushita, and Sony.

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 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

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 grow at a CAGR of 11.5 percent from 1988 to 1992.

Application Market Overview—Europe

INTRODUCTION

Dataquest's European Components Group (ECG) has developed a new module called European Semiconductor Applications Markets (ESAM) that provides a complete analysis of semiconductor consumption in Europe by application market segment. This product is intended to support decision makers who must take a tactical or strategic approach in their analysis of the semiconductor market, from either an application (or demand) side or end-use perspective.

This section gives a top-level overview of the semiconductor applications markets in Europe by the following six market segments:

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

For a complete analysis of these segments, readers should refer to the ESAM module.

EUROPEAN END-USE SEGMENTS

The data processing segment comprises all equipment with the main function of information processing. Included in this segment are all types of computers, from personal computers to mainframes, and all computer peripheral equipment such as memory storage systems and data terminals.

The communications segment consists of all forms of equipment used for electronic communication. This equipment includes devices used on customers' premises (e.g., PABXs, telephones, facsimile), the public network (switches and transmission), radio, and studio and broadcast equipment.

The industrial segment covers all forms of manufacturing-related equipment including energy management, automated manufacturing systems, robotics, medical systems, and commercial aviation.

The consumer segment covers equipment that is retailed through retail stores and designed primarily for domestic or personal use, such as home audio and video equipment; white goods appliances (e.g., microwave ovens and washing machines), and personal electronics (e.g., watches, hearing-aids).

Military equipment consists of electronic equipment used for weapons or weapon-support systems and is classified by specific budget areas. To avoid double counting of items that logically belong to other segments, it excludes nonspecific electronic equipment procured by governments.

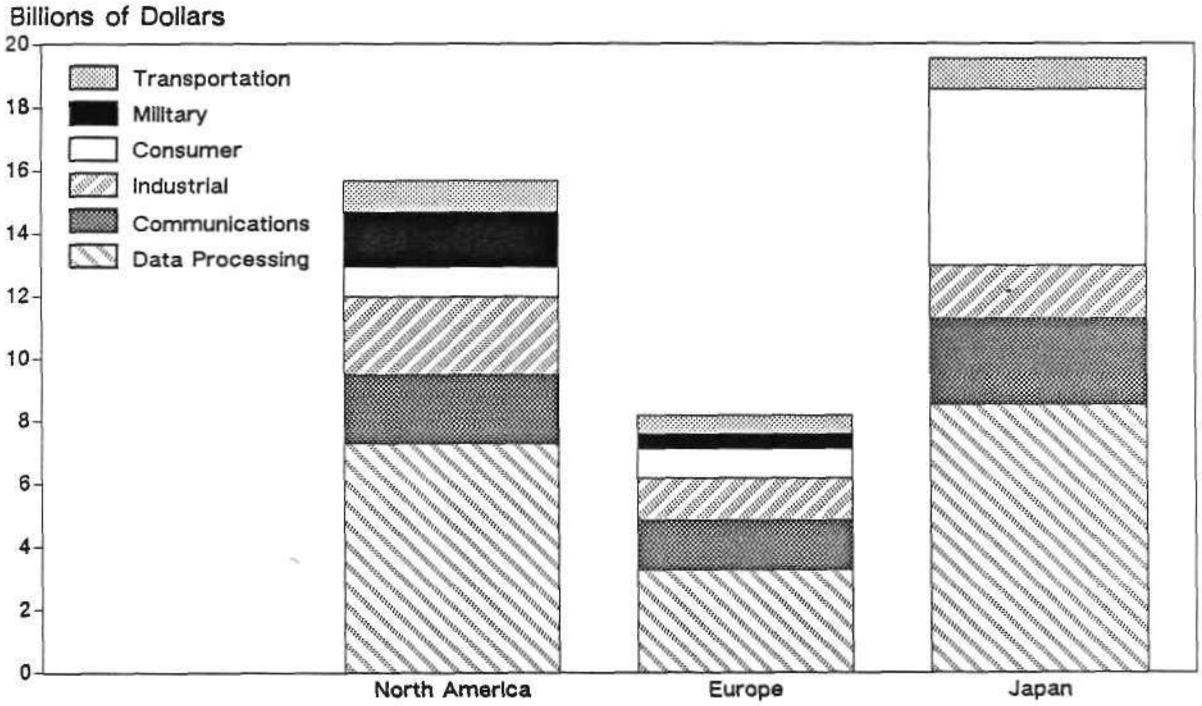
Transportation segment consists mainly of automotive and light truck electronics. This designation leaves room to analyze other markets, such as off-highway equipment, that are potentially large users of semiconductors.

EUROPEAN OVERVIEW

The European electronic market exhibits significant differences from those in the United States or Japan in terms of the percentage of consumption by end-use segment (see Figure 3.0-1).

Figure 1

1988 Semiconductor Consumption by Application Markets



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Source: Dataquest
August 1989

Application Market Overview—Europe

In North America the emphasis lies in the data processing segment, which Dataquest estimates accounted for 49.4 percent of 1988 U.S. semiconductor consumption, in contrast with 39.8 percent in Europe (or 43.3 percent in Japan). In Europe, the communications segment continues to occupy a high, 19.2 percent share of total consumption, compared with 13.5 percent in the United States and 12.9 percent in Japan. This difference is due largely to the regulatory environment in Europe, where the Public Telephone and Telegraph (PTT) operator in each country favors local equipment suppliers.

The consumer market in Japan continues to occupy a greater proportion of semiconductor consumption, 31 percent, than either Europe (11.5 percent) or the United States (5.4 percent).

EUROPEAN SEMICONDUCTOR MARKETS

Table 3.0-1 describes Dataquest's five-year forecast by top level end-use segment for 1989 to 1994, with an overall compound annual growth rate (CAGR) of 18.9 percent predicted for this period.

Table 1

Estimated European Semiconductor Consumption by End-Use Application

	1989		1994		
Category	($B)	%	($B)	%	CAGR
Data Processing	$3.40	35.0%	$ 7.50	32.5%	17.2%
Communications	2.04	21.0	4.60	19.9	17.7%
Industrial	1.73	17.8	3.44	14.9	14.8%
Consumer	1.18	12.2	3.80	16.5	26.3%
Military	0.58	6.0	1.30	5.6	17.3%
Transportation	0.76	8.0	2.43	10.6	26.1%
Total	$9.69	100.0%	$23.07	100.0%	18.9%

Source: Dataquest
August 1989

Data Processing

Rapidly rising DRAM prices have distorted the consumption of semiconductors in this segment during the past couple of years. In 1988, data processing consumption represented 39.8 percent of the total European market. With an outlook of falling DRAM prices, we expect this fraction to drop to 35 percent this year, returning to a long-run 32.5 percent by 1994.

Table 3.0-2 shows the data processing market in Europe broken down by subsegment. Computers occupied the lion's share of this market in 1988, accounting for an estimated 78.3 percent of the semiconductor market in the data processing segment. Following this segment were data storage systems (largely hard disks) with 9.8 percent and dedicated systems with 6.3 percent.

Table 2

Estimated 1988 European Data Processing Semiconductor Consumption by Subsegment

Subsegment	Millions of Dollars	Percent
Data Processing		
Computers	$2,645	78.3%
Data Storage Subsystems	333	9.8
Terminals	28	0.8
Input/Output	165	4.8
Dedicated Systems	210	6.3
Total	$3,381	100.0%

Source: Dataquest
August 1989

Dataquest estimates that overall semiconductor consumption in the data processing segment will experience a 17.2 percent CAGR during the next five years. Laser printers and workstations represent the two most dynamic markets in this segment.

The growing affordability of laser printers, combined with tougher European local content rules that are driving greater local production, will cause this subsegment to show a 34 percent CAGR between 1989 and 1994. The growth in semiconductors consumed for the workstation market will be almost as dramatic, with an estimated 31 percent.

Communications

Table 3.0-3 shows the communications market in Europe for 1988 broken down by subsegment. Customer-premises equipment (telephones, facsimile, data terminals, modems, PBXs) account for the greatest proportion of revenue in this segment, 38.4 percent.

Table 3

Estimated 1988 European Communications Semiconductor Consumption by Subsegment

Subsegment	Millions of Dollars	Percent
Communications		
Customer Premises	$ 628	38.4%
Public Telecommunications	496	30.4
Radio	261	16.0
Broadcast and Studio	137	8.4
Other	112	6.8
Total	$1,634	100.0%

Source: Dataquest
August 1989

Although overall growth for communications—17.7 percent CAGR—ranks behind the consumer and transportation sectors, it contains the highest growth applications for the next five years.

With ISDN services recently announced in France and West Germany, Dataquest expects ISDN semiconductor revenue to show a sharp increase, reflecting an average 90 percent CAGR. By 1992 the market for dedicated ISDN ICs is estimated to be worth $137 million.

The new digital cordless telephone technologies, CT2 and DECT (Digital European Cordless Telephone), also are poised to make a strong impact in the next five years—growing at an estimated 54 percent during this period. Dataquest estimates that the market for CT2 semiconductors in Europe alone will be worth between $90 million and $170 million by 1994.

For the most part, facsimile machines are imported and in the past have not accounted for significant component sales in Europe. Dataquest estimates that in 1988 only 15 percent of this high-growth market was satisfied by production in Europe.

However, the trend here is toward rising local production with both Japanese and European companies expected to expand production in Europe, driving an average 45 percent CAGR in semiconductor consumption during the next five years.

Industrial

The industrial segment covers a diverse range of applications. Table 3.0-4 shows a breakdown for industrial consumption in Europe by subsegment for 1988.

Table 4

Estimated 1988 European Industrial Semiconductor Consumption by Subsegment

Subsegment	Millions of Dollars	Percent
Industrial		
Energy Management	$ 125	8.9%
Manufacturing Systems	795	57.1
Robot Systems	26	1.9
Medical Systems	217	15.6
Commercial Aviation	75	5.5
Other	153	11.0
Total	$1,392	100.0%

Source: Dataquest
August 1989

Manufacturing systems (production systems, instrumentation) accounted for 59.1 percent of this market, with medical systems accounting for much of the remainder (15.6 percent). However, the energy management systems sector is the one in which Dataquest predicts the main growth (38 percent CAGR) in this segment during the next five years. In this time period, smart electronic metering systems are forecast to gradually replace existing electromechanical meters for electricity, gas, and water.

Consumer

Table 3.0-5 shows the consumer semiconductor consumption in Europe for 1988 broken down by subsegment. Video equipment (television and video recorders) represent the greatest share, with 68 percent of the market, followed by white goods appliances (microwave ovens, washing machines, dishwashers) with 16 percent and audio equipment (hifi, radios) with 12 percent.

Dataquest expects the consumer segment to show the strongest growth in semiconductor consumption, with a 26.3 percent CAGR during the next five years. A key factor behind this growth is the European Commission (EC)'s rules on local content and antidumping, which are especially strong on products in this segment—particularly regarding televisions and video recorders.

Table 5

Estimated 1988 European Consumer
Semiconductor Consumption by Subsegment

Subsegment	Millions of Dollars	Percent
Consumer		
Audio	$117	12.0%
Video	666	68.2
Personal Electronics	29	2.9
Appliances	158	16.2
Other	6	0.7
Total	$976	100.0%

Source: Dataquest
August 1989

Where there are new markets presently dominated by imports, Dataquest expects the EC to move to encourage local production. One proposal before the commission is to raise tariffs on imported camcorders from 4.9 percent to 14 percent. In Europe, camcorders represent a $2 billion market, of which almost all are imported.

The semiconductor content per unit in this segment also is steadily increasing, as chips will continue to replace electromechanical controllers in washing machines, dishwashers, and microwave ovens during the coming years. Except for microwave ovens, these items will continue to be produced mainly in Europe by strong, locally owned manufacturers such as Electrolux, Philips, and Bosch-Siemens.

Transportation

The trends in semiconductor consumption for transportation are similar to those for the consumer market. The most prominent of these trends is a market that is shifting toward greater semiconductor content in a legislative environment in which local production is increasingly favored.

Application Market Overview—Europe

Features like antilock braking and fuel injection were at one time luxuries that distinguished top-range performance cars from low-end ones, but this is changing and these items increasingly are being offered as standard equipment on all models.

The EC's target of tightening of regulations regarding car pollution by 1993 is another major factor. These rules will require a much higher proportion of cars to use microprocessor-controlled engine management systems.

Table 3.0-6 shows Dataquest's estimation of transportation semiconductor consumption for Europe broken down by subsegment for 1988. Power train systems (electronic fuel injection and engine management) account for the greatest (41 percent) share of this market, followed by safety and convenience systems (mainly antilock braking) with 22.2 percent and entertainment systems with 19.1 percent.

Table 6

Estimated 1988 European Transportation Semiconductor Consumption by Subsegment

Subsegment	Millions of Dollars	Percent
Transportation		
Entertainment	$117	19.1%
Body Controls	72	11.8
Safety and Convenience	136	22.2
Power Train	251	41.0
Driver Information	36	5.9
Total	$612	100.0%

Source: Dataquest
August 1989

Military

Semiconductor consumption for the military segment will remain static in real terms during the next five years.

The current political climate between the West and east bloc countries is such that further cuts in defense budgets in Europe are probable, which will result in declining orders for military systems. However, Dataquest predicts that electronic content will continue to increase and, as procurement budgets shrink, military electronic systems will go through successive phases of modernization rather than replacement.

Application Market Overview--Europe

Consolidation through horizontal integration and joint consortia is likely in a European military market that is deeply fragmented along national lines. The main impetus for consolidation in this market comes from the fact that R&D costs are escalating rapidly. Examples include Ferranti's venture with Teledyne to manufacture acoustic sensors, Plessey's 49 percent stake in Electtronic and GEC's 5 percent holding in Matra. Further consolidation is likely.

Electronic Equipment Companies

The following is a list of material in this section:

- Electronic Equipment Company Revenue

Electronic Equipment Company Revenue

INTRODUCTION

This section forms the Semiconductor Application Markets (SAM) service's first major database. The other databases include the electronic equipment production database, the semiconductor consumption (by application market) database, and the (semiconductor) input/(electronic equipment) output—or input/output (I/O) ratio database.

The electronic equipment revenue database has the following three purposes:

- To provide concrete historical information—The section provides a database of the electronic equipment revenue of the 50 largest US electronics manufacturers. We estimate that these 50 companies' electronic revenue accounts for 64 percent of the 200 largest US companies' electronics shipments in 1989 and therefore represents a good base for examining trends in the electronic equipment marketplace. This database is an efficient tool for analyzing growth by application market segment of the activities of individual companies.
- To offer a check on other summary data—The information complements a historical view of semiconductor consumption with an equipment viewpoint rather than simply a product-shipment analysis.
- To serve as a cross-check in the development of I/O ratios—Tracking the actual semiconductor consumption (both merchant and captive) and the actual electronic equipment revenue of given users allows an analysis of the I/O ratio, which is the relationship between semiconductor dollar value and the dollar value of the equipment in which the semiconductors are used.

In addition to electronic system semiconductor consumption analysis, Dataquest has developed and verified I/O ratios by interviewing procurement, contract, and materials managers who are experts in knowing their individual companies' merchant and captive use of semiconductors. We have interviewed more than 200 leading electronics manufacturers that have given us proprietary information on their semiconductor procurement, their captive production, and their relationships to the equipment or divisions in which the devices are used.

Dataquest has agreed to use this information only for internal purposes and report these ratios only on an aggregate basis. The I/O ratios that we develop are applied to the forecasts of electronic equipment production to estimate the associated level of semiconductor consumption. Information in those I/O ratios are available to clients that subscribe to our on-line services and can also be solicited from our analysts by using their inquiry privilege. The result is a series of forecasts of semiconductor consumption by application market presented in the "Semiconductor Consumption Analysis" section.

OVERVIEW

The information that follows is the result of a comprehensive database that tracks and analyzes the electronic equipment revenue of the 50 largest US electronic equipment manufacturing companies. Major companies' revenue is listed, segmented and presented in this section in various ways. Accordingly, the data, covering a ten-year span (1979 to 1989), are presented as follows:

- Table 1—Data Processing Equipment-Derived Revenue by Company, 1979 to 1989
- Table 2—Communications Equipment-Derived Revenue by Company, 1979 to 1989

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METHODOLOGY

The following criterion is used to select companies for inclusion in the database: Include the 50 largest US electronic systems manufacturers, based on their respective total electronic-system derived revenue for 1989. These companies are selected from a much larger sample of US companies, the annual "Electronic Business 200" feature of *Electronic Business.*

Company annual reports and 10K reports provided the main source of information on equipment shipments. (I/O ratios were developed with subsequent detailed analysis.) Virtually every annual report lists a company's revenue by line of business, with each line of business usually being referred to as a segment. Descriptions of each segment's revenue also are reported. Dataquest used these descriptions to determine whether or not a segment's revenue should be added to the database.

Given that the information in some annual reports is limited, Dataquest developed the following protocols to provide continuity to the database:

- The latest annual report was always used. For example, a typical 1989 report might have historical segment data for a three- or five-year period. If only three years were reported, the 1988 report was examined for 1986 information and the data for 1988 and 1987 were simply checked against the information in the 1989 report to ensure that a company had not reclassified its reporting structure. Using the latest annual report provided continuity in the segments and their revenue.
- The large companies' segments included nonelectronic equipment. If electronic equipment made up the majority of the segment or if there was a heavy technical influence in the description, the entire revenue was added to the database. Unless specifically detailed or additional information was obtainable, percentages were not applied to segment revenue based on the proportion or type of electronic equipment in that segment.
- Despite the name a company gave to a given segment, a description of the equipment in a segment was used to determine in which of the six Dataquest application market segments the revenue belonged. Some of the larger companies' segments had such a varied product mix that they crossed over the Dataquest segmentation. In such cases, the major product influence in that segment's description mandated which of our categories the revenue went into.

- In segments where there was little or no clear evidence of electronic equipment, the revenue was not added to the database. Nonelectronic lines of business also were not included.
- Services, interest, supply, rentals, and other additional or product-support revenue were eliminated from the database if they were listed in the report. Most companies in the database separated such revenue. Software revenue also was eliminated when it was broken out as a separate line item or if additional information indicated a percentage.

These gray areas appeared in only a portion of the companies in the database. Because Dataquest dealt with them using the standards just described, we believe that this sample of companies provides a thorough and useful alternative (to more aggregate production data) snapshot of activity in the six application market segments that affect semiconductor consumption. The strength of this database lies in its power to identify and examine broad electronic system production trends with respect to specific companies. As additional years' data accumulate, we can examine the link between electronic equipment production and semiconductor consumption more closely and analyze their historical effects on each other.

Table 1

Data Processing Equipment-Derived Revenue by Company 1979 to 1989 (Millions of Dollars)

Company	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Allied-Signal	0	0	0	0	0	0	0	0	0	0	0
Amdahl	NA	NA	NA	NA	692	550	584	696	1,174	1,442	1,723
Apple Computer	48	113	325	533	873	1,301	1,668	1,807	2,645	3,940	5,210
AT&T	0	0	0	0	0	96	592	721	459	890	1,000
Boeing	0	0	0	0	0	0	0	0	0	0	0
Chrysler	0	0	0	0	0	0	0	0	0	0	0
Compaq Computer	0	0	0	0	111	329	504	625	1,224	2,066	2,876
Control Data	1,148	1,473	1,660	1,699	1,916	2,128	2,246	1,880	1,870	1,626	1,216
Data General	439	549	589	617	596	884	912	919	850	914	875
Digital Equipment	1,382	1,779	2,384	2,794	2,854	3,796	4,266	4,753	5,479	6,269	6,867
Emerson Electric	0	0	0	0	0	0	0	0	0	0	0
E-Systems	0	0	0	0	0	0	0	0	0	0	0
Ford Motor	0	0	0	0	0	0	0	0	0	0	0
General Dynamics	0	0	0	0	0	0	0	0	0	0	0
General Electric	0	0	0	0	0	0	0	0	0	0	0
General Instrument	NA	NA	NA	NA	NA	NA	NA	NA	135	221	318
GM Hughes	0	0	0	0	0	0	0	0	0	0	0
GTE	0	0	0	0	0	0	0	0	0	0	0
Harris[1]	366	464	556	622	656	679	327	295	223	229	356
Hewlett-Packard	848	1,208	1,386	1,694	1,936	2,234	2,405	2,809	3,199	4,174	5,223
Honeywell	748	828	895	788	778	936	1,081	940	0	0	0
IBM	12,050	14,124	15,808	18,850	22,164	28,341	34,690	32,954	33,909	36,239	36,369
Intel[2]	251	280	264	275	347	428	345	274	416	525	697
ITT	0	0	0	0	0	0	0	0	0	0	0
Kodak	533	652	681	767	721	857	788	932	1,048	1,181	1,260
Litton Industries	0	0	0	0	0	0	0	0	0	0	0
Lockheed	0	0	0	0	0	0	0	0	0	0	0
Loral	0	0	0	0	0	0	0	0	0	0	0
Martin-Marietta	0	0	0	0	0	0	0	0	0	0	0
McDonnell Douglas	NA	NA	NA	NA	167	162	175	206	211	189	0
Motorola	116	296	371	427	463	558	598	496	427	566	552
NCR	1,510	1,683	1,696	1,703	1,710	1,972	2,158	2,410	2,983	3,085	3,122
Pitney Bowes	NA	NA	NA	NA	NA	NA	1,386	1,506	1,726	1,956	2,119
Prime Computer	NA	NA	NA	NA	417	479	564	541	582	937	826
Raytheon	0	0	0	0	0	0	0	0	0	0	0
Rockwell International	0	0	0	0	0	0	0	0	0	0	0
Seagate Technology	0	0	0	0	0	344	215	460	958	1,266	1,372
Sun Microsystems	0	0	0	0	9	39	115	200	457	894	1,500
Tandem Computers	NA	NA	NA	NA	400	477	533	622	829	951	1,220

(Continued)

Table 1 (Continued)

Data Processing Equipment-Derived Revenue by Company 1979 to 1989 (Millions of Dollars)

Company	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Tandy	91	165	370	550	771	864	802	953	1,046	1,150	1,267
Tektronix	240	326	391	441	455	529	567	534	501	238	279
Texas Instruments[3]	759	888	958	1,024	962	963	862	789	769	851	900
3M	695	772	797	808	854	946	906	929	918	1,130	1,186
TRW	0	0	0	0	0	0	0	0	0	0	0
Unisys[4]	NA	NA	NA	NA	NA	NA	NA	1,953	3,670	3,737	3,861
Varian Associates	0	0	0	0	0	0	0	0	0	0	0
Wang Laboratories	NA	NA	NA	NA	1,793	2,270	2,254	1,600	1,690	1,701	1,493
Westinghouse Electric	0	0	0	0	0	0	0	0	0	0	0
Xerox[5]	2,390	3,043	3,410	3,289	3,695	4,282	4,318	4,822	5,702	6,174	6,696
Zenith Electronics[6]	38	104	120	132	172	249	352	548	1,036	1,356	0

[1] Data processing revenue restated back through 1985.
[2] Data processing revenue = Net Revenue (per annual report) less total semiconductor revenue (per Dataquest market share estimates).
[3] Data processing revenue restated back through 1987.
[4] Formerly Bouroughs, Sperry; merged in 1987. Revenue combined in prior years.
[5] Data processing revenue restated back through 1987.
[6] Data processing operation sold to Group Bull in December 1989.
NA = Not available
Source: Dataquest (October 1990)

Table 2

Communications Equipment-Derived Revenue by Company 1979 to 1989

Company	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Allied-Signal	0	0	0	0	0	0	0	0	0	0	0
Amdahl	NA	NA	NA	NA	65	80	81	47	70	90	63
Apple Computer	0	0	0	0	0	0	0	0	0	0	0
AT&T	5,954	6,467	7,306	7,770	8,429	10,093	10,002	8,676	8,875	9,005	9,042
Boeing	0	0	0	0	0	0	0	0	0	0	0
Chrysler	0	0	0	0	0	0	0	0	0	0	0
Compaq Computer	0	0	0	0	0	0	0	0	0	0	
Control Data	0	0	0	0	0	0	0	0	0	0	0
Data General	0	0	0	0	0	0	0	0	0	0	0
Digital Equipment	0	0	0	0	14	38	86	177	207	225	225
Emerson Electric	0	0	0	0	0	0	0	0	0	0	0
E-Systems	0	0	0	0	0	0	0	0	0	0	0
Ford Motor	0	0	0	0	0	0	0	0	0	0	0
General Dynamics	0	0	0	0	0	0	0	0	0	0	0
General Electric	104	160	164	220	218	228	239	771	828	1,064	1,091
General Instrument	NA	NA	NA	NA	NA	NA	NA	NA	764	794	817
GM Hughes	0	0	0	0	0	0	0	0	0	0	0
GTE	985	1,006	1,066	1,185	1,298	1,178	1,289	1,212	562	663	723
Harris*	232	245	306	397	391	369	301	291	243	250	350
Hewlett-Packard	0	0	0	0	0	0	0	0	0	0	0
Honeywell	0	0	0	0	0	0	0	0	0	0	0
IBM	0	0	0	0	0	0	600	900	1,100	1,600	3,000
Intel	0	0	0	0	0	0	0	0	0	0	0
ITT	0	0	0	0	0	0	0	0	0	0	0
Kodak	0	0	0	0	0	0	0	0	0	0	0
Litton Industries	0	0	0	0	0	0	0	0	0	0	0
Lockheed	0	0	0	0	0	0	0	0	0	0	0
Loral	0	0	0	0	0	0	0	0	0	0	0
Martin-Marietta	0	0	0	0	0	0	0	0	0	0	0
McDonnell Douglas	0	0	0	0	0	109	125	180	81	36	0
Motorola	845	1,156	1,328	1,405	1,490	1,891	2,118	2,637	2,981	3,754	4,587
NCR	0	0	0	0	0	0	0	0	0	0	0
Pitney Bowes	0	0	0	0	0	0	0	0	0	0	0
Prime Computer	0	0	0	0	0	0	0	0	0	0	0
Raytheon	0	0	0	0	0	0	0	0	0	0	0
Rockwell International	316	342	363	379	488	579	733	761	860	843	836
Seagate Technology	0	0	0	0	0	0	0	0	0	0	0
Sun Microsystems	0	0	0	0	0	0	0	0	0	0	0
Tandem Computers	0	0	0	0	0	0	0	0	0	140	150
Tandy	43	78	110	148	223	264	283	352	401	436	477

(Continued)

Table 2 (Continued)

Communications Equipment-Derived Revenue by Company 1979 to 1989

Company	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Tektronix	100	129	150	171	192	221	236	216	255	247	296
Texas Instruments	0	0	0	0	0	0	0	0	0	0	0
3M	0	0	0	0	0	0	0	0	0	0	0
TRW	0	0	0	0	0	0	0	0	0	0	0
Unisys	0	0	0	0	0	0	0	0	0	0	0
Varian Associates	0	0	0	0	0	0	0	0	0	0	0
Wang Laboratories	NA	NA	NA	NA	NA	0	0	68	90	96	80
Westinghouse Electric	0	0	0	0	0	0	0	0	0	0	0
Xerox	0	0	0	0	0	0	0	0	0	0	0
Zenith Electronics	0	8	27	64	122	146	53	58	73	90	90

*Communication revenue restated back through 1985.
NA = Not available
Source: Dataquest (October 1990)

Table 3

Industrial Equipment-Derived Revenue by Company 1979 to 1989

Company	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Allied-Signal	379	426	487	576	784	950	893	1,517	0	0	0
Amdahl	0	0	0	0	0	0	0	0	0	0	0
Apple Computer	0	0	0	0	0	0	0	0	0	0	0
AT&T	0	0	0	0	0	0	0	0	0	0	0
Boeing	0	0	0	0	0	0	0	0	0	0	0
Chrysler	0	0	0	0	0	0	0	0	0	0	0
Compaq Computer	0	0	0	0	0	0	0	0	0	0	0
Control Data	0	0	0	0	0	0	0	0	0	0	0
Data General	0	0	0	0	0	0	0	0	0	0	0
Digital Equipment	0	0	0	0	0	0	0	0	0	0	0
Emerson Electric	NA	NA	NA	NA	NA	NA	NA	NA	1,410	1,554	1,710
E-Systems	0	0	0	0	0	0	0	0	0	0	0
Ford Motor	0	0	0	0	0	0	0	0	0	0	0
General Dynamics	0	0	0	0	0	0	0	0	0	0	0
General Electric	714	895	1,127	1,467	1,586	2,303	2,564	3,356	3,854	5,303	5,348
General Instrument	0	0	0	0	0	0	0	0	0	0	0
GM Hughes	0	0	0	0	0	0	821	769	647	929	1,486
GTE	0	0	0	0	0	0	0	0	0	0	0
Harris	0	0	0	0	0	0	0	0	0	0	0
Hewlett-Packard	1,301	1,589	1,795	2,072	2,290	2,504	2,529	2,651	2,983	3,479	4,164
Honeywell	1,986	2,239	2,384	2,444	2,452	2,628	2,736	2,878	3,071	3,436	3,569
IBM	0	0	0	0	0	0	0	0	0	0	0
Intel	0	0	0	0	0	0	0	0	0	0	0
ITT[1]	2,111	1,869	1,877	1,754	1,657	1,813	983	748	741	839	960
Kodak	703	861	899	973	882	885	901	933	1,048	1,181	1,260
Litton Industries	749	933	988	992	952	1,054	861	940	997	1,280	1,411
Lockheed	0	0	0	0	0	0	0	0	0	0	0
Loral	0	0	0	0	0	0	0	0	0	0	0
Martin-Marietta	0	0	0	0	0	0	0	0	0	0	0
McDonnell Douglas	0	0	0	0	0	0	0	0	0	0	0
Motorola	19	21	22	25	32	39	40	42	44	42	41
NCR	0	0	0	0	0	0	0	0	0	0	0
Pitney Bowes	0	0	0	0	0	0	0	0	0	0	0
Prime Computer	0	0	0	0	0	0	0	0	0	0	0
Raytheon	0	0	0	0	0	0	0	0	0	0	0
Rockwell International[2]	351	369	384	403	424	455	669	1,076	1,080	1,249	1,389
Seagate Technology	0	0	0	0	0	0	0	0	0	0	0
Sun Microsystems	0	0	0	0	0	0	0	0	0	0	0
Tandem Computers	0	0	0	0	0	0	0	0	0	0	0
Tandy	0	0	0	0	0	0	0	0	0	0	0

(Continued)

Table 3 (Continued)

Industrial Equipment-Derived Revenue by Company 1979 to 1989

Company	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Tektronix	438	504	508	568	527	564	615	583	618	882	858
Texas Instruments	0	0	0	0	0	0	0	0	0	0	0
3M	219	265	292	300	305	319	323	353	398	479	501
TRW	0	0	0	0	0	0	0	0	0	0	0
Unisys	0	0	0	0	0	0	0	0	0	0	0
Varian Associates	268	327	358	369	403	544	590	472	531	679	816
Wang Laboratories	0	0	0	0	0	0	0	0	0	0	0
Westinghouse Electric	0	0	0	0	0	0	0	0	0	0	0
Xerox	0	0	0	0	0	0	0	0	0	0	0
Zenith Electronics	0	0	0	0	0	0	0	0	0	0	0

[1] Industrial revenue restated back through 1987.
[2] Industrial revenue restated back through 1985.
NA = Not available
Source: Dataquest (October 1990)

Table 4

Consumer Equipment-Derived Revenue by Company 1979 to 1989 (Millions of Dollars)

Company	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Allied-Signal	0	0	0	0	0	0	0	0	0	0	0
Amdahl	0	0	0	0	0	0	0	0	0	0	0
Apple Computer	0	0	0	0	0	0	0	0	0	0	0
AT&T	0	0	0	0	0	0	0	0	0	0	0
Boeing	0	0	0	0	0	0	0	0	0	0	0
Chrysler	0	0	0	0	0	0	0	0	0	0	0
Compaq Computer	0	0	0	0	0	0	0	0	0	0	0
Control Data	0	0	0	0	0	0	0	0	0	0	0
Data General	0	0	0	0	0	0	0	0	0	0	0
Digital Equipment	0	0	0	0	0	0	0	0	0	0	0
Emerson Electric	NA	NA	NA	NA	NA	NA	NA	NA	97	100	97
E-Systems	0	0	0	0	0	0	0	0	0	0	0
Ford Motor	0	0	0	0	0	0	0	0	0	0	0
General Dynamics	0	0	0	0	0	0	0	0	0	0	0
General Electric	4,347	4,274	4,460	3,973	4,246	4,853	5,549	7,144	7,746	5,289	5,620
General Instrument	0	0	0	0	0	0	0	0	0	0	0
GM Hughes	0	0	0	0	0	0	0	0	0	0	0
GTE	0	0	0	0	0	0	0	0	0	0	0
Harris	0	0	0	0	0	0	0	0	0	0	0
Hewlett-Packard	0	0	0	0	0	0	0	0	0	0	0
Honeywell	0	0	0	0	0	0	0	0	0	0	0
IBM	0	0	0	0	0	0	0	0	0	0	0
Intel	0	0	0	0	0	0	0	0	0	0	0
ITT	0	0	0	0	0	0	0	0	0	0	0
Kodak	874	1,069	1,117	1,180	1,042	1,023	1,126	1,242	1,398	1,575	1,680
Litton Industries	175	173	189	166	167	248	240	190	0	0	0
Lockheed	0	0	0	0	0	0	0	0	0	0	0
Loral	0	0	0	0	0	0	0	0	0	0	0
Martin-Marietta	0	0	0	0	0	0	0	0	0	0	0
McDonnell Douglas	0	0	0	0	0	0	0	0	0	0	0
Motorola	0	5	9	11	13	16	17	18	19	18	18
NCR	0	0	0	0	0	0	0	0	0	0	0
Pitney Bowes	0	0	0	0	0	0	0	0	0	0	0
Prime Computer	0	0	0	0	0	0	0	0	0	0	0
Raytheon	97	129	128	113	142	159	157	175	181	196	214
Rockwell International	0	0	0	0	0	0	0	0	0	0	0
Seagate Technology	0	0	0	0	0	0	0	0	0	0	0
Sun Microsystems	0	0	0	0	0	0	0	0	0	0	0
Tandem Computers	0	0	0	0	0	0	0	0	0	0	0

(Continued)

Table 4 (Continued)

Consumer Equipment-Derived Revenue by Company 1979 to 1989 (Millions of Dollars)

Company	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Tandy	859	881	985	896	983	1,067	1,186	1,363	1,540	1,696	1,865
Tektronix	0	0	0	0	0	0	0	0	0	0	0
Texas Instruments	0	0	0	0	0	0	0	0	0	0	0
3M	0	0	0	0	0	0	0	0	0	0	0
TRW	0	0	0	0	0	0	0	0	0	0	0
Unisys	0	0	0	0	0	0	0	0	0	0	0
Varian Associates	0	0	0	0	0	0	0	0	0	0	0
Wang Laboratories	0	0	0	0	0	0	0	0	0	0	0
Westinghouse Electric	0	0	0	0	0	0	0	0	0	0	0
Xerox	0	0	0	0	0	0	0	0	0	0	0
Zenith Electronics	1,012	1,003	1,041	939	923	1,062	1,062	1,154	1,026	1,039	1,178

NA = Not available
Source: Dataquest (October 1990)

Table 5

Military/Civil Aerospace Equipment-Derived Revenue by Company 1979 to 1989 (Millions of Dollars)

Company	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Allied-Signal[1]	545	641	734	745	815	850	475	745	820	825	908
Amdahl	0	0	0	0	0	0	0	0	0	0	0
Apple Computer	0	0	0	0	0	0	0	0	0	0	0
AT&T[1]	NA	NA	NA	NA	NA	NA	485	545	570	580	610
Boeing[2]	NA	NA	NA	NA	NA	NA	705	853	990	1,050	1,040
Chrysler	0	0	0	0	0	0	0	0	0	0	0
Compaq Computer	0	0	0	0	0	0	0	0	0	0	0
Control Data	0	0	0	0	0	0	0	0	0	0	0
Data General	0	0	0	0	0	0	0	0	0	0	0
Digital Equipment	0	0	0	0	0	0	0	0	0	0	0
Emerson Electric[2]	NA	NA	NA	NA	NA	NA	555	561	545	552	540
E-Systems[1]	323	362	489	623	705	733	926	1,135	1,227	1,301	1,470
Ford Motor[2]	NA	NA	NA	NA	NA	NA	1,100	1,165	1,200	1,180	1,210
General Dynamics	NA	NA	NA	NA	NA	NA	1,120	1,210	1,175	1,182	1,165
General Electric[1]	714	1,549	1,878	2,079	2,237	2,509	3,215	3,818	4,209	4,273	4,215
General Instrument	0	0	0	0	0	0	0	0	0	0	0
GM Hughes[2]	0	0	0	0	0	0	5,128	5,635	5,847	6,060	5,664
GTE[1]	585	597	634	707	736	719	787	1,050	1,100	1,145	1,080
Harris[1]	218	263	307	399	529	630	1,025	1,030	1,100	1,080	1,155
Hewlett-Packard[2]	0	0	0	0	0	0	0	0	0	0	0
Honeywell[2]	499	598	662	755	878	918	1,119	1,219	1,899	1,840	2,004
IBM[1]	525	555	617	737	1,110	1,412	1,501	1,821	2,130	1,977	1,921
Intel	0	0	0	0	0	0	0	0	0	0	0
ITT[1]	768	703	797	992	1,020	1,213	1,122	1,279	1,280	839	960
Kodak	0	0	0	0	0	0	0	0	0	0	0
Litton Industries[1]	587	741	977	996	1,338	1,588	1,916	2,172	2,231	2,291	2,143
Lockheed[1]	1,321	1,802	2,196	2,673	2,776	3,735	2,243	2,519	3,169	3,184	3,054
Loral	NA	NA	NA	NA	NA	NA	472	625	638	1,072	1,121
Martin-Marietta[1]	1,049	1,062	1,474	1,668	1,775	2,156	1,571	1,745	1,869	2,078	2,238
McDonnell Douglas[1]	400	459	559	556	618	736	330	378	435	480	495
Motorola[2]	176	227	236	245	369	441	496	526	540	648	698
NCR	0	0	0	0	0	0	0	0	0	0	0
Pitney Bowes	0	0	0	0	0	0	0	0	0	0	0
Prime Computer	0	0	0	0	0	0	0	0	0	0	0
Raytheon[1]	1,500	1,649	1,946	2,160	2,614	2,959	2,844	3,253	3,569	3,760	4,015
Rockwell International[1]	1,112	1,243	1,267	1,331	1,458	1,678	2,035	2,384	2,370	2,135	2,197
Seagate Technology	0	0	0	0	0	0	0	0	0	0	0
Sun Microsystems	0	0	0	0	0	0	0	0	0	0	0
Tandem Computers	0	0	0	0	0	0	0	0	0	0	0

(Continued)

Table 5 (Continued)

Military/Civil Aerospace Equipment-Derived Revenue by Company 1979 to 1989 (Millions of Dollars)

Company	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Tandy	0	0	0	0	0	0	0	0	0	0	0
Tektronix	0	0	0	0	0	0	0	0	0	0	0
Texas Instruments[1]	545	738	876	1,059	1,204	1,392	1,480	1,717	1,967	2,142	2,148
3M	0	0	0	0	0	0	0	0	0	0	0
TRW[1]	854	1,003	1,202	1,253	1,479	1,551	2,370	2,434	2,906	2,985	2,990
Unisys[2]	NA	NA	NA	NA	NA	NA	NA	2,765	2,354	2,365	2,255
Varian Associates	0	0	0	0	0	0	0	0	0	0	0
Wang Laboratories	0	0	0	0	0	0	0	0	0	0	0
Westinghouse Electric[1]	652	810	912	1,524	1,561	1,640	1,605	1,720	1,807	1,936	1,982
Xerox	0	0	0	0	0	0	0	0	0	0	0
Zenith Electronics	0	0	0	0	0	0	0	0	0	0	0

[1]Revenue restated back through 1985 per Dataquest's MilAero Service.
[2]As per Dataquest's MilAero Service.
NA = Not available
Source: Dataquest (October 1990)

Table 6

Transportation Equipment-Derived Revenue by Company 1979 to 1989 (Millions of Dollars)

Company	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Allied-Signal	199	200	218	225	237	263	205	287	355	410	385
Amdahl	0	0	0	0	0	0	0	0	0	0	0
Apple Computer	0	0	0	0	0	0	0	0	0	0	0
AT&T	0	0	0	0	0	0	0	0	0	0	0
Boeing	0	0	0	0	0	0	0	0	0	0	0
Chrysler	NA	NA	NA	NA	NA	NA	NA	NA	700	845	846
Compaq Computer	0	0	0	0	0	0	0	0	0	0	0
Control Data	0	0	0	0	0	0	0	0	0	0	0
Data General	0	0	0	0	0	0	0	0	0	0	0
Digital Equipment	0	0	0	0	0	0	0	0	0	0	0
Emerson Electric	0	0	0	0	0	0	0	0	0	0	0
E-Systems	0	0	0	0	0	0	0	0	0	0	0
Ford Motor	0	0	0	0	0	0	734	951	1,200	1,308	1,360
General Dynamics	0	0	0	0	0	0	0	0	0	0	0
General Electric	0	0	0	0	0	0	0	0	0	0	0
General Instrument	0	0	0	0	0	0	0	0	0	0	0
GM Hughes	0	0	0	0	0	0	3,061	3,180	3,216	3,800	4,000
GTE	0	0	0	0	0	0	0	0	0	0	0
Harris	0	0	0	0	0	0	0	0	0	0	0
Hewlett-Packard	0	0	0	0	0	0	0	0	0	0	0
Honeywell	0	0	0	0	0	0	0	0	0	0	0
IBM	0	0	0	0	0	0	0	0	0	0	0
Intel	0	0	0	0	0	0	0	0	0	0	0
ITT	768	735	735	730	786	923	784	1,014	1,176	1,346	1,426
Kodak	0	0	0	0	0	0	0	0	0	0	0
Litton Industries	0	0	0	0	0	0	0	0	0	0	0
Lockheed	0	0	0	0	0	0	0	0	0	0	0
Loral	0	0	0	0	0	0	0	0	0	0	0
Martin-Marietta	0	0	0	0	0	0	0	0	0	0	0
McDonnell Douglas	0	0	0	0	0	0	0	0	0	0	0
Motorola	159	201	203	223	250	294	288	302	314	301	292
NCR	0	0	0	0	0	0	0	0	0	0	0
Pitney Bowes	0	0	0	0	0	0	0	0	0	0	0
Prime Computer	0	0	0	0	0	0	0	0	0	0	0
Raytheon	0	0	0	0	0	0	0	0	0	0	0
Rockwell International	0	0	0	0	0	0	0	0	0	0	0
Seagate Technology	0	0	0	0	0	0	0	0	0	0	0
Sun Microsystems	0	0	0	0	0	0	0	0	0	0	0
Tandem Computers	0	0	0	0	0	0	0	0	0	0	0

(Continued)

Table 6 (Continued)

Transportation Equipment-Derived Revenue by Company 1979 to 1989 (Millions of Dollars)

Company	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Tandy	0	0	0	0	0	0	0	0	0	0	0
Tektronix	0	0	0	0	0	0	0	0	0	0	0
Texas Instruments	0	0	0	0	0	0	0	0	0	0	0
3M	0	0	0	0	0	0	0	0	0	0	0
TRW	944	920	888	806	937	935	977	1,077	1,224	1,995	2,233
Unisys	0	0	0	0	0	0	0	0	0	0	0
Varian Associates	0	0	0	0	0	0	0	0	0	0	0
Wang Laboratories	0	0	0	0	0	0	0	0	0	0	0
Westinghouse Electric	0	0	0	0	0	0	0	0	0	0	0
Xerox	0	0	0	0	0	0	0	0	0	0	0
Zenith Electronics	0	0	0	0	0	0	0	0	0	0	0

NA = Not available
Source: Dataquest (October 1990)

Table 7

Total Electronic Equipment-Derived Revenue by Company 1979 to 1989 (Millions of Dollars)

Company	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Allied-Signal	1,123	1,267	1,439	1,546	1,836	2,063	1,573	2,549	1,175	1,235	1,293
Amdahl	NA	NA	NA	NA	757	630	665	743	1,244	1,532	1,786
Apple Computer	48	113	325	533	873	1,301	1,668	1,807	2,645	3,940	5,210
AT&T	NA	NA	NA	NA	NA	NA	11,079	9,942	9,904	10,475	10,652
Boeing	NA	NA	NA	NA	NA	NA	705	853	990	1,050	1,040
Chrysler	NA	NA	NA	NA	NA	NA	NA	NA	700	845	846
Compaq Computer	0	0	0	0	111	329	504	625	1,224	2,066	2,876
Control Data	1,148	1,473	1,660	1,699	1,916	2,128	2,246	1,880	1,870	1,626	1,216
Data General	439	549	589	617	596	884	912	919	850	914	875
Digital Equipment	1,382	1,779	2,384	2,794	2,868	3,834	4,352	4,930	5,686	6,494	7,092
Emerson Electric	NA	NA	NA	NA	NA	NA	NA	NA	2,052	2,206	2,347
E-Systems	323	362	489	623	705	733	926	1,135	1,227	1,301	1,470
Ford Motor	NA	NA	NA	NA	NA	NA	1,834	2,116	2,400	2,488	2,570
General Dynamics	NA	NA	NA	NA	NA	NA	1,120	1,210	1,175	1,182	1,165
General Electric	5,879	6,878	7,629	7,739	8,287	9,893	11,567	15,089	16,637	15,929	16,274
General Instrument	NA	NA	NA	NA	NA	NA	NA	NA	899	1,015	1,135
GM Hughes	0	0	0	0	0	0	9,010	9,584	9,710	10,789	11,150
GTE	1,570	1,603	1,700	1,892	2,034	1,897	2,076	2,262	1,662	1,808	1,803
Harris	816	972	1,169	1,418	1,576	1,678	1,653	1,616	1,566	1,559	1,861
Hewlett-Packard	2,149	2,797	3,181	3,766	4,226	4,738	4,934	5,460	6,182	7,653	9,387
Honeywell	3,233	3,665	3,941	3,987	4,108	4,482	4,936	5,037	4,970	5,276	5,573
IBM	12,575	14,679	16,425	19,587	23,274	29,753	36,791	35,675	37,139	39,816	41,290
Intel	251	280	264	275	347	428	345	274	416	525	697
ITT	3,647	3,307	3,409	3,476	3,463	3,949	2,889	3,041	3,197	3,024	3,346
Kodak	2,110	2,582	2,697	2,920	2,645	2,765	2,815	3,107	3,494	3,937	4,200
Litton Industries	1,511	1,847	2,154	2,154	2,457	2,890	3,017	3,302	3,228	3,571	3,554
Lockheed	1,321	1,802	2,196	2,673	2,776	3,735	2,243	2,519	3,169	3,184	3,054
Loral	NA	NA	NA	NA	NA	NA	472	625	638	1,072	1,121
Martin-Marietta	1,049	1,062	1,474	1,668	1,775	2,156	1,571	1,745	1,869	2,078	2,238
McDonnell Douglas	NA	NA	NA	NA	785	1,007	630	764	727	705	495
Motorola	1,315	1,906	2,169	2,336	2,617	3,239	3,557	4,021	4,325	5,329	6,188
NCR	1,510	1,683	1,696	1,703	1,710	1,972	2,158	2,410	2,983	3,085	3,122
Pitney Bowes	NA	·NA	NA	NA	NA	NA	1,386	1,506	1,726	1,956	2,119
Prime Computer	NA	NA	NA	NA	417	479	564	541	582	937	826
Raytheon	1,597	1,778	2,074	2,273	2,756	3,118	3,001	3,428	3,750	3,956	4,229
Rockwell International	1,779	1,954	2,014	2,113	2,370	2,712	3,437	4,221	4,310	4,227	4,422

(Continued)

Table 7 (Continued)

Total Electronic Equipment-Derived Revenue by Company 1979 to 1989 (Millions of Dollars)

Company	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Seagate Technology	0	0	0	0	0	344	215	460	958	1,266	1,372
Sun Microsystems	0	0	0	0	9	39	115	200	457	894	1,500
Tandem Computers	NA	NA	NA	NA	400	477	533	622	829	1,091	1,370
Tandy	993	1,124	1,465	1,594	1,977	2,195	2,271	2,668	2,987	3,282	3,609
Tektronix	778	959	1,049	1,180	1,174	1,314	1,418	1,333	1,374	1,367	1,433
Texas Instruments	1,304	1,626	1,834	2,083	2,166	2,355	2,342	2,506	2,736	2,993	3,048
3M	914	1,037	1,089	1,108	1,159	1,265	1,229	1,282	1,316	1,609	1,687
TRW	1,798	1,923	2,090	2,059	2,416	2,486	3,347	3,511	4,130	4,980	5,223
Unisys*	NA	NA	NA	NA	NA	NA	NA	4,718	6,024	6,102	6,116
Varian Associates	268	327	358	369	403	544	590	472	531	679	816
Wang Laboratories	NA	NA	NA	NA	1,793	2,270	2,254	1,668	1,780	1,797	1,573
Westinghouse Electric	652	810	912	1,524	1,561	1,640	1,605	1,720	1,807	1,936	1,982
Xerox	2,390	3,043	3,410	3,289	3,695	4,282	4,318	4,822	5,702	6,174	6,696
Zenith Electronics	1,050	1,115	1,188	1,135	1,217	1,457	1,467	1,760	2,135	2,485	1,268

*Formerly Bouroughs, Sperry; merged in 1987. Revenue combined in prior years.
NA = Not available
Source: Dataquest (October 1990)

Table 8

Total Equipment Plus Semiconductor-Derived Revenue by Company 1979 to 1989 (Millions of Dollars)

Company	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Allied-Signal	1,123	1,267	1,439	1,546	1,836	2,063	1,573	2,549	1,175	1,235	1,293
Amdahl	NA	NA	NA	NA	757	630	665	743	1,244	1,532	1,786
Apple Computer	48	113	325	533	873	1,301	1,668	1,807	2,645	3,940	5,210
AT&T	NA	NA	NA	NA	NA	NA	11,079	10,835	10,706	11,334	11,525
Boeing	NA	NA	NA	NA	NA	NA	705	853	990	1,050	1,040
Chrysler	NA	NA	NA	NA	NA	NA	NA	NA	700	845	846
Compaq Computer	0	0	0	0	111	329	504	625	1,224	2,066	2,876
Control Data	1,148	1,473	1,660	1,699	1,916	2,128	2,246	1,880	1,870	1,626	1,216
Data General	439	549	589	617	596	884	912	919	850	914	875
Digital Equipment	1,382	1,779	2,384	2,794	2,868	3,834	4,352	4,930	5,686	6,494	7,092
Emerson Electric	NA	NA	NA	NA	NA	NA	NA	NA	2,052	2,206	2,347
E-Systems	323	362	489	623	705	733	926	1,135	1,227	1,301	1,470
Ford Motor	NA	NA	NA	NA	NA	NA	1,834	2,116	2,400	2,488	2,570
General Dynamics	NA	NA	NA	NA	NA	NA	1,120	1,210	1,175	1,182	1,165
General Electric	NA	NA	7,750	7,841	8,402	10,029	11,685	15,610	17,157	16,484	16,274
General Instrument	NA	NA	NA	NA	NA	NA	NA	NA	899	1,015	1,135
GM Hughes	NA	NA	NA	NA	NA	NA	9,046	9,623	9,753	10,836	11,187
GTE	1,570	1,603	1,726	1,924	2,053	1,921	2,103	2,284	1,686	1,808	1,803
Harris	816	972	1,334	1,574	1,747	1,934	1,900	1,883	1,841	1,888	2,691
Hewlett-Packard	2,149	2,797	3,273	3,868	4,356	4,920	5,140	5,678	6,425	7,923	9,656
Honeywell	3,233	3,665	3,959	4,007	4,132	4,546	5,024	5,174	5,157	5,458	5,629
IBM	12,575	14,679	16,425	19,587	23,274	29,753	36,791	35,675	37,139	39,816	41,290
Intel	661	855	789	900	1,122	1,629	1,365	1,265	1,907	2,875	3,127
ITT	3,647	3,307	3,584	3,666	3,648	4,199	3,159	3,353	3,554	3,384	3,736
Kodak	2,110	2,582	2,697	2,920	2,645	2,765	2,815	3,107	3,494	3,937	4,200
Litton Industries	1,511	1,847	2,154	2,154	2,457	2,890	3,017	3,302	3,228	3,571	3,554
Lockheed	1,321	1,802	2,196	2,673	2,776	3,735	2,243	2,519	3,169	3,184	3,054
Loral	NA	NA	NA	NA	NA	NA	472	625	638	1,072	1,121
Martin-Marietta	1,049	1,062	1,474	1,668	1,775	2,156	1,571	1,745	1,869	2,078	2,238
McDonnell Douglas	NA	NA	NA	NA	785	1,007	630	764	727	705	495
Motorola	1,315	1,906	3,359	3,555	4,264	5,558	5,387	6,046	6,759	8,364	9,507
NCR	1,510	1,683	1,696	1,731	1,785	2,052	2,233	2,504	3,099	3,217	3,242
Pitney Bowes	NA	NA	NA	NA	NA	NA	1,386	1,506	1,726	1,956	2,119
Prime Computer	NA	NA	NA	NA	417	479	564	541	582	937	826
Raytheon	1,597	1,778	2,125	2,325	2,821	3,213	3,080	3,512	3,839	4,055	4,325

(Continued)

Table 8 (Continued)

Total Equipment Plus Semiconductor-Derived Revenue by Company 1979 to 1989 (Millions of Dollars)

Company	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Rockwell International	1,779	1,954	2,084	2,193	2,427	2,769	3,481	4,345	4,482	4,401	4,587
Seagate Technology	0	0	0	0	0	344	215	460	958	1,266	1,372
Sun Microsystems	0	0	0	0	9	39	115	200	457	894	1,500
Tandem Computers	NA	NA	NA	NA	400	477	533	622	829	1,091	1,370
Tandy	993	1,124	1,465	1,594	1,977	2,195	2,271	2,668	2,987	3,282	3,609
Tektronix	778	959	1,049	1,180	1,174	1,314	1,418	1,333	1,374	1,367	1,433
Texas Instruments	1,304	1,626	3,129	3,388	3,804	4,839	4,084	4,287	4,863	5,734	5,835
3M	914	1,037	1,089	1,108	1,159	1,265	1,229	1,282	1,316	1,609	1,687
TRW	1,798	1,923	2,204	2,175	2,534	2,633	3,472	3,616	4,247	5,041	5,250
Unisys	NA	NA	NA	NA	NA	NA	NA	4,718	6,024	6,102	6,116
Varian Associates	268	327	358	369	403	544	590	472	531	679	816
Wang Laboratories	NA	NA	NA	NA	1,793	2,270	2,254	1,668	1,780	1,797	1,573
Westinghouse Electric	652	810	971	1,577	1,619	1,692	1,657	1,720	1,807	1,936	1,982
Xerox	2,390	3,043	3,410	3,289	3,695	4,282	4,318	4,822	5,702	6,174	6,696
Zenith Electronics	1,050	1,115	1,188	1,135	1,217	1,457	1,467	1,760	2,135	2,485	1,268

NA = Not available
Source: Dataquest (October 1990)

Table 9

Total Revenue by Company 1979 to 1989 (Millions of Dollars)

Company	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Allied-Signal	7,480	9,164	10,511	9,414	8,159	8,864	8,183	9,888	11,116	11,909	11,942
Amdahl	NA	NA	NA	NA	NA	NA	862	966	1,505	1,802	2,101
Apple Computer	48	117	335	583	983	1,516	1,918	1,902	2,661	4,071	5,284
AT&T[1]	19,208	20,861	23,567	25,064	27,190	33,187	34,496	34,213	33,768	35,210	36,112
Boeing	NA	NA	NA	NA	NA	NA	13,745	16,444	15,505	16,962	20,276
Chrysler	NA	NA	NA	NA	NA	NA	21,256	22,586	25,293	30,526	30,567
Compaq Computer	0	0	0	0	111	329	504	625	1,224	2,066	2,876
Control Data	2,249	2,772	3,120	3,301	3,408	3,693	3,680	3,347	3,367	3,628	2,935
Data General	507	654	737	806	829	1,161	1,239	1,268	1,274	1,365	1,314
Digital Equipment	1,804	2,368	3,198	3,881	4,272	5,584	6,686	7,590	9,389	11,475	12,742
Emerson Electric	NA	3,410	3,846	3,807	3,810	4,587	4,921	5,242	6,170	6,652	7,071
E-Systems	394	442	572	754	827	819	949	1,135	1,227	1,439	1,626
Ford Motor	NA	NA	NA	NA	NA	56,323	57,616	69,695	79,893	92,446	96,146
General Dynamics	3,314	4,100	4,524	5,937	6,841	7,328	7,993	8,959	9,412	9,551	10,043
General Electric	22,461	24,959	27,240	26,500	26,797	27,947	29,240	36,728	40,515	40,292	42,650
General Instrument	NA	NA	NA	NA	NA	NA	612	788	1,155	1,305	1,377
GM Hughes[2]	0	0	0	0	0	0	9,504	10,440	10,481	11,244	11,359
GTE	8,499	9,486	10,506	11,500	12,237	13,248	14,372	15,112	15,421	16,460	17,424
Harris[3]	NA	976	1,121	1,301	1,467	1,671	1,967	1,907	1,797	1,798	2,214
Hewlett-Packard	2,361	3,099	3,528	4,189	4,710	6,044	6,505	7,102	8,090	9,831	11,899
Honeywell[4]	4,270	4,870	5,261	5,387	4,241	3,888	4,209	4,475	5,590	5,857	6,059
IBM[1]	22,863	26,213	29,070	34,364	40,180	45,937	50,718	52,160	55,256	59,681	62,710
Intel	661	855	789	900	1,122	1,629	1,365	1,265	1,907	2,875	3,127
ITT[5]	21,996	23,819	23,197	21,921	20,249	19,553	13,781	16,271	18,195	19,355	20,054
Kodak	8,028	9,734	10,337	10,815	10,170	10,600	10,631	11,550	13,305	17,304	18,398
Litton Industries	3,066	3,294	3,978	4,124	3,959	4,606	4,591	4,521	4,420	4,864	5,023
Lockheed[1]	3,532	4,445	5,176	5,613	6,154	7,881	9,223	9,942	11,078	10,433	9,891
Loral	201	238	282	310	418	502	664	676	1,136	1,187	1,274
Martin Marietta[1]	1,908	1,930	2,680	3,033	3,228	3,920	4,421	4,763	5,173	5,727	5,796
McDonnell Douglas	5,332	6,125	7,454	7,412	8,424	9,819	11,618	12,772	13,289	14,438	14,589
Motorola	2,700	3,284	3,570	3,786	4,328	5,534	5,456	5,905	6,727	8,250	9,620
NCR	3,003	3,322	3,433	3,526	3,731	4,074	4,317	4,882	5,641	5,990	5,956
Pitney Bowes	NA	NA	NA	NA	NA	NA	1,787	1,989	2,270	2,576	2,876
Prime Computer	153	268	365	436	517	643	770	860	961	1,595	1,520
Raytheon	4,177	4,775	5,384	5,217	5,631	5,996	6,409	7,308	7,659	8,192	8,796
Rockwell International	6,176	6,907	7,040	7,395	8,098	9,322	11,338	12,296	12,123	11,946	12,518
Seagate Technology	NA	NA	NA	NA	NA	344	215	460	958	1,266	1,372
Sun Microsystems	0	0	0	0	9	39	115	210	538	1,052	1,765
Tandem Computers	NA	NA	NA	NA	NA	NA	636	778	1,048	1,315	1,633
Tandy	1,216	1,387	1,699	1,832	2,241	2,490	2,596	3,036	3,452	3,794	4,181
Tektronix	787	971	1,062	1,196	1,191	1,333	1,438	1,352	1,396	1,412	1,433

(Continued)

Table 9 (Continued)

Total Revenue by Company 1979 to 1989 (Millions of Dollars)

Company	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Texas Instruments[1]	3,224	4,075	4,206	4,327	4,580	5,742	4,930	4,988	5,816	6,447	6,522
3M[4]	5,440	6,080	6,508	6,601	7,039	7,947	8,117	9,056	10,004	11,323	11,990
TRW	3,967	4,336	4,597	4,452	4,840	5,369	5,917	6,036	6,821	6,982	7,340
Unisys[6]	NA	NA	NA	NA	NA	NA	NA	7,431	9,732	9,935	10,097
Varian Associates	400	510	598	656	724	884	936	891	983	1,171	1,344
Wang Laboratories	321	543	856	1,158	1,535	2,174	2,331	2,607	2,724	2,915	2,869
Westinghouse Electric[1]	7,443	8,514	9,368	9,745	9,533	10,265	11,269	11,370	11,332	12,500	12,844
Xerox[2]	6,715	7,786	8,316	8,073	10,274	11,242	11,761	13,046	15,108	16,441	17,635
Zenith Electronics	1,186	1,186	1,275	1,239	1,361	1,716	1,624	1,892	2,363	2,686	1,549

NA = Not available
[1] Total revenue restated back through 1985 per 1989 annual report.
[2] Total revenue restated back through 1987 per 1989 annual report.
[3] Total revenue restated back through 1980.
[4] Total revenue restated back through 1984 per 1989 annual report.
[5] Total revenue restated back through 1985.
[6] Total revenue restated back through 1986 per 1989 annual report.
Source: Dataquest (October 1990)

Electronic Equipment Forecast

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

- Overview--Electronic Equipmnt Forecast
- Electronic Equipment Forecast

NOTE: The arrow symbol indicates the latest document(s) correct location behind this subject tab.

Overview—Electronic Equipment Forecast

This section presents the methodology used in structuring the forecast data on North American electronic equipment production, describes the organization of the tables, and provides the complete equipment database.

METHODOLOGY

The Electronic Equipment Forecast provides detailed information on the estimated production of electronic equipment in North America for the years 1983 through 1994. This set of tables is the second of two major databases upon which the forecast of semiconductor consumption by application market is based.

The equipment shipment data presented here are used in conjunction with input/output ratios to generate semiconductor consumption estimates by application market. (For a more in-depth discussion on this subject, see the Input/Output Ratios section behind the tab entitled "Introduction.")

The first database, located behind the tab entitled "Company Electronic Equipment Revenue" presents the electronic equipment revenue of various electronic equipment manufacturers. These data provide historical trend information on North American equipment manufacturers and serve as an important input for developing the I/O ratios that we use in our analysis.

Within SAM, Dataquest uses the term "North American shipments" to refer to the value of equipment *produced* in North America. In this context, "shipments" does not refer to the value of products consumed or purchased within the U.S. market.

Data reflecting production in North America are used in this database on the assumption that North American regional semiconductor consumption is more accurately forecast based on the current production of North American electronic equipment and the forecast growth rates of individual equipment types. Much of the currently available data on semiconductor consumption by application market were obtained through surveys of semiconductor manufacturers, and this tends to give a view one step removed from the geographic markets. These latter data indicate the percentage of a semiconductor manufacturer's sales by application area, such as data processing or industrial, but do not indicate in what geographical areas the sales were made, or if they were to North American, Far Eastern, or Western European equipment manufacturers.

For example, typical breakouts of semiconductor consumption obtained from U.S. semiconductor manufacturers often indicate as much as 20 percent of the semiconductors going to consumer applications. When one looks at the percentage of North American-manufactured electronic equipment that is of a consumer type, one sees a very different picture. Dataquest estimates that, although there is a large and volatile consumer electronic equipment market in the United States, consumer electronics account for less than 10 percent of the total electronic equipment produced by North American manufacturers.

North American production statistics are gathered from a variety of sources. The major components of the database are Dataquest's Industry Services and the U.S. Department of Commerce Current Industrial Reports. Other sources include industry contacts, trade association data, and foreign government data.

Dataquest's Industry Services report equipment revenue in terms of factory revenue. Because many of the I/O ratios are developed from information on North American manufacturers' equipment revenue and semiconductor consumption, they may not reflect actual end-user cost due to the variety of potential distribution channels and distributor discounts. For example, revenue reported by a small computer manufacturer that sells to a retailer such as Computerworld may not reflect the actual end-user cost of the equipment, and the I/O ratios derived for that company would be overstated. At present, an informal look into this area indicates that the actual differences in I/Os developed when taking into account the range of companies that have lengthy distribution channels balanced compared with those that sell direct did not significantly impact the long-term forecast of semiconductors consumed.

ORGANIZATION OF THE ELECTRONIC EQUIPMENT FORECAST TABLES

The equipment forecast section contains a series of tables presenting the current and forecast shipments of electronic equipment produced in North America, by application market segment and by individual type of equipment. The first table in the series is an application market segment overview. The overview table presents a condensed version of each of the six segments: data processing, communications, industrial, consumer, military, and transportation. For each segment, the major equipment subcategories are shown. For example, communications has five subsegments: customer premises, public telecommunication, radio, broadcast and studio, and other.

The segment overview is followed by detailed tables—one for each of the six segments. For example, the communications segment has its own table, with the subsegments broken down into detailed equipment types and accompanied by their respective forecasts. To provide flexibility, all equipment types are presented as line items. Where possible, as in the case of medical electronic equipment in the industrial segment, we have supplied subtotals that make it easy to extract and relocate particular equipment types. Line-item values and subtotals are provided for the convenience of notebook users who may require more than six segments, or who need to reconfigure any of the segments to meet individual market segmentation requirements.

The percent growth in equipment in 1990 as well as the CAGR from 1989 through 1994 are calculated in the detail tables. A discussion of the overall assumptions made in developing Dataquest's entire analysis of semiconductor consumption by application market, including segmentation and definitions of specific equipment types, is located behind the Introduction tab of this binder.

Electronic Equipment Forecast

Table 1a

North American Electronic Equipment Production Segment Overview History (Millions of Dollars)

Equipment Type	1983	1984	1985	1986	1987	1988	1989
Computers	37,365	49,449	55,563	56,479	62,788	68,769	74,757
Data Storage/ Subsystems (Total)	5,711	7,388	9,598	11,792	11,882	16,120	17,998
Data Storage/Subsystems (Net)	5,711	7,338	9,598	11,792	11,082	13,200	14,940
Terminals	3,247	3,662	6,781	3,607	3,448	3,110	2,584
Input/Output	7,112	7,649	7,348	7,543	9,216	10,541	11,336
Dedicated Systems	4,836	5,546	5,829	5,404	5,315	5,375	5,324
Data Processing	58,271	73,644	85,119	84,825	91,849	100,995	108,941
Premise Telecom Equipment	6,513	7,681	8,623	9,124	9,940	11,046	12,517
Public Telecommunications	4,511	5,117	5,886	6,144	6,336	6,887	7,175
Mobile Communications Equip.	3,118	4,073	4,399	4,712	5,392	5,985	6,418
Broadcast & Studio	1,415	1,436	1,467	1,492	1,780	1,965	2,145
Other Telecom	892	1,174	1,544	1,442	1,541	1,600	1,660
Communications	16,449	19,481	21,919	22,914	24,989	27,483	29,915
Security/Energy Management	1,997	1,960	1,967	2,069	2,211	2,393	2,506
Manufacturing Systems	10,027	12,712	13,182	12,781	13,380	15,200	16,286
Instrumentation	5,607	6,461	6,571	6,570	7,180	7,774	8,122
Medical Equipment	4,740	4,880	4,759	5,002	5,345	5,785	6,117
Civil Aerospace	1,764	5,763	6,454	6,906	6,930	7,116	8,149
Other Industrial	3,456	3,889	4,102	4,364	4,777	5,356	5,719
Industrial	27,591	35,665	37,035	37,692	39,823	43,624	46,899
Audio	270	246	252	269	269	279	285
Video	4,969	5,308	5,284	5,232	5,522	5,628	5,749
Personal Electronics	1,048	473	331	235	249	241	239
Appliances	8,942	10,172	10,889	11,673	12,672	12,830	13,147
Other Consumer	509	647	810	897	945	992	1,037
Consumer	15,738	16,846	17,566	18,306	19,657	19,970	20,457
Military	0	0	47,300	49,370	50,932	51,063	51,727
Transportation	5,547	7,441	8,480	9,580	10,199	10,744	11,292
Total	123,596	153,077	217,419	222,687	237,449	253,879	269,231

Source: Dataquest March 1990

Table 1b

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

Equipment Type	Actual 1989	1990	1991	Estimated 1992	1993	1994	CAGR 1989-1990	CAGR 1989-1994
Computers	74,757	80,892	88,073	96,980	105,998	115,910	8.2%	9.2%
Data Storage/ Subsystems (Total)	17,998	19,736	20,254	21,262	23,077	24,144	9.7%	6.1%
Data Storage/ Subsystems (Net)	14,940	16,410	16,545	16,913	17,979	18,273	9.8%	4.1%
Terminals	2,584	2,081	1,712	1,446	1,238	1,173	(19.5%)	(14.6%)
Input/Output	11,336	12,281	13,287	14,339	15,560	17,034	8.3%	8.5%
Dedicated Systems	5,324	5,333	5,481	5,194	5,137	5,159	0.2%	(0.6%)
Data Processing	108,941	116,997	125,098	134,872	145,912	157,549	7.4%	7.7%
Premise Telecom Equipment	12,517	13,866	15,102	16,116	17,137	19,530	10.8%	9.3%
Public Telecommunications	7,175	7,590	8,019	8,870	9,666	10,328	5.8%	7.6%
Mobile Communications Equipment	6,418	6,748	7,083	7,400	7,746	8,092	5.1%	4.7%
Broadcast & Studio	2,145	2,315	2,465	2,615	2,765	2,915	7.9%	6.3%
Other Telecom	1,660	1,720	1,790	1,860	1,930	2,000	3.6%	3.8%
Communications	29,915	32,239	34,459	36,861	39,244	42,865	7.8%	7.5%
Security/Energy Management	2,506	2,639	2,822	3,020	3,203	3,397	5.3%	6.3%
Manufacturing Systems	16,286	16,965	18,538	20,106	21,484	22,976	4.2%	7.1%
Instrumentation	8,122	8,436	9,142	9,683	10,136	10,614	3.9%	5.5%
Medical Equipment	6,117	6,485	6,896	7,171	7,530	7,916	6.0%	5.3%
Civil Aerospace	8,149	9,411	10,807	12,228	13,694	15,347	15.5%	13.5%
Other Industrial	5,719	6,053	6,537	6,991	7,467	7,980	5.8%	6.9%
Idustrial	46,899	49,989	54,742	59,199	63,514	68,230	6.6%	7.8%
Audio	285	292	299	306	311	318	2.5%	2.2%
Video	5,749	5,864	6,014	6,206	6,432	6,708	2.0%	3.1%
Personal Electronics	239	240	241	239	239	239	0.4%	0
Appliances	13,147	13,512	13,918	14,317	14,650	14,950	2.8%	2.6%
Other Consumer	1,037	1,078	1,126	1,171	1,157	1,157	4.0%	2.2%
Consumer	20,457	20,986	21,598	22,239	22,789	23,372	2.6%	2.7%
Military	51,727	52,918	54,263	55,845	57,866	59,998	2.3%	3.0%
Transportation	11,292	11,828	12,897	13,952	14,836	15,449	4.7%	6.5%
Total	269,231	284,957	303,057	322,968	344,161	367,463	5.8%	6.4%

Source: Dataquest March 1990

Table 2a

North American Electronic Equipment Production
Data Processing History
(Millions of Dollars)

Equipment Type	1983	1984	1985	1986	1987	1988	1989
Corporate Resource	11,664	12,956	12,968	13,530	15,168	15,718	16,540
Business Unit	5,184	5,682	6,155	7,121	7,369	7,811	8,372
Large Department	6,287	7,030	7,475	7,139	6,970	8,033	8,456
Work Group & Small Dept.	7,019	10,061	11,708	12,303	13,391	14,346	15,216
Workstation	193	558	1,116	1,835	2,850	3,900	5,398
Personal Computer	7,018	13,162	16,141	14,551	17,040	18,961	20,775
Computers	37,365	49,449	55,563	56,479	62,788	68,769	74,757
14 Inch	2,248	3,139	3,223	3,891	4,239	4,680	4,593
8-10 Inch	943	1,188	1,630	1,927	2,220	2,623	3,060
5.25 Inch	681	1,299	1,760	2,611	2,783	3,185	3,192
3-4 Inch	7	48	96	322	969	1,805	2,990
Fixed Disk (Total)	3,879	5,674	6,709	8,751	10,211	12,293	13,835
Fixed Disk (Sold to OEMs)	0	0	0	0	(2,800)	(2,920)	(3,058)
Fixed Disk (Net)	3,879	5,674	6,709	8,751	7,411	9,373	10,777
WORM Optical Disk Drive	0	0	21	56	88	96	101
Erasable Optical Disk Drive	0	0	0	0	0	5	19
Optical Disk	0	0	21	56	88	101	120
Tape Drive	1,832	1,664	2,868	2,985	3,583	3,726	4,043
Data Storage/Subsystems (Total)	5,711	7,338	9,598	11,792	13,882	16,120	17,998
Data Storage/Subsystems (Net)	5,711	7,338	9,598	11,792	11,082	13,200	14,940

Source: Dataquest
March 1990

Table 2b

North American Electronic Equipment Production
Data Processing Forecast
(Millions of Dollars)

Equipment Type	Actual 1989	1990	1991	Estimated 1992	1993	1994	CAGR 1989-1990	CAGR 1989-1994
Corporate Resource	16,540	17,335	18,420	19,617	21,030	22,481	4.8%	6.3%
Business Unit	8,372	8,966	9,712	10,528	11,454	12,428	7.1%	8.2%
Large Department	8,456	8,972	9,501	10,052	10,575	11,135	6.1%	5.7%
Work Group & Small Dept.	15,216	15,946	16,696	17,464	18,232	18,943	4.8%	4.5%
Workstation	5,398	7,160	9,030	11,155	13,322	16,653	32.6%	25.3%
Personal Computer	20,775	22,513	24,714	28,164	31,385	34,270	8.4%	10.5%
Computers	74,757	80,892	88,073	96,980	105,998	115,910	8.2%	9.2%
14 Inch	4,593	4,427	4,106	3,861	3,920	3,854	(3.6%)	(3.4%)
8-10 Inch	3,060	3,325	3,305	3,031	2,702	2,390	8.7%	(4.8%)
5.25 Inch	3,192	3,146	2,788	2,662	2,608	2,486	(1.4%)	(4.9%)
3-4 Inch	2,990	4,209	5,156	6,033	7,195	7,696	40.8%	20.8%
Fixed Disk (Total)	13,835	15,107	15,355	15,587	16,425	16,426	9.2%	3.5%
Fixed Disk (Sold to OEMs)	(3,058)	(3,326)	(3,709)	(4,349)	(5,098)	(5,871)	8.8%	13.9%
Fixed Disk (Net)	10,777	11,781	11,646	11,238	11,327	10,555	9.3%	(0.4%)
WORM Optical Disk Drive	101	141	198	363	552	707	39.6%	47.6%
Erasable Optical Disk Drive	19	81	194	407	808	1,349	326.3%	134.6%
Optical Disk	120	222	392	770	1,360	2,056	85.0%	76.5%
Tape Drive	4,043	4,407	4,507	4,905	5,292	5,662	9.0%	7.0%
Data Storage/ Subsystems (Total)	17,998	19,736	20,254	21,262	23,077	24,144	9.7%	6.1%
Data Storage/ Subsystems (Net)	14,940	16,410	16,545	16,913	17,979	18,273	9.8%	4.1%

Source: Dataquest March 1990

Table 2c

North American Electronic Equipment Production
Data Processing History
(Millions of Dollars)

Equipment Type	1983	1984	1985	1986	1987	1988	1989
Minicomputer-Based	1,357	1,490	1,237	928	954	1,098	835
Non-IBM, Protocol Specific	172	202	171	95	85	99	73
IBM 3270	810	909	1,042	873	802	414	358
Host/Vendor-Independent	421	437	431	447	480	474	402
Alphanumeric	2,760	3,038	2,881	2,343	2,321	2,085	1,668
Graphics Terminals	487	624	3,900	1,264	1,127	1,025	916
Terminals	3,247	3,662	6,781	3,607	3,448	3,110	2,584
Remote Batch, Job Entry and Output	60	122	275	276	270	290	301
Key Entry Equipment	102	80	70	57	43	30	15
Media-to-Media Data Conversion	102	135	143	140	147	165	180
Magnetic Ink Regcognition	91	79	60	33	28	18	12
Optical Scanning Equipment	195	253	253	274	320	368	412
Computer Plotters	232	241	466	477	525	588	592
Impact, Dot Matrix	2,790	2,299	2,171	2,262	3,016	3,090	3,127
Impact, Fully Formed	1,044	1,033	381	46	162	124	100
Nonimpact, Direct Thermal	120	175	70	46	32	24	17
Nonimpact, Thermal Transfer	0	33	214	116	120	53	52
Nonimpact, Ink-Jet	32	109	97	71	115	281	354
Serial Printers	3,986	3,649	2,933	2,541	3,445	3,572	3,650
Impact, Dot Matrix	332	420	521	611	599	632	660
Impact, Fully Formed	1,423	1,471	1,439	1,370	1,024	976	899
Nonimpact, Direct Thermal	13	5	2	1	0	0	0
Nonimpact, Thermal Transfer	3	7	12	18	29	44	55
Line Printers	1,771	1,903	1,974	2,000	1,652	1,652	1,614
Nonimpact, Plain Paper	573	1,187	1,174	1,745	2,786	3,858	4,560
Page Printers	573	1,187	1,174	1,745	2,786	3,858	4,560
Input/Output	7,112	7,649	7,348	7,543	9,216	10,541	11,336

Source: Dataquest
March 1990

Table 2d

North American Electronic Equipment Production
Data Processing Forecast
(Millions of Dollars)

Equipment Type	Actual 1989	1990	1991	Estimated 1992	1993	1994	CAGR 1989-1990	CAGR 1989-1994
Minicomputer-Based	835	602	431	291	176	162	(27.9%)	(28.0%)
Non-IBM, Protocol Specific	73	46	29	18	8	6	(37.0%)	(39.3%)
IBM 3270	358	318	212	170	136	116	(11.2%)	(20.2%)
Host/Vendor-Independent	402	254	203	163	122	107	(36.8%)	(23.3%)
Alphanumeric	1,668	1,220	875	642	442	391	(26.9%)	(25.2%)
Graphics Terminals	916	861	837	804	796	782	(6.0%)	(3.1%)
Terminals	2,584	2,081	1,712	1,446	1,238	1,173	(19.5%)	(14.6%)
Remote Batch, Job Entry and Output	301	312	335	350	366	370	3.7%	4.2%
Key Entry Equipment	15	10	8	5	3	2	(33.3%)	(33.2%)
Media-to-Media Data Conversion	180	175	169	162	155	152	(2.8%)	(3.3%)
Magnetic Ink Regcognition	12	10	8	6	4	3	(16.7%)	(24.2%)
Optical Scanning Equipment	412	466	531	616	708	794	13.1%	14.0%
Computer Plotters	592	603	614	622	628	631	1.9%	1.3%
Impact, Dot Matrix	3,127	3,063	2,910	2,650	2,355	2,070	(2.0%)	(7.9%)
Impact, Fully Formed	100	80	54	51	43	36	(20.0%)	(18.5%)
Nonimpact, Direct Thermal	17	11	10	9	7	4	(35.3%)	(25.1%)
Nonimpact, Thermal Transfer	52	51	50	49	48	46	(1.9%)	(2.4%)
Nonimpact, Ink-Jet	354	489	695	986	1,344	1,765	38.1%	37.9%
Serial Printers	3,650	3,694	3,719	3,745	3,797	3,921	1.2%	1.4%
Impact, Dot Matrix	660	669	669	654	621	595	1.4%	(2.1%)
Impact, Fully Formed	899	833	781	716	665	630	(7.3%)	(6.9%)
Nonimpact, Direct Thermal	0	0	0	0	0	0	N/M	N/M
Nonimpact, Thermal Transfer	55	59	58	63	68	71	7.3%	5.2%
Line Printers	1,614	1,561	1,508	1,433	1,354	1,296	(3.3%)	(4.3%)
Nonimpact, Plain Paper	4,560	5,450	6,395	7,400	8,545	9,865	19.5%	16.7%
Page Printers	4,560	5,450	6,395	7,400	8,545	9,865	19.5%	16.7%
Input/Output	11,336	12,281	13,287	14,339	15,560	17,034	8.3%	8.5%

N/M = Not Meaningful

Source: Dataquest March 1990

Table 2e

North American Electronic Equipment Production
Data Processing History
(Millions of Dollars)

Equipment Type	1983	1984	1985	1986	1987	1988	1989
PC	0	0	0	0	0	0	19
Segment 1	150	141	90	137	153	142	129
Segment 2	20	49	120	86	83	102	113
Segment 3	90	173	155	187	191	177	163
Segment 4	48	52	22	229	259	280	302
Segment 5	836	951	957	498	677	681	697
Segment 6	199	208	313	546	586	618	643
Copiers and Duplicators	1,343	1,574	1,657	1,683	1,949	2,000	2,066
Electronic Calculators	188	174	151	149	152	158	155
Dictating, Transcribing	33	19	15	12	9	8	6
Portable and Compact	0	86	162	398	440	462	501
Low-End, Full-Size	40	85	189	162	155	126	100
Midrange, Full-Size	36	40	45	44	4	4	0
Hign-End, Full-Size	141	252	292	355	320	265	253
Display & Monitor Display	0	39	64	70	83	88	81
Electronic Typewriters	217	502	752	1,029	1,002	945	935
Standalone	515	551	400	137	17	6	2
Shared Systems	888	963	754	232	42	18	3
WP File Servers	0	0	384	108	22	8	1
Word Processors	1,403	1,514	1,538	477	81	32	6
Office Automation	3,184	3,783	4,113	3,350	3,193	3,143	3,168
Check-Handling Systems	58	68	111	137	152	170	180
Funds Transfer Terminals	307	373	307	288	321	343	338
Banking Systems	365	441	418	425	473	513	518
Point-of-Sale Terminals	454	491	414	510	515	530	478
Cash Registers	77	27	45	16	13	11	9
Mailing, Letter Handling, Addressing	508	562	596	793	809	858	818
Other Specialized Terminals	248	242	243	310	312	320	333
Dedicated Systems	4,836	5,546	5,829	5,404	5,315	5,375	5,324
Data Processing	58,271	73,644	85,119	84,825	91,849	100,995	108,941

Source: Dataquest
March 1990

Table 2f

North American Electronic Equipment Production
Data Processing Forecast
(Millions of Dollars)

Equipment Type	Actual 1989	1990	1991	Estimated 1992	1993	1994	CAGR 1989-1990	CAGR 1989-1994
PC	19	22	26	29	36	39	15.8%	15.5%
Segment 1	129	117	113	108	110	113	(9.3%)	(2.6%)
Segment 2	113	128	153	149	147	146	13.3%	5.3%
Segment 3	163	149	139	131	125	118	(8.6%)	(6.3%)
Segment 4	302	324	338	370	405	436	7.3%	7.6%
Segment 5	697	642	600	525	450	411	(7.9%)	(10.0%)
Segment 6	643	687	700	525	480	455	6.8%	(6.7%)
Copiers and Duplicators	2,066	2,069	2,069	1,837	1,753	1,718	0.1%	(3.6%)
Electronic Calculators	155	152	149	146	144	143	(1.9%)	(1.6%)
Dictating, Transcribing	6	5	4	4	3	3	(16.7%)	(12.9%)
Portable and Compact	501	487	458	441	427	414	(2.8%)	(3.7%)
Low-End, Full-Size	100	77	51	44	38	34	(23.0%)	(19.4%)
Midrange, Full-Size	0	0	0	0	0	0	N/M	N/M
Hign-End, Full-Size	253	216	180	112	70	53	(14.6%)	(26.8%)
Display & Monitor Display	81	69	66	50	40	32	(14.8%)	(17.0%)
Electronic Typewriters	935	849	755	647	575	533	(9.2%)	(10.6%)
Standalone	2	0	0	0	0	0	(100.0%)	(100.0%)
Shared Systems	3	0	0	0	0	0	(100.0%)	(100.0%)
WP File Servers	1	0	0	0	0	0	(100.0%)	(100.0%)
Word Processors	6	0	0	0	0	0	(100.0%)	(100.0%)
Office Automation	3,168	3,075	2,977	2,634	2,475	2,397	(2.9%)	(5.4%)
Check-Handling Systems	180	198	209	215	219	228	10.0%	4.8%
Funds Transfer Terminals	338	365	390	415	448	476	8.0%	7.1%
Banking Systems	518	563	599	630	667	704	8.7%	6.3%
Point-of-Sale Terminals	478	497	574	620	687	742	4.0%	9.2%
Cash Registers	9	5	3	2	1	1	(44.4%)	(35.6%)
Mailing, Letter Handling, Addressing	818	857	988	950	922	904	4.8%	2.0%
Other Specialized Terminals	333	336	340	358	385	411	0.9%	4.3%
Dedicated Systems	5,324	5,333	5,481	5,194	5,137	5,159	0.2%	(0.6%)
Data Processing	108,941	116,997	125,098	134,872	145,912	157,549	7.4%	7.7%

N/M = Not Meaningful

Source: Dataquest March 1990

Table 3a

North American Electronic Equipment Production Communications History (Millions of Dollars)

Equipment Type	1983	1984	1985	1986	1987	1988	1989
Facsimile	0	0	0	0	0	0	0
Video Teleconferencing	0	0	18	27	32	44	54
Telex	0	0	0	0	0	0	0
Videotex	0	0	0	0	0	0	0
Image & Text Communication Eqp.	0	0	18	27	32	44	54
300/1200 bps	203	242	258	205	88	70	58
2400 bps	165	191	230	283	207	226	238
4800 bps	170	190	210	220	145	113	96
9600 bps	277	303	339	401	650	622	597
14.4 Kbps	101	110	111	110	133	148	140
16.8 Kbps	0	4	8	10	13	13	14
19.2 Kbps	0	6	10	14	63	76	94
Modems	916	1,046	1,166	1,243	1,299	1,268	1,237
Statistical Multiplexers	245	289	303	319	258	193	184
Time-Division Multiplexers	0	0	0	0	0	0	0
T-1 Multiplexers	30	61	158	241	309	403	469
Front-End Processors	383	426	474	527	477	488	502
Data PBX	77	119	143	86	82	80	78
Data Network Management Sys.	0	0	0	43	61	0	0
DSU/CSU	36	70	72	86	101	119	136
Protocol Converters	75	140	154	160	161	164	164
Local Area Networks	150	326	593	913	1,630	2,580	3,774
Response	0	36	34	28	30	32	33
Modem Network Management	0	53	60	66	71	75	79
Matrix	0	50	58	62	64	68	71
Switch/Path	0	72	74	75	78	80	81
Analyers	0	91	96	102	106	108	113
Nodes	63	112	149	201	238	297	340
PADs	19	30	42	42	47	43	47
Switch Concentrator	2	6	11	19	27	0	0
Private Packet Data Switching	84	148	202	262	312	340	387
Public Packet Data Switching	0	0	0	0	0	0	0
Data Communication Equipment	1,996	2,927	3,587	4,213	5,039	5,998	7,308

Source: Dataquest March 1990

Table 3b

North American Electronic Equipment Production Communications Forecast (Millions of Dollars)

Equipment Type	Actual 1989	1990	1991	Estimated 1992	1993	1994	CAGR 1989-1990	CAGR 1989-1994
Facsimile	0	0	0	0	0	0	N/M	N/M
Video Teleconferencing	54	78	109	131	141	150	44.4%	22.7%
Telex	0	0	0	0	0	0	N/M	N/M
Videotex	0	0	0	0	0	0	N/M	N/M
Image & Text Communication Eqp.	54	78	109	131	141	150	44.4%	22.7%
300/1200 bps	58	43	26	17	12	12	(25.9%)	(27.0%)
2400 bps	238	240	215	190	184	184	0.8%	(5.0%)
4800 bps	96	84	74	63	54	54	(12.5%)	(10.9%)
9600 bps	597	546	510	459	431	431	(8.5%)	(6.3%)
14.4 Kbps	140	124	96	71	49	49	(11.4%)	(18.9%)
16.8 Kbps	14	13	10	7	5	5	(7.1%)	(18.6%)
19.2 Kbps	94	89	81	71	60	60	(5.3%)	(8.6%)
Modems	1,237	1,139	1,012	878	795	795	(7.9%)	(8.5%)
Statistical Multiplexers	184	169	150	130	110	90	(8.2%)	(13.3%)
Time-Division Multiplexers	0	0	0	0	0	0	N/M	N/M
T-1 Multiplexers	469	554	627	694	750	800	18.1%	11.3%
Front-End Processors	502	548	578	598	637	666	9.2%	5.8%
Data PBX	78	76	75	70	68	68	(2.6%)	(2.7%)
Data Network Management Sys.	0	0	0	0	0	0	N/M	N/M
DSU/CSU	136	156	178	200	234	265	14.7%	14.3%
Protocol Converters	164	153	143	140	135	130	(6.7%)	(4.5%)
Local Area Networks	3,774	4,959	6,084	7,020	7,857	9,828	31.4%	21.1%
Response	33	32	30	29	28	27	(3.0%)	(3.9%)
Modem Network Management	79	76	71	66	61	56	(3.8%)	(6.7%)
Matrix	71	74	76	78	80	82	4.2%	2.9%
Switch/Path	81	78	72	65	60	55	(3.7%)	(7.5%)
Analyzers	113	119	126	136	144	153	5.3%	6.2%
Nodes	340	386	425	465	505	556	13.5%	10.3%
PADs	47	44	42	38	33	28	(6.4%)	(9.8%)
Switch Concentrator	0	0	0	0	0	0	N/M	N/M
Private Packet Data Switching	387	430	467	503	538	584	11.1%	8.6%
Public Packet Data Switching	0	0	0	0	0	0	N/M	N/M
Data Communication Equipment	7,308	8,563	9,689	10,607	11,497	13,599	17.2%	13.2%

N/M = Not Meaningful

Source: Dataquest March 1990

Table 3c

North American Electronic Equipment Production
Communications History
(Millions of Dollars)

Equipment Type	1983	1984	1985	1986	1987	1988	1989
1-40 Lines	93	97	97	130	139	147	150
41-100 Lines	425	447	461	495	529	536	551
101-400 Lines	703	732	727	800	777	800	792
401-1,000 Lines	495	548	564	553	546	535	522
>1,000 Lines	643	769	797	741	769	758	727
PBX Telephone Systems	2,359	2,593	2,646	2,719	2,760	2,776	2,742
Key Telephone Systems	1,304	1,293	1,101	984	866	810	808
Premise Switching Equipment	3,663	3,886	3,747	3,703	3,626	3,586	3,550
Voice Messaging	37	82	117	182	284	472	675
Interactive Voice Response Sys.	0	0	0	0	0	0	0
Call Accounting	182	193	201	243	243	268	282
Automatic Call Distributors	207	224	222	233	265	299	334
Call Processing Equipment	426	499	540	658	792	1,039	1,291
Telephones	0	0	285	200	168	126	82
Integrated Services Digital Network	0	0	0	0	0	0	0
Asynchronous	33	55	73	25	24	20	17
Synchronous	2	6	14	11	9	8	6
PC	6	6	62	23	1	1	0
Add-On	0	8	25	6	4	4	4
Integrated Voice/Data Workstations	41	75	174	65	38	33	27
Teleprinters	387	294	272	258	245	220	205
Answering Machines	0	0	0	0	0	0	0
Desktop Terminal Equipment	428	369	731	523	451	379	314
Premise Telecom Equipment	6,513	7,681	8,623	9,124	9,940	11,046	12,517

Source: Dataquest
March 1990

Table 3d

North American Electronic Equipment Production
Communications Forecast
(Millions of Dollars)

Equipment Type	Actual 1989	1990	1991	Estimated 1992	1993	1994	CAGR 1989-1990	CAGR 1989-1994
1-40 Lines	150	151	149	152	157	162	0.7%	1.6%
41-100 Lines	551	545	548	565	623	678	(1.1%)	4.2%
101-400 Lines	792	767	764	772	787	792	(3.2%)	0
401-1,000 Lines	522	519	502	502	502	502	(0.6%)	(0.8%)
>1,000 Lines	727	6 99	6 96	702	702	702	(3.9%)	(0.7%)
PBX Telephone Systems	2,742	2,681	2,659	2,693	2,771	2,836	(2.2%)	0.7%
Key Telephone Systems	808	780	754	731	710	690	(3.5%)	(3.1%)
Premise Switching Equipment	3,550	3,461	3,413	3,424	3,481	3,526	(2.5%)	(0.1%)
Voice Messaging	675	825	897	917	926	1,093	22.2%	10.1%
Interactive Voice Response System	0	0	0	0	0	0	N/M	N/M
Call Accounting	282	301	332	365	395	425	6.7%	8.5%
Automatic Call Distributors	334	383	431	488	548	620	14.7%	13.2%
Call Processing Equipment	1,291	1,509	1,660	1,770	1,869	2,138	16.9%	10.6%
Telephones	82	40	37	34	34	34	(51.2%)	(16.1%)
Integrated Services Digital Network	0	0	0	0	0	0	N/M	N/M
Asynchronous	17	15	13	11	9	7	(11.8%)	(16.3%)
Synchronous	6	5	4	3	2	1	(16.7%)	(30.1%)
PC	0	0	0	0	0	0	N/M	N/M
Add-On	4	5	5	6	6	7	25.0%	11.8%
Integrated Voice/Data Workstations	27	25	22	20	17	15	(7.4%)	(11.1%)
Teleprinters	205	190	172	130	98	68	(7.3%)	(19.8%)
Answering Machines	0	0	0	0	0	0	N/M	N/M
Desktop Terminal Equipment	314	255	231	184	149	117	(18.8%)	(17.9%)
Premise Telecom Equipment	12,517	13,866	15,102	16,116	17,137	19,530	10.8%	9.3%

N/M = Not Meaningful

Source: Dataquest March 1990

Table 3e

North American Electronic Equipment Production
Communications History
(Millions of Dollars)

Equipment Type	1983	1984	1985	1986	1987	1988	1989
Multiplex	658	727	812	912	942	1,377	1,507
Carrier System	1,088	1,217	1,372	1,431	1,555	1,689	1,843
Microwave Radio	339	368	404	438	482	480	482
Satellite Earth Station Eqp.	500	560	574	563	592	651	693
Satellite Communication Eqp.	500	560	574	563	592	651	693
Transmission Equipment	2,585	2,872	3,162	3,344	3,571	4,197	4,525
Central Office Switching Eqp.	1,926	2,245	2,724	2,800	2,765	2,690	2,650
Digital Access Cross-Connect System	0	0	0	0	0	0	0
Public Switching Equipment	1,926	2,245	2,724	2,800	2,765	2,690	2,650
Public Telecommunications	4,511	5,117	5,886	6,144	6,336	6,887	7,175
Cellular Telephones	114	326	422	499	723	890	923
Paging Equipment	0	0	0	0	0	0	0
PMR	641	895	908	793	1,160	1,415	1,650
Cordless Telephony	755	1,221	1,330	1,292	1,883	2,305	2,573
Mobile Radio Base Station Eqp.	188	199	217	354	327	350	375
Mobile Radio System Equipment	943	1,420	1,547	1,646	2,210	2,655	2,948
Broadcast Radio Receivers, Transmitter	1,391	1,678	1,953	2,001	1,927	1,925	1,900
Amateur Radio	3	3	5	5	9	10	10
Citizen's Band; Mobile & Base	3	3	5	5	9	10	10
Portable Radio Receivers, Transmitters	536	717	648	779	921	1,050	1,200
Radio Checkout Monitor, Evaluation, etc.	242	252	241	277	317	335	350
Comm. Antenna <890 MHz	0	0	0	0	0	0	0
Microwave Antenna >890 MHz	0	0	0	0	0	0	0
Mobile Communication Equipment	3,118	4,073	4,399	4,712	5,392	5,985	6,418

Source: Dataquest
March 1990

Table 3f

North American Electronic Equipment Production Communications Forecast (Millions of Dollars)

Equipment Type	Actual 1989	1990	1991	Estimated 1992	1993	1994	CAGR 1989-1990	CAGR 1989-1994
Multiplex	1,507	1,577	1,653	1,757	1,998	2,144	4.6%	7.3%
Carrier System	1,843	2,010	2,200	2,415	2,664	2,912	9.1%	9.6%
Microwave Radio	482	491	505	527	539	550	1.9%	2.7%
Satellite Earth Station Eqp.	693	752	801	993	1,150	1,265	8.5%	12.8%
Satellite Communication Equipment	693	752	801	993	1,150	1,265	8.5%	12.8%
Transmission Equipment	4,525	4,830	5,159	5,692	6,351	6,871	6.7%	8.7%
Central Office Switching Equipment	2,650	2,760	2,860	3,178	3,315	3,457	4.2%	5.5%
Digital Access Cross-Connect System	0	0	0	0	0	0	N/M	N/M
Public Switching Equipment	2,650	2,760	2,860	3,178	3,315	3,457	4.2%	5.5%
Public Telecommunications	7,175	7,590	8,019	8,870	9,666	10,328	5.8%	7.6%
Cellular Telephones	923	953	988	1,005	1,051	1,097	3.3%	3.5%
Paging Equipment	0	0	0	0	0	0	N/M	N/M
PMR	1,650	1,800	1,950	2,100	2,250	2,400	9.1%	7.8%
Cordless Telephony	2,573	2,753	2,938	3,105	3,301	3,497	7.0%	6.3%
Mobile Radio Base Station Eqp.	375	400	425	450	475	500	6.7%	5.9%
Mobile Radio System Equipment	2,948	3,153	3,363	3,555	3,776	3,997	7.0%	6.3%
Broadcast Radio Receivers, Transmitter	1,900	1,900	1,900	1,900	1,900	1,900	0	0
Amateur Radio	10	10	10	10	10	10	0	0
Citizen's Band; Mobile & Base	10	10	10	10	10	10	0	0
Portable Radio Receivers, Transmitters	1,200	1,300	1,400	1,500	1,600	1,700	8.3%	7.2%
Radio Checkout Monitor, Evaluation, etc.	350	375	400	425	450	475	7.1%	6.3%
Comm. Antenna <890 MHz	0	0	0	0	0	0	N/M	N/M
Microwave Antenna >890 MHz	0	0	0	0	0	0	N/M	N/M
Mobile Communication Equipment	6,418	6,748	7,083	7,400	7,746	8,092	5.1%	4.7%

N/M = Not Meaningful

Source: Dataquest March 1990

Table 3g

North American Electronic Equipment Production
Communications History
(Millions of Dollars)

Equipment Type	1983	1984	1985	1986	1987	1988	1989
Audio Equipment	187	219	210	209	267	305	325
Video Equipment	461	496	509	527	641	710	800
Transmitters, RF Power Amps	111	107	135	122	124	125	125
Studio Transmitter Links	42	8	19	17	17	15	15
Cable TV Equipment	452	410	375	383	468	530	580
CCTV	99	109	125	141	165	180	200
Broadcast Transmitter Antenna	0	0	0	0	0	0	0
Other (Studio, Theater)	63	87	94	93	98	100	100
Broadcast & Studio	1,415	1,436	1,467	1,492	1,780	1,965	2,145
Intercomm. Equip Elec. Ampl.	176	213	172	195	221	230	250
Fiber Optic	275	254	529	568	701	755	800
Other (Laser, Infrared)	137	461	485	309	290	275	260
Light Communication System	412	715	1,014	877	991	1,030	1,060
Telemetering Systems	304	246	358	370	329	340	350
Other Telecom	892	1,174	1,544	1,442	1,541	1,600	1,660
Communications	16,449	19,481	21,919	22,914	24,989	27,483	29,915

Source: Dataquest
March 1990

Table 3h

North American Electronic Equipment Production Communications Forecast (Millions of Dollars)

Equipment Type	Actual 1989	1990	1991	Estimated 1992	1993	1994	CAGR 1989-1990	CAGR 1989-1994
Audio Equipment	325	350	375	400	425	450	7.7%	6.7%
Video Equipment	800	850	900	950	1,000	1,050	6.3%	5.6%
Transmitters, RF Power Amps	125	125	125	125	125	125	0	0
Studio Transmitter Links	15	15	15	15	15	15	0	0
Cable TV Equipment	580	650	700	750	800	850	12.1%	7.9%
CCTV	200	225	250	275	300	325	12.5%	10.2%
Broadcast Transmitter Antenna	0	0	0	0	0	0	N/M	N/M
Other (Studio, Theater)	100	100	100	100	100	100	0	0
Broadcast & Studio	2,145	2,315	2,465	2,615	2,765	2,915	7.9%	6.3%
Intercomm. Equip Elec. Ampl.	250	270	290	310	330	350	8.0%	7.0%
Fiber Optic	800	850	900	950	1,000	1,050	6.3%	5.6%
Other (Laser, Infrared)	260	250	250	250	250	250	(3.8%)	(0.8%)
Light Communication System	1,060	1,100	1,150	1,200	1,250	1,300	3.8%	4.2%
Telemetering Systems	350	350	350	350	350	350	0	0
Other Telecom	1,660	1,720	1,790	1,860	1,930	2,000	3.6%	3.8%
Communications	29,915	32,239	34,459	36,861	39,244	42,865	7.8%	7.5%

N/M = Not Meaningful

Source: Dataquest March 1990

Table 4a

North American Electronic Equipment Production
Industrial History
(Millions of Dollars)

Equipment Type	1983	1984	1985	1986	1987	1988	1989
Intrusion Detection	516	568	590	679	781	878	930
Fire Detection	364	477	431	427	436	473	509
Alarm Systems	880	1,045	1,021	1,106	1,217	1,351	1,439
Discrete Devices	537	548	565	582	599	622	636
MPU Load Programmers	26	19	20	23	26	29	32
Computerized Engy. Ctl. Sys.	554	348	361	358	369	391	399
Security/Energy Management	1,997	1,960	1,967	2,069	2,211	2,393	2,506
Semiconductor Production	945	1,795	1,598	1,199	1,258	1,914	2,157
ATE	1,188	1,300	1,422	1,609	1,694	1,974	2,047
General	3,654	4,445	4,548	4,503	4,818	5,203	5,431
Test Equipment	4,842	5,745	5,970	6,112	6,512	7,177	7,478
Process Control Systems	1,803	1,969	2,129	2,279	2,413	2,648	2,875
Programmable Machine Tools	677	740	921	767	754	815	892
Mech. Assembly Equipment	243	397	391	360	361	376	401
Plastic Process Machinery	567	779	604	588	621	645	699
Assembly	36	67	95	66	52	67	73
Material Handling/Loading	51	79	112	81	81	88	95
Painting	32	54	60	52	37	39	29
Spot Welding	33	61	106	85	61	55	48
Arc Welding	31	57	63	58	59	60	60
Machining, Other	49	62	56	37	28	29	44
Robot Systems	232	380	492	379	318	338	349
Guided Vehicles	40	130	160	117	117	130	142
Programmable Conveyors	323	378	450	409	436	474	511
Storage/Retrieval Systems	166	182	208	255	265	309	355
Programmable Monorails	20	36	65	138	137	160	185
Warehousing	160	170	181	173	183	209	236
Other	9	11	13	5	5	5	6
Automated Material Handling	718	907	1,077	1,097	1,143	1,287	1,435
Manufacturing Systems	10,027	12,712	13,182	12,781	13,380	15,200	16,286

Source: Dataquest
March 1990

Table 4b

North American Electronic Equipment Production
Industrial Forecast
(Millions of Dollars)

Equipment Type	Actual 1989	1990	1991	Estimated 1992	1993	1994	CAGR 1989-1990	CAGR 1989-1994
Intrusion Detection	930	999	1,069	1,140	1,223	1,312	7.4%	7.1%
Fire Detection	509	544	585	617	649	683	6.9%	6.0%
Alarm Systems	1,439	1,543	1,654	1,757	1,872	1,995	7.2%	6.7%
Discrete Devices	636	655	675	715	749	785	3.0%	4.3%
MPU Load Programmers	32	36	43	46	50	54	12.5%	11.2%
Computerized Engy. Ctl. Sys.	399	405	450	502	532	564	1.5%	7.2%
Security/Energy Management	2,506	2,639	2,822	3,020	3,203	3,397	5.3%	6.3%
Semiconductor Production	2,157	2,083	2,649	3,264	3,631	4,039	(3.4%)	13.4%
ATE	2,047	2,106	2,243	2,373	2,499	2,632	2.9%	5.2%
General	5,431	5,644	5,977	6,270	6,527	6,795	3.9%	4.6%
Test Equipment	7,478	7,750	8,220	8,643	9,026	9,426	3.6%	4.7%
Process Control Systems	2,875	3,090	3,345	3,612	3,952	4,324	7.5%	8.5%
Programmable Machine Tools	892	942	999	1,048	1,079	1,111	5.6%	4.5%
Mechanical Assembly Equipment	401	411	425	430	440	450	2.5%	2.3%
Plastic Process Machinery	699	744	785	831	882	936	6.4%	6.0%
Assembly	73	80	87	85	90	95	9.6%	5.5%
Material Handling/ Loading	95	102	108	114	120	126	7.4%	5.9%
Painting	29	31	32	34	35	36	6.9%	4.4%
Spot Welding	48	44	40	37	34	31	(8.3%)	(8.2%)
Arc Welding	60	61	62	63	64	65	1.7%	1.6%
Machining, Other	44	46	47	49	51	53	4.5%	3.8%
Robot Systems	349	364	376	382	394	407	4.3%	3.1%
Guided Vehicles	142	154	166	176	188	201	8.5%	7.2%
Programmable Conveyors	511	544	591	644	699	759	6.5%	8.2%
Storage/Retrieval Systems	355	403	450	494	549	610	13.5%	11.4%
Programmable Monorails	185	210	236	260	285	312	13.5%	11.0%
Warehousing	236	263	289	314	350	390	11.4%	10.6%
Other	6	7	7	8	9	10	16.7%	11.0%
Automated Material Handling	1,435	1,581	1,739	1,896	2,080	2,282	10.2%	9.7%
Manufacturing Systems	16,286	16,965	18,538	20,106	21,484	22,976	4.2%	7.1%

Source: Dataquest
March 1990

Table 4c

North American Electronic Equipment Production
Industrial History
(Millions of Dollars)

Equipment Type	1983	1984	1985	1986	1987	1988	1989
Integrating and Totalizing Meters for Gas & Liquids	449	493	547	557	601	651	649
Counting Devices	173	209	198	202	198	211	220
Digital Panel Meters	27	36	34	33	34	41	41
Analog Panel Meters	10	5	6	6	6	5	6
Panel Type	116	128	119	124	141	162	163
Elapsed-Time Meters	27	16	12	11	13	16	12
Portable Elec. Measuring Instr.	22	23	18	18	23	25	20
Electronic Recording Instr.	323	418	438	469	517	568	559
Physical Property Test, Inpection & Measure	564	652	678	690	750	820	870
Comm. Meteorological & Gen. Purpose Instruments	294	381	334	300	350	378	447
Nuclear Radiation Detection & Monitoring Instruments	503	495	514	543	526	558	580
Surveying & Drafting Instr.	246	327	368	390	461	487	511
Ultrasonic Cleaners, Drills	107	127	112	108	124	139	148
Metorological	79	86	112	140	167	181	197
Geophysical	228	316	313	266	285	306	328
Analytical & Scientific Intr.	2,439	2,749	2,768	2,713	2,984	3,226	3,371
Instrumentation	5,607	6,461	6,571	6,570	7,180	7,774	8,122
Automatic Blood Analyzer	744	724	715	787	865	952	1,047
CAT Scanner	510	666	513	457	416	407	387
Digital Radiography	55	60	57	63	68	81	87
Electrocardiographs	72	118	96	98	106	114	122
Electrencephalographs	15	20	13	15	16	18	20
Nuclear Magnetic Resonanc	69	81	155	264	385	500	590
Respiratory Analysis	16	17	15	15	16	16	16
Ultrasonic Scanners	376	294	187	168	182	208	218
X-Ray	711	656	685	719	751	788	805
Other Diagnostic	291	254	263	276	280	292	303
Diagnostic	2,859	2,890	2,699	2,862	3,085	3,376	3,595
Patient Monitoring	659	577	640	666	699	741	771
Hearing Aids	340	363	395	419	444	477	500
Prosthetic	340	363	395	419	444	477	500
Surgical Support	104	130	181	217	239	250	256
Defibrillators	86	91	104	111	117	126	130
Dialysis, Diatheray	73	65	71	74	78	85	87
Electrosurgical	64	81	80	79	83	89	95
Pacemakers	263	371	304	312	320	318	336
Ultrasonic Generators	18	32	27	25	27	30	34
Other Therapeutic	274	280	258	237	253	293	313
Therapeutic	778	920	844	838	878	941	995
Medical Equipment	4,740	4,880	4,759	5,002	5,345	5,785	6,117

Source: Dataquest
March 1990

Table 4d

North American Electronic Equipment Production Industrial Forecast (Millions of Dollars)

Equipment Type	Actual 1989	1990	1991	Estimated 1992	1993	1994	CAGR 1989-1990	CAGR 1989-1994
Integrating and Totalizing Meters for Gas & Liquids	649	634	685	720	748	777	(2.3%)	3.7%
Counting Devices	220	223	258	281	305	331	1.4%	8.5%
Digital Panel Meters	41	44	50	57	63	70	7.3%	11.2%
Analog Panel Meters	6	6	5	4	4	4	0	(7.8%)
Panel Type	163	196	214	222	235	249	20.2%	8.8%
Elapsed-Time Meters	12	13	15	18	20	22	8.3%	13.1%
Portable Elec. Measuring Instr.	20	21	22	27	30	33	5.0%	10.8%
Electronic Recording Instruments	559	584	656	689	723	759	4.5%	6.3%
Physical Property Test, Inpection & Measure	870	921	1,000	1,065	1,125	1,188	5.9%	6.4%
Comm. Meteorological & Gen. Purpose Instruments	447	470	506	530	565	602	5.1%	6.1%
Nuclear Radiation Detection & Monitoring Instruments	580	559	601	643	665	688	(3.6%)	3.5%
Surveying & Drafting Instruments	511	538	581	619	655	693	5.3%	6.3%
Ultrasonic Cleaners, Drills	148	159	172	187	202	218	7.4%	8.1%
Metorological	197	209	234	252	273	296	6.1%	8.5%
Geophysical	328	347	377	407	439	474	5.8%	7.6%
Analytical & Scientific Intruments	3,371	3,512	3,766	3,962	4,084	4,210	4.2%	4.5%
Instrumentation	8,122	8,436	9,142	9,683	10,136	10,614	3.9%	5.5%
Automaic Blood Analyzer	1,047	1,152	1,267	1,361	1,475	1,599	10.0%	8.8%
CAT Scanner	387	360	331	315	297	280	(7.0%)	(6.3%)
Digital Radiography	87	97	110	119	130	142	11.5%	10.3%
Electrocardiographs	122	129	135	143	151	159	5.7%	5.5%
Electrencephalographs	20	23	26	28	31	34	15.0%	11.4%
Nuclear Magnetic Resonanc	590	649	714	771	846	928	10.0%	9.5%
Respiratory Analysis	16	17	18	19	20	21	6.3%	5.6%
Ultrasonic Scanners	218	243	257	269	284	300	11.5%	6.6%
X-Ray	805	841	877	896	921	947	4.5%	3.3%
Other Diagnostic	303	312	324	333	343	353	3.0%	3.1%
Diagnostic	3,595	3,823	4,059	4,254	4,498	4,764	6.3%	5.8%
Patient Monitoring	771	817	882	882	902	922	6.0%	3.7%
Hearing Aids	500	534	570	589	615	642	6.8%	5.1%
Prosthetic	500	534	570	589	615	642	6.8%	5.1%
Surgical Support	256	270	287	298	310	322	5.5%	4.7%
Defibrillators	130	135	142	149	156	163	3.8%	4.7%
Dialysis, Diatheray	87	89	92	99	105	111	2.3%	5.1%
Electrosurgical	95	98	105	113	121	130	3.2%	6.4%
Pacemakers	336	345	357	373	389	406	2.7%	3.8%
Ultrasonic Generators	34	36	37	40	44	48	5.9%	7.3%
Other Therapeutic	313	338	365	374	390	407	8.0%	5.4%
Therapeutic	995	1,041	1,098	1,148	1,205	1,265	4.6%	4.9%
Medical Equipment	6,117	6,485	6,896	7,171	7,530	7,916	6.0%	5.3%

Source: Dataquest March 1990

Table 4e

North American Electronic Equipment Production
Industrial History
(Millions of Dollars)

Equipment Type	1983	1984	1985	1986	1987	1988	1989
Radar	0	0	0	1,493	1,590	1,825	2,080
Space	0	0	0	2,911	2,693	2,470	2,818
Navigation/Communication	0	0	0	625	663	713	808
Aircraft Flight Systems	0	0	0	1,692	1,783	1,892	2,198
Simulation & Training	0	0	0	185	201	216	245
Civil Aerospace	1,764	5,763	6,454	6,906	6,930	7,116	8,149
Vending Machines	334	394	429	408	386	398	415
Laser Systems (Exc. Communications)	545	623	621	625	679	760	821
Power Supplies	815	964	1,131	1,338	1,580	1,881	2,052
Traffic Control	481	474	453	462	485	509	537
Particle Accelerator Elec.	34	29	19	17	20	23	25
Industrial & Scientific X-Ray	21	53	61	67	75	83	90
Laboratory & Scientific Apparatus	976	1,101	1,136	1,194	1,290	1,397	1,451
Teaching Machines and Aids	65	64	67	70	77	84	90
Scientific Not Elsewhere Classified	185	187	185	183	185	221	238
Other Industrial	3,456	3,889	4,102	4,364	4,777	5,356	5,719
Industrial	27,591	35,665	37,035	37,692	39,823	43,624	46,899

Source: Dataquest
March 1990

Table 4f

North American Electronic Equipment Production
Industrial Forecast
(Millions of Dollars)

Equipment Type	Actual 1989	1990	1991	Estimated 1992	1993	1994	CAGR 1989-1990	CAGR 1989-1994
Radar	2,080	2,355	2,645	2,949	3,228	3,533	13.2%	11.2%
Space	2,818	3,330	3,865	4,456	5,145	5,941	18.2%	16.1%
Navigation/ Communication	808	910	1,074	1,185	1,298	1,422	12.6%	12.0%
Aircraft Flight Systems	2,198	2,536	2,892	3,245	3,559	3,903	15.4%	12.2%
Simulation & Training	245	280	331	393	464	548	14.3%	17.5%
Civil Aerospace	8,149	9,411	10,807	12,228	13,694	15,347	15.5%	13.5%
Vending Machines	415	421	427	459	459	459	1.4%	2.0%
Laser Systems (Exc. Communications)	821	893	984	1,087	1,188	1,298	8.8%	9.6%
Power Supplies	2,052	2,205	2,432	2,613	2,843	3,093	7.5%	8.6%
Traffic Control	537	562	587	619	651	685	4.7%	5.0%
Particle Accelerator Electronic	25	24	25	26	27	28	(4.0%)	2.3%
Industrial & Scientific X-Ray	90	95	102	109	116	123	5.6%	6.5%
Laboratory & Scientific Apparatus	1,451	1,495	1,589	1,670	1,751	1,836	3.0%	4.8%
Teaching Machines and Aids	90	97	105	111	118	125	7.8%	6.9%
Scientific Not Elsewhere Classified	238	261	286	297	314	332	9.7%	6.9%
Other Industrial	5,719	6,053	6,537	6,991	7,467	7,980	5.8%	6.9%
Industrial	46,899	49,989	54,742	59,199	63,514	68,230	6.6%	7.8%

Source: Dataquest March 1990

Table 5a

North American Electronic Equipment Production
Consumer History
(Millions of Dollars)

Equipment Type	1983	1984	1985	1986	1987	1988	1989
Audio Amplifiers	23	16	17	16	14	11	12
Compact Disc Players	0	0	0	0	0	0	0
Radio	19	23	18	19	25	30	33
Stereo (Hi-Fi) Components	202	186	193	205	200	207	210
Stereo Headphone	0	0	0	0	0	0	0
Musical Instruments	11	10	13	15	17	18	19
Tape Recorders	15	11	11	14	13	13	11
Audio	270	246	252	269	269	279	285
Videocameras	303	354	225	60	35	20	10
VTRs (VCRs)	20	58	78	105	157	184	205
Videodisc Players	0	3	5	6	8	9	9
Color Televisions	4,473	4,834	4,936	5,028	5,298	5,395	5,510
Black & White Televisions	173	59	40	33	24	20	15
Video	4,969	5,308	5,284	5,232	5,522	5,628	5,749
Games	959	383	236	137	141	132	130
Cameras	13	15	18	17	20	23	25
Watches	68	62	64	67	72	69	65
Clocks	8	13	13	14	16	17	19
Personal Electronics	1,048	473	331	235	249	241	239
Air Conditioners	873	991	1,286	1,140	1,140	1,200	1,250
Microwave Ovens	1,044	1,252	1,300	1,300	1,350	1,400	1,450
Washers & Dryers	1,876	2,079	2,168	2,700	3,400	3,350	3,350
Refrigerators	2,249	2,573	2,718	2,894	3,082	3,080	3,247
Dishwashers, Disposals	1,600	1,800	1,900	2,050	2,100	2,150	2,150
Ranges & Ovens	1,300	1,477	1,517	1,589	1,600	1,650	1,700
Appliances	8,942	10,172	10,889	11,673	12,672	12,830	13,147
Automatic Garage Door Openers	187	198	184	208	222	232	240
Consumer Elec. Equip. Not Elsewhere Class	322	449	626	689	723	760	797
Other Consumer	509	647	810	897	945	992	1,037
Consumer	15,738	16,846	17,566	18,306	19,657	19,970	20,457

Source: Dataquest March 1990

Table 5b

North American Electronic Equipment Production
Consumer Forecast
(Millions of Dollars)

Equipment Type	Actual 1989	1990	1991	Estimated 1992	1993	1994	CAGR 1989-1990	CAGR 1989-1994
Audio Amplifiers	12	12	11	10	10	10	0	(3.6%)
Compact Disc Players	0	0	0	0	0	0	N/M	N/M
Radio	33	36	38	43	45	48	9.1%	7.8%
Stereo (Hi-Fi) Components	210	214	220	223	225	228	1.9%	1.7%
Stereo Headphone	0	0	0	0	0	0	N/M	N/M
Musical Instruments	19	20	21	22	23	24	5.3%	4.8%
Tape Recorders	11	10	9	8	8	8	(9.1%)	(6.2%)
Audio	285	292	299	306	311	318	2.5%	2.2%
Videocameras	10	0	0	0	0	0	(100.0%)	(100.0%)
VTRs (VCRs)	205	200	200	200	200	200	(2.4%)	(0.5%)
Videodisc Players	9	8	7	8	8	8	(11.1%)	(2.3%)
Color Televisions	5,510	5,646	5,807	5,998	6,224	6,500	2.5%	3.4%
Black & White Televisions	15	10	0	0	0	0	(33.3%)	(100.0%)
Video	5,749	5,864	6,014	6,206	6,432	6,708	2.0%	3.1%
Games	130	130	130	130	130	130	0	0
Cameras	25	26	26	24	24	24	4.0%	(0.8%)
Watches	65	61	59	57	57	57	(6.2%)	(2.6%)
Clocks	19	23	26	28	28	28	21.1%	8.1%
Personal Electronics	239	240	241	239	239	239	0.4%	0
Air Conditioners	1,250	1,300	1,350	1,400	1,450	1,500	4.0%	3.7%
Microwave Ovens	1,450	1,500	1,550	1,600	1,650	1,700	3.4%	3.2%
Washers & Dryers	3,350	3,400	3,450	3,500	3,550	3,600	1.5%	1.4%
Refrigerators	3,247	3,312	3,468	3,617	3,700	3,750	2.0%	2.9%
Dishwashers, Disposals	2,150	2,250	2,300	2,350	2,400	2,450	4.7%	2.6%
Ranges & Ovens	1,700	1,750	1,800	1,850	1,900	1,950	2.9%	2.8%
Appliances	13,147	13,512	13,918	14,317	14,650	14,950	2.8%	2.6%
Automatic Garage Door Openers	240	246	257	272	257	257	2.5%	1.4%
Consumer Elec. Equip. Not Elsewhere Class	797	832	869	899	900	900	4.4%	2.5%
Other Consumer	1,037	1,078	1,126	1,171	1,157	1,157	4.0%	2.2%
Consumer	20,457	20,986	21,598	22,239	22,789	23,372	2.6%	2.7%

Source: Dataquest March 1990

Table 6a

North American Electronic Equipment Production
Military History
(Millions of Dollars)

Equipment Type	1983	1984	1985	1986	1987	1988	1989
Radar	N/A	N/A	N/A	6,911	6,945	6,521	6,456
Sonar	N/A	N/A	N/A	2,754	2,875	2,984	2,870
Missile-Weapon	N/A	N/A	N/A	5,937	6,228	6,385	6,461
Space	N/A	N/A	N/A	5,025	5,281	5,148	5,552
Navigation	N/A	N/A	N/A	1,465	1,537	1,606	1,602
Communications	N/A	N/A	N/A	4,388	4,616	4,791	4,944
Electronic Warfare	N/A	N/A	N/A	3,250	3,029	3,044	3,021
Reconnaissance	N/A	N/A	N/A	2,314	2,422	2,495	2,550
Aircraft Systems	N/A	N/A	N/A	4,330	4,555	4,327	4,312
Computer Systems	N/A	N/A	N/A	1,983	2,112	2,207	2,308
Simulation & Training	N/A	N/A	N/A	632	671	744	845
Misc. Equipment	N/A	N/A	N/A	10,381	10,661	10,811	10,806
Military	N/A	N/A	47,300	49,370	50,932	51,063	51,727

N/A = Not Available

Source: Dataquest March 1990

Table 6b

North American Electronic Equipment Production
Military Forecast
(Millions of Dollars)

Equipment Type	Actual 1989	1990	1991	Estimated 1992	1993	1994	CAGR 1989-1990	CAGR 1989-1994
Radar	6,456	6,552	6,650	6,783	7,089	7,435	1.5%	2.9%
Sonar	2,870	3,050	3,172	3,270	3,405	3,558	6.3%	4.4%
Missile-Weapon	6,461	6,450	6,665	6,895	7,120	7,298	(0.2%)	2.5%
Space	5,552	5,898	6,329	6,760	7,220	7,718	6.2%	6.8%
Navigation	1,602	1,635	1,686	1,740	1,794	1,849	2.1%	2.9%
Communications	4,944	5,118	5,245	5,409	5,580	5,750	3.5%	3.1%
Electronic Warfare	3,021	3,112	3,235	3,335	3,458	3,565	3.0%	3.4%
Reconnaissance	2,550	2,615	2,696	2,796	2,893	2,962	2.5%	3.0%
Aircraft Systems	4,312	4,337	4,411	4,624	4,929	5,302	0.6%	4.2%
Computer Systems	2,308	2,421	2,545	2,708	2,892	3,088	4.9%	6.0%
Simulation & Training	845	946	1,054	1,170	1,328	1,495	12.0%	12.1%
Misc. Equipment	10,806	10,784	10,575	10,355	10,158	9,978	(0.2%)	(1.6%)
Military	51,727	52,918	54,263	55,845	57,866	59,998	2.3%	3.0%

Source: Dataquest March 1990

Table 7a

North American Electronic Equipment Production
Transportation History
(Millions of Dollars)

Equipment Type	1983	1984	1985	1986	1987	1988	1989
Entertainment	1,549	2,142	2,380	2,647	2,780	2,876	2,968
Body Controls	777	1,060	1,261	1,513	1,640	1,772	1,912
Driver Information	798	1,060	1,237	1,458	1,583	1,708	1,839
Powertrain	1,933	2,473	2,782	3,007	3,155	3,259	3,351
Safety & Convenience	490	706	820	955	1,041	1,129	1,222
Transportation	5,547	7,441	8,480	9,580	10,199	10,744	11,292

Source: Dataquest
March 1990

Table 7b

North American Electronic Equipment Production
Transportation Forecast
(Millions of Dollars)

Equipment Type	Actual 1989	1990	1991	Estimated 1992	1993	1994	CAGR 1989-1990	CAGR 1989-1994
Entertainment	2,968	3,028	3,192	3,338	3,468	3,548	2.0%	3.6%
Body Controls	1,912	2,075	2,415	2,704	2,903	3,052	8.5%	9.8%
Driver Information	1,839	1,959	2,170	2,381	2,545	2,658	6.5%	7.6%
Powertrain	3,351	3,441	3,595	3,724	3,839	3,933	2.7%	3.3%
Safety & Convenience	1,222	1,325	1,525	1,805	2,081	2,258	8.4%	13.1%
Transportation	11,292	11,828	12,897	13,952	14,836	15,449	4.7%	6.5%

Source: Dataquest
March 1990

Semiconductor Purchasing Locations

Each year, Dataquest's Semiconductor Applications Market (SAM) service gathers information for semiconductor manufacturers about their customers and markets in the United States. Our target audience is largely manufacturers listed in a comprehensive annual ranking of the top electronics manufacturers, which is published by Electronic Business.

The original list of 200 companies was pared down to 158 companies to eliminate semiconductor and other types of component manufacturers that do not buy semiconductors for use in their electronic systems and subassemblies. From the list of the remaining 158 companies, we have located more than 650 semiconductor purchasing locations. Each of these locations has been classified into one of the six SAM major lines of business (LOB): data processing (DP), communications (COMM), industrial (IND), consumer (CON), military (MIL), and transportation (TRAN).

This section displays the purchasing location information in three formats:

- An alphabetical list of the 158 companies (Table 1)
- A list of the 158 companies' semiconductor purchasing locations (Table 2) including a 5-digit Standard Industrial Code (SIC) to specify each location's major LOB
- Lists of semiconductor purchasing locations by line of business (Tables 3 through 8) including each location's specific 5-digit SIC
- A cross-reference index matching the 5-digit SICs to electronic equipment segmentation within the six major LOBs (Table 9).

Table 1

Directory of Electronic Business 200 Corporations

Company Code	Company Name	Semiconductor Application Markets
CCCOM	3Com	DP, COMM, IND
ADC	ADC Telecommunications, Inc.	COMM
ADT	ADT Inc.	IND
AM	AM International, Inc.	DP, IND
AST	AST Research, Inc.	DP
ALLEN	Allen Group Inc., The	COMM, IND
ALLIED	Allied-Signal, Inc.	IND, MIL, TRAN
ALTO	Altos Computer Systems	DP
AMDH	Amdahl Corporation	DP, COMM
ATT	American Telephone & Telegraph	COMM
AMETEK	Ametek Inc.	DP, IND, CON, MIL
ANALOGIC	Analogic Corporation	IND
ANDR	Andrew Corporation	COMM
APOL	Apollo Computer, Inc.	DP
APPLE	Apple Computer, Inc.	DP
APMATS	Applied Materials, Inc.	IND
ATARI	Atari Corporation	DP
AYDIN	Aydin Corporation	DP, COMM, MIL
BRIN	BRIntec Corporation	DP
BALL	Ball Corporation	IND, MIL
BECT	Becton, Dickinson and Co.	IND
BELLHO	Bell & Howell Co.	DP, CON
BELLS	Bell Industries	MIL
BOE	Boeing Co.	IND, MIL
BOLT	Bolt Beranek and Newman Inc.	COMM
CTS	CTS Corporation	COMM
CHERRY	Cherry Electrical Prod. Corp.	DP, IND
CHRY	Chrysler Corporation	TRAN
CINCI	Cincinnati Milacron, Inc.	IND
CIPHER	Cipher Data Products, Inc.	DP
COHER	Coherent, Inc.	IND
COMPAQ	Compaq Computer Corporation	DP
COMPUGR	Compugraphic Corporation	DP
COMPCONS	Computer Consoles, Inc.	DP
CONTEL	Contel Corporation	DP
CD	Control Data Corporation	DP

(Continued)

Table 1 (Continued)

Directory of Electronic Business 200 Corporations

Company Code	Company Name	Semiconductor Application Markets
CRAY	Cray Research, Inc.	DP
CUBIC	Cubic Corporation	DP, COMM, IND
DSC	DSC Communications Corporation	COMM
DGC	Data General Corporation	DP, COMM
DATACARD	DataCard Corporation	DP, IND
DPOC	Datapoint Corporation	DP, COMM
DPRC	Dataproducts Corporation	DP, MIL
DECIC	Decision Industries Corporation	DP
DIAS	Diasonics, Inc.	IND
DIEBOLD	Diebold Inc.	DP, IND
DCAI	Digital Comm. Associates, Inc.	DP, COMM
DEC	Digital Equipment Corporation	DP, COMM
DYNASCO	Dynascan Corporation	COMM, CON
DYNATECH	Dynatech Corporation	DP, COMM, IND, TRAN
ESYS	E-Systems, Inc.	MIL
KODAK	Eastman Kodak Company	DP, IND, CON
EATON	Eaton Corporation	DP, COMM, IND, CON, MIL, TRAN
ELECTRO	Electrospace Systems, Inc.	MIL
ELI	Eli Lilly and Co.	IND
EMER	Emerson Electric Co.	COMM, IND, CON, MIL
ESTER	Esterline Corporation	IND
FAIR	Fairchild Industries, Inc.	MIL
FERRANTI	Ferranti Internat. Signal Inc.	IND, MIL
FIGGIE	Figgie International, Inc.	IND, MIL
FORD	Ford Motor Company	COMM, MIL, TRAN
FOX	Foxboro Co.	IND
GTE	GTE Corporation	COMM, MIL
GENRAD	GenRad, Inc.	IND
GENCORP	Gencorp Inc.	MIL
GDCI	General DataCom Industries	COMM
GD	General Dynamics Corporation	DP, IND, MIL
GE	General Electric Co.	COMM, IND, CON, MIL, TRAN
GI	General Instrument Corporation	COMM, MIL
GM	General Motors Corporation	DP, COMM, IND, MIL, TRAN
GSIG	General Signal Corporation	COMM, IND, MIL
GENI	Genicom Corporation	DP

(Continued)

Table 1 (Continued)

Directory of Electronic Business 200 Corporations

Company Code	Company Name	Semiconductor Application Markets
GERBER	Gerber Scientific, Inc.	DP, IND
GOULD	Gould Inc.	IND
GRUM	Grumman Corporation	MIL
HARRIS	Harris Corporation	DP, COMM, MIL
HP	Hewlett-Packard Co.	DP, COMM, IND, CON, MIL
HONEY	Honeywell, Inc.	DP, COMM, IND, MIL
IBM	IBM	DP, COMM
ITT	ITT Corporation	IND, MIL
INTEL	Intel Corporation	DP
INTELSYS	Intelligent Systems Corporation	DP
INTER	Intergraph Corporation	DP
FLUKE	John Fluke Mfg. Co., Inc.	IND
JCI	Johnson Controls, Inc.	IND
LTV	LTV Corporation	MIL
LTX	LTX Corporation	IND
LANDIS	Landis & Gyr, Inc.	IND
LITTON	Litton Industries, Inc.	IND, CON, MIL
LOCK	Lockheed Corporation	DP, MIL
LORAL	Loral Corporation	MIL
MACOM	M/A-COM, Inc.	MIL
MAIBASIC	MAI Basic Four Inc.	DP
MARKCON	Mark Controls Corporation	IND
MARKIV	Mark IV Industries, Inc.	DP, COMM, IND, CON, MIL
MM	Martin Marietta Corporation	IND, MIL
MAXTOR	Maxtor Corporation	DP
MCDD	McDonnell Douglas Corporation	DP, MIL
MEAS	Measurex Corporation	IND
MEDTI	Medtronic, Inc.	IND
MEMTEL	Memorex Telex Corporation	DP, COMM, IND, CON, MIL
MICOM	Micom Systems, Inc.	COMM
MICROP	Micropolis Corporation	DP
MINISCR	Miniscribe Corporation	DP
MMM	Minnesota Mining & Mfg. Co.	DP, IND
MOTO	Motorola, Inc.	DP, COMM, IND, CON, MIL, TRAN
NBI	NBI, Inc.	DP
NCR	NCR Corporation	DP, COMM

(Continued)

Table 1 (Continued)

Directory of Electronic Business 200 Corporations

Company Code	Company Name	Semiconductor Application Markets
NSC	National Semiconductor	DP
PHILIPS	North American Philips Corporation	COMM, IND, CON, MIL, TRAN
NORTHROP	Northrop Corporation	IND, MIL
OLIN	Olin Corporation	MIL
PARA	Paradyne Corporation	COMM
PENNCEN	Penn Central Corporation	MIL
PERK	Perkin-Elmer Corporation	DP, COMM, IND, MIL
PB	Pitney Bowes, Inc.	DP, COMM
POLAROID	Polaroid Corporation	CON
PRIME	Prime Computer, Inc.	DP
QUANTUM	Quantum Corporation	DP
RAYTHEON	Raytheon Co.	MIL
RECOG	Recognition Equipment, Inc.	DP
REYN	Reynolds & Reynolds Company	IND
ROCK	Rockwell International Corporation	DP, COMM, IND, MIL
SCISI	SCI Systems Inc.	DP, COMM, MIL
SCIATL	Scientific-Atlanta Inc.	COMM, IND, MIL
SEAGATE	Seagate Technology	DP
SEQUA	Sequa Corporation	IND, MIL
SINGER	Singer Company	IND, MIL
SKB	SmithKline Beckman Corporation	IND
SPEC	Spectra-Physics, Inc.	DP, IND
SQUARE	Square D Co.	DP, IND, MIL
STC	Storage Technology Corporation	DP
STRATUS	Stratus Computer Inc.	DP
SUNECORP	Sun Electric Corporation	TRAN
SUNMIC	Sun Microsystems Inc.	DP
SUNDSC	Sundstrand Corporation	IND, CON, MIL
TRW	TRW, Inc.	COMM, IND, MIL, TRAN
TANDEM	Tandem Computers	DP
TANDON	Tandon Corporation	DP
TANDY	Tandy Corporation	DP, COMM
TEK	Tektronix, Inc	DP, COMM, IND
TELEDY	Teledyne, Inc.	IND, MIL
TERAD	Teradyne, Inc.	COMM, IND
TI	Texas Instruments, Inc.	DP, IND, CON, MIL

(Continued)

Table 1 (Continued)

Directory of Electronic Business 200 Corporations

Company Code	Company Name	Semiconductor Application Markets
TEXTRON	Textron Inc.	IND
TBCORP	Thomas & Betts Corporation	IND
TRACOR	Tracor Inc.	IND, MIL
UNISYS	Unisys Corporation	DP, MIL
UICORP	United Industrial Corporation	IND, MIL
UTC	United Technologies Corporation	IND, MIL
VAR	Varian Associates, Inc.	IND, MIL
VEECO	Veeco Instruments, Inc.	IND
WANG	Wang Laboratories, Inc.	DP, COMM
WATK	Watkins-Johnson Co.	IND, MIL
WEC	Westinghouse Electric Corporation	IND, MIL
WYSE	Wyse Technology	DP
XEROX	Xerox Corporation	DP
ZEN	Zenith Electronics Corporation	DP, IND, CO

Source: Electronic Business
Dataquest
November 1988

Table 2

Electronic Business 200 Purchasing Locations

Parent Company Code	Location Name	City	State	Bus. Segment	SIC Code
MMM	3M	St. Paul	MN	DP	35732
MMM	3M Broadcasting & Related Prod.	Huntsville	AL	COMM	36622
MMM	3M Static Control	Austin	TX	IND	38252
ADC	ADC Telecommunications, Inc.	Minnesota	MN	COMM	36621
ADT	ADT Inc.	Clifton	NJ	IND	36624
AM	AM Int.-Multigraphics Division	Mount Prospect	IL	DP	35795
AM	AM Int.-Varityper Division	East Hanover	NJ	IND	35690
BOE	ARGO Systems, Inc.	Sunnyvale	CA	MIL	36620
PERK	ARK Electronic Products, Inc.	Melbourne	FL	COMM	36612
AST	AST Research Inc.	Irvine	CA	DP	35731
ATT	AT&T Tech-Corp Procurement Ctr.	Allentown	PA	COMM	36611
ALLIED	Air Research	Tucson	AZ	MIL	37612
ALLIED	Air Research	Tucson	AZ	MIL	37612
ALLEN	Allen Automated Systems Co. Dv.	Livonia	MI	IND	38252
ALLEN	Allen Test Products Division	Kalamazoo	MI	IND	38252
ALLEN	Allen-Antenna Specialists Co.	Solon	OH	COMM	36621
ROCK	Allen-Bradley Drives Division	Fullerton	CA	IND	35690
ROCK	Allen-Bradley Drives Division	Cedarsburg	WI	IND	35690
ALLIED	Allied Signal Aerospace Co.	Torrance	CA	MIL	37612
ALLIED	Allied-Sig. Aerospace Comm Dv.	Baltimore	MD	MIL	36625
ALLIED	Allied-Signal Aerospace Division	Kansas City	MO	MIL	36620
ALLIED	Allied-Signal Air Transport Dv.	Fort Lauderdale	FL	MIL	37213
ALLIED	Allied-Signal Corporate Proc.	Morristown	NJ	MIL	37211
ALLIED	Allied-Signal Endevco Division	San Juan Cap.	CA	IND	38253
ALLIED	Allied-Signal Flight Services	South Montrose	PA	MIL	37213
ALTO	Altos Computer Systems	San Jose	CA	DP	35731
AMDH	Amdahl Comm. Systems Division	Richardson	TX	COMM	36611
AMDH	Amdahl Comm. Systems Dv.-Proc	Richardson	TX	COMM	36612
AMDH	Amdahl Corporate Procurement	Sunnyvale	CA	DP	35731
AMETEK	Ametek Controls Division	Feasterville	PA	IND	38230
AMETEK	Ametek Houston Instrument Dv.	Austin	TX	DP	35732
AMETEK	Ametek Lamb Electric Division	Kent	OH	IND	35690
AMETEK	Ametek Mansfield & Green Dv.	Largo	FL	IND	38292
AMETEK	Ametek McCrometer Division	Hemet	CA	IND	38242
AMETEK	Ametek Panalarm Division	Skokie	IL	IND	38230
AMETEK	Ametek Process Equipment	Santee	CA	IND	35593
AMETEK	Ametek Straza Division	El Cajon	CA	MIL	36620

(Continued)

Table 2 (Continued)

Electronic Business 200 Purchasing Locations

Parent Company Code	Location Name	City	State	Bus. Segment	SIC Code
AMETEK	Ametek Thermox Instruments Dv.	Pittsburgh	PA	IND	38252
AMETEK	Ametek U.S. Gauge Division	Sellersville	PA	IND	38292
ANALOGIC	Analogic Corporation	Peabody	MA	IND	38230
ANALOGIC	Analogic Medical Division	Peabody	MA	IND	36931
ANDR	Andrew Corporation	Richardson	TX	COMM	36621
APOL	Apollo Computer Inc.	Chelmsford	MA	DP	35731
APOL	Apollo Computer, Inc. (NH)	Exeter	NH	DP	35731
APPLE	Apple Computer, Inc.	Cupertino	CA	DP	35731
APPLE	Apple Computer, Inc.	Fremont	CA	DP	35731
APMATS	Applied Materials, Inc.	Santa Clara	CA	IND	35595
ALLIED	Aquatech Systems Division	Warren	NJ	DP	35731
ATARI	Atari Corporation	Sunnyvale	CA	DP	35731
FIGGIE	Automatic Sprinkler Corporation	Broadview Hghts	OH	IND	38220
AYDIN	Aydin Computer Systems	Horsham	PA	MIL	35731
AYDIN	Aydin Controls	Fort Washington	PA	DP	35731
AYDIN	Aydin Microwave and Radar Dv.	San Jose	CA	MIL	36625
AYDIN	Aydin Monitor Systems Division	Ft. Washington	PA	COMM	36612
AYDIN	Aydin Vector Division	Newton	PA	MIL	36620
BRIN	BRIntec-Gary Electronics	Langhorn	PA	DP	35731
BALL	Ball Corp Aerospace Systems Dv.	Boulder	CO	MIL	37612
BALL	Ball Corp Aerospace Systems Dv.	Boulder	CO	MIL	37612
BALL	Ball Corp.-Efratom Division	Irvine	CA	MIL	37211
BALL	Ball Industrial Systems Division	Broomfield	CO	IND	38230
ALLIED	Baron-Blakeslee, Inc.	Melrose Park	IL	IND	35492
BECT	Becton, Dickinson FACS Inst.	Mountain View	CA	IND	36933
BECT	Becton-Diagnostic Instruments	Towson	MD	IND	36933
BELLHO	Bell & Howell Co.	Garden Grove	CA	CON	36516
BELLS	Bell Ind. Illuminated Displays	Redmond	WA	MIL	37213
BELLHO	Bell & Howell-Microfilm Products	Chicago	IL	DP	35732
ALLIED	Bendix Automotive Brakes Dv.	South Bend	IN	TRAN	36947
ALLIED	Bendix Cheshire Corporation	Cheshire	CT	MIL	37213
ALLIED	Bendix Electric Power Division	Eatontown	NJ	IND	35690
ALLIED	Bendix Electrodynamics Division	North Hollywood	CA	MIL	37213
ALLIED	Bendix Engine Controls Division	South Bend	IN	MIL	37213
ALLIED	Bendix Engine Controls Division	Jacksonville	FL	MIL	37213
ALLIED	Bendix Engine Controls Division	Jacksonville	FL	IND	38291
ALLIED	Bendix Environmental Systems	Baltimore	MD	IND	36625

(Continued)

Table 2 (Continued)

Electronic Business 200 Purchasing Locations

Parent Company Code	Location Name	City	State	Bus. Segment	SIC Code
ALLIED	Bendix Environmental Systems	Baltimore	MD	IND	36625
ALLIED	Bendix Guidance Systems Division	Teterboro	NJ	IND	38111
ALLIED	Bendix Heavy Vehicle Systems	Elyria	OH	TRAN	0
ALLIED	Bendix Heavy Vehicle Systems	Elyria	OH	TRAN	0
ALLIED	Bendix Wheels & Brakes Division	South Bend	IN	MIL	37213
MICOM	Black Box Corporation	Pittsburgh	PA	COMM	36611
BOE	Boeing Advanced Systems	Seattle	WA	MIL	37612
BOE	Boeing Aerospace Company	Huntsville	AL	MIL	37612
BOE	Boeing Commercial Airplanes	Renton	WA	MIL	37213
BOE	Boeing Electronics (Texas)	Irving	TX	MIL	37211
BOE	Boeing Electronics Co.-Proc.	Seattle	WA	MIL	37211
BOE	Boeing Helicopters	Philadelphia	PA	MIL	37213
BOE	Boeing Huntsville Division	Huntsville	AL	MIL	37612
BOE	Boeing Military Airplane Co.	Wichita	KS	MIL	37211
BOLT	Bolt Beranek and Newman Inc.	Billerica	MA	MIL	36620
TRW	Brandt Solids Control Division	Conroe	TX	IND	38230
EMER	Branson IPC	Hayward	CA	IND	35595
EMER	Branson Ultrasonic Corporation	Danbury	CN	IND	36629
AM	Bruning Computer Graphics	Martinez	CA	DP	35732
HONEY	Business Commuter Aviation Sys.	Glendale	AZ	IND	38111
HONEY	Business Commuter Aviation Sys.	Glendale	AZ	MIL	37213
BELLHO	Business Data Products Division	Baldwin Park	CA	DP	35732
CTS	CTS Corporation	Eden Prarie	MN	COMM	36612
MOTO	CTX International	Sunnyvale	CA	IND	38230
LOCK	CalComp Communications	Anaheim	CA	DP	35732
LOCK	CalComp Digitizer Division	Scottsdale	AZ	DP	35732
FIGGIE	Chemetron Fire Systems, Inc.	University Park	IL	IND	36624
CHERRY	Cherry Display Products	El Paso	TX	DP	35732
CHERRY	Cherry Electrical Prod. Corp.	Waukegan	IL	DP	35732
CHRY	Chrysler Huntsville Elect. Dv.	Huntsville	AL	TRAN	36510
CINCI	Cincinnati Mil. Electronic Sys.	Lebanon	OH	IND	35694
CIPHER	Cipher Data Products	Mountain View	CA	DP	35732
CIPHER	Cipher Data Products, Inc.	San Diego	CA	DP	35732
MOTO	Codex Corporation	Canton	MA	COMM	36612
COHER	Coherent Components Group	Auburn	CA	IND	36795
COHER	Coherent Components Group-Proc.	Auburn	CA	IND	36795
COHER	Coherent General, Inc.	Sturbridge	MA	IND	36621

(Continued)

Table 2 (Continued)

Electronic Business 200 Purchasing Locations

Parent Company Code	Location Name	City	State	Bus. Segment	SIC Code
COHER	Coherent General, Inc. (Proc.)	Sturbridge	MA	IND	36621
COHER	Coherent Medical Group	Palo Alto	CA	IND	36621
COHER	Coherent Medical Group	Palo Alto	CA	IND	36621
EMER	Commercial Cam Division	Wheeling	IL	IND	35492
COMPAQ	Compaq Computer Corporation	Plano	TX	DP	35731
COMPAQ	Compaq Computer Corporation	Houston	TX	DP	35731
COMPUGR	Compugraphic Corporation	Wilmington	MA	DP	35731
COMPCONS	Computer Consoles, Inc.	Rochester	NY	DP	35731
FIGGIE	Consolidated Packaging Machnry.	Alden	NY	IND	35492
SPEC	Construction & Agriculture Dv.	Dayton	OH	IND	36933
CONTEL	Contel Business Systems	Torrance	CA	DP	35731
CONTEL	Contel Business Systems	Torrance	CA	DP	35731
CONTEL	Contel Federal Systems	Fairfax	VA	DP	35731
CONTEL	Contel IPC	Westbrook	CT	DP	35732
CD	Control Data Corporation	Bloomington	MN	DP	35731
UNISYS	Convergent Technologies, Inc.	Roseville	CA	DP	35731
ALLIED	Courter Operations	Boyne City	MI	MIL	37211
CRAY	Cray Research, Inc.	Chippewa Falls	WI	DP	35731
CUBIC	Cubic Communications (Proc.)	Oceanside	CA	COMM	36622
CUBIC	Cubic Communications, Inc.	Oceanside	CA	COMM	36622
CUBIC	Cubic Corp-U.S. Elevator	Spring Valley	CA	IND	35690
CUBIC	Cubic Defense Systems Division	San Diego	CA	MIL	37211
CUBIC	Cubic Western Data	San Diego	CA	DP	35732
DSC	DSC Comm-Bus. Network Sys. Grp.	Santa Clara	CA	COMM	36612
DSC	DSC Comm-Elect Cross Connt. Sys.	Santa Clara	CA	COMM	36612
DSC	DSC Switching Group	Plano	TX	COMM	36611
GC	Data General Corp.	Westborough	MA	DP	35731
DGC	Data General Corp.	Southborough	MA	DP	35731
DGC	Data General Corp.	Sunnyvale	CA	DP	35731
DATACARD	DataCard Addressograph	Holmesville	OH	IND	35690
DATACARD	DataCard Corporation	Minneapolis	MN	DP	35732
DATACARD	DataCard Datatrol Division	Hudson	MA	DP	35732
ROCK	DataMyte Corporation	Minnetonka	MN	DP	35743
NSC	Datachecker Systems Division	Santa Clara	CA	DP	35743
DPOC	Datapoint Corporation	San Antonio	TX	DP	35732
DPRC	Dataproducts (New England)	Wallingford	CT	MIL	37612
DPRC	Dataproducts Corp. (Calif.)	Woodland Hills	CA	DP	35732

(Continued)

Table 2 (Continued)

Electronic Business 200 Purchasing Locations

Parent Company Code	Location Name	City	State	Bus. Segment	SIC Code
INTELSYS	Datavue	Norcross	GA	DP	35731
DECIC	Decision Industries Corporation	Horsham	PA	DP	35732
HONEY	Defense Systems Divison	Albuquerque	NM	MIL	37211
DIAS	Diasonics, Inc.	Milpitas	CA	IND	36933
PB	Dictaphone Corporation	Stratford	CN	COMM	36612
DIEBOLD	Diebold Inc.	North Canton	OH	DP	35743
DIEBOLD	Diebold, Inc.	Hebron	OH	DP	35743
DIEBOLD	Diebold, Inc.	Southborough	MA	DP	35743
DCAI	Digital Comm. Assocs.-Cohesive	Los Gatos	CA	COMM	36612
CAI	Digital Communications Assocs.	Alpharetta	GA	COMM	36611
DCAI	Digital Communications-Forte	San Jose	CA	DP	35732
DEC	Digital Equipment Corp. (Ariz)	Phoenix	AZ	DP	35731
DEC	Digital Equipment Corporation	Marlboro	MA	DP	35731
TEK	Dubner Computer Systems	Paramus	NJ	DP	35732
DYNASCO	Dynascan Corporation	Chicago	IL	COMM	36621
DYNATECH	Dynatech Data Systems	Springfield	VA	COMM	36611
DYNATECH	Dynatech Frontier Corporation	Albuquerque	NM	IND	38292
DYNATECH	Dynatech Interface Technology	Glendora	CA	IND	38252
DYNATECH	Dynatech Laboratories, Inc.	Chantilly	VA	IND	36933
DYNATECH	Dynatech Nevada, Inc.	Carson City	NV	IND	36933
DYNATECH	Dynatech Packet Technology Inc.	Woodbridge	VA	COMM	36611
DYNATECH	Dynatech Prec. Sampling Corp.	Baton Rouge	LA	IND	35690
DYNATECH	Dynatech Telecom Techniques Dv.	Gaithersburg	MD	COMM	36621
DYNATECH	Dynatech Trans-Met Engineering	Anaheim	CA	IND	38252
DYNATECH	Dynatech-Advanced Develop. Ctr.	Fort Lauderdale	FL	COMM	36622
DYNATECH	Dynatech-Colorgraphics Systems	Madison	WI	DP	35732
DYNATECH	Dynatech-Computer Power, Inc.	Scotts Valley	CA	IND	36795
DYNATECH	Dynatech-Controlonics Corp.	Westford	MA	COMM	36621
DYNATECH	Dynatech-Integra, Inc.	Milpitas	CA	IND	38252
DYNATECH	Dynatech-Lighting Loc. & Prot.	Tucson	AZ	IND	38220
DYNATECH	Dynatech-Sensors, Inc.	Saline	MI	TRAN	36947
DYNATECH	Dynatech-Trigon Ind., Inc.	Milpitas	CA	IND	35694
ESYS	E-Sys. Communications & Mfg. Dv.	St. Petersburg	FL	MIL	36620
ESYS	E-Systems Garland Division	Garland	TX	MIL	36620
ESYS	E-Systems Greenville Division	Greenville	TX	MIL	36625
ESYS	E-Systems Melpar Division	Falls Church	VA	MIL	36625
ESYS	E-Systems Montek Division	Salt Lake City	UT	MIL	37211

(Continued)

Table 2 (Continued)

Electronic Business 200 Purchasing Locations

Parent Company Code	Location Name	City	State	Bus. Segment	SIC Code
AMETEK	Eastport International, Inc.	Upper Marlboro	MD	MIL	36620
EATON	Eaton Controls Division	Carol Stream	IL	IND	35690
EATON	Eaton Elec. Instrumentation Dv.	Los Angeles	CA	IND	38252
EATON	Eaton Electronics Instrument.	Los Angeles	CA	IND	38252
EATON	Eaton Information Mgt. Division	Westlake Villge	CA	MIL	35731
EATON	Eaton Ion Beam Systems Division	Beverly	MA	IND	35595
EATON	Eaton Memory Test Division	Irvine	CA	IND	38252
EATON	Eaton Microlithography Division	San Jose	CA	IND	35595
EATON	Eaton Microwave Products Dv.	Sunnyvale	CA	MIL	36625
EATON	Eaton Printer Products	Riverton	WY	DP	35732
EATON	Eaton-Kenway	Bountiful	UT	IND	38230
EATON	Eaton-MSC Products	Costa Mesa	CA	MIL	37211
BALL	Efratom Division	Irvine	CA	MIL	36010
BALL	Efratom Division	Irvine	CA	MIL	38110
UTC	Electro Systems Division	Columbus	MS	IND	35690
MCDD	Electro-Mechanical Division	Grand Rapids	MI	IND	35690
HONEY	Electro-Optics Division	Lexington	MA	MIL	36620
ESYS	Electronic Communications, Inc.	St. Petersburg	FL	MIL	36620
ELECTRO	Electrospace Systems, Inc.	Richardson	TX	MIL	37211
ELECTRO	Electrotel, Inc.	W. Ballanger	TX	MIL	36625
ELI	Eli-Cardiac Pacemakers, Inc.	St. Paul	MN	IND	36933
ELI	Eli-IVAC Corporation	San Diego	CA	IND	36933
ELI	Eli-Physio-Control Corporation	Redmond	WA	IND	36933
EMER	Emerson-Beckman Industrial	Fullerton	CA	MIL	37611
EMER	Emerson EMC	Chanhassen	MN	IND	38230
EMER	Emerson EMC	Chanhassen	MN	IND	38230
EMER	Emerson Electric-Corp Proc.	St. Louis	MO	IND	38230
EMER	Emerson-ACDC Electronics Dv.	Oceanside	CA	IND	36292
EMER	Emerson-Alco Controls Division	St. Louis	MO	IND	38230
EMER	Emerson-Alco Controls Division	Hazelhurst	GA	IND	38230
EMER	Emerson-Brooks Instruments	Hatfield	PA	IND	38230
EMER	Emerson-Chance Load Management	Hazelwood	MO	IND	38230
EMER	Emerson-Commercial Cam Dv.	Wheeling	IL	IND	35492
EMER	Emerson-Computer Power Systems	Arson	CA	MIL	35731
EMER	Emerson-Doerr Electrical Dv.	Cedarsburg	WI	IND	35690
EMER	Emerson-Doric Scientific Dv.	San Diego	CA	IND	38230
EMER	Emerson-Electronic Navigation	Rochester	NY	MIL	37211

(Continued)

Table 2 (Continued)

Electronic Business 200 Purchasing Locations

Parent Company Code	Location Name	City	State	Bus. Segment	SIC Code
EMER	Emerson-Electronics & Space Dv.	St. Louis	MO	MIL	36625
EMER	Emerson-Industrial Controls Dv.	Santa Ana	CA	IND	36292
EMER	Emerson-Industrial Products	Brea	CA	IND	38253
EMER	Emerson-Rantec Division	Calabasas	CA	MIL	36625
EMER	Emerson-Rosemont Inc.	Eden Prairie	MN	IND	38230
EMER	Emerson-Rosemont Inc.	Irvine	CA	IND	38242
EMER	Emerson-Rosemont Inc.	La Habra	CA	IND	38230
EMER	Emerson-Special Products Dv.	Hazelwood	MO	CON	36629
EMER	Emerson-Varec, Inc.	Cypress	CA	MIL	38110
EMER	Emerson-White Rodgers Division	Harrison	AK	IND	36292
EMER	Emerson-White Rodgers Division	St. Louis	MO	MIL	36620
ESTER	Esterline Angus Instrument Corp.	Indianapolis	IN	IND	38326
ESTER	Esterline Excellon Automation	Torrance	CA	IND	35595
ESTER	Esterline-Federal Products Corp.	Providence	RI	IND	38253
FAIR	Fairchild Communications & Elec.	Germantown	MD	MIL	36620
FAIR	Fairchild Space Co.	Germantown	MD	MIL	37612
FERRANTI	Ferrant Internat. Signal Inc.	Lancaster	PA	MIL	36620
FIGGIE	Figgie Intl. -CASI-RUSCO	Glendale	CA	IND	36624
FIGGIE	Figgie Intl. American LaFrance	Bluefield	VA	IND	38230
FIGGIE	Figgie Intl. American LaFrance	Bluefield	VA	IND	38230
FIGGIE	Figgie-Hartman Systems	Huntington Sta	NY	MIL	37312
FIGGIE	Figgie-Interstate Electronics	Anaheim	CA	MIL	36625
FORD	Ford Aero. & Comm. Corp (Mich.)	Dearborn	MI	MIL	85120
FORD	Ford Aeronutronic Division	Newport Beach	Ca	MIL	37611
FORD	Ford Aerospace & Comm. Corp-CA	Newport Beach	CA	MIL	37611
FORD	Ford Aerospace & Comm. Corp-CO	Colorado Springs	CO	MIL	36620
FORD	Ford Aerospace & Comm. Corp-TX	Houston	TX	MIL	35731
FORD	Ford Aerospace-Space Sys. Dv.	Palo Alto	CA	MIL	37612
FORD	Ford Electrical/Electronics Dv.	Ypsilanti	MI	TRAN	36947
FOX	Foxboro Analytical Division	Plymouth	MA	IND	38326
FOX	Foxboro Analytical Division	Plymouth	MA	IND	38326
FOX	Foxboro Company	Valencia	CA	IND	38230
FOX	Foxboro Company	Foxboro	MA	IND	38230
LORAL	Frequency Sources Inc.-East	S. Chelmsford	MA	MIL	36620
LORAL	Frequency Sources Inc.-West	San Jose	CA	MIL	36620
GE	GE Aerospace & Defense Auto. Sys.	Burlington	MA	COMM	36628
GE	GE Aerospace Controls Systems	Binghamton	NY	MIL	37211

(Continued)

Table 2 (Continued)

Electronic Business 200 Purchasing Locations

Parent Company Code	Location Name	City	State	Bus. Segment	SIC Code
GE	GE Aerospace Electronic Sys. Mfg.	Utica	NY	MIL	37211
GE	GE Aircraft Instruments Division	Wilmington	MA	IND	38111
GE	GE Appliance Control Dept.	Morrison	IL	TRAN	36947
GE	GE Armament & Elec. Systems	Erie	PA	MIL	38110
GE	GE Armament Electric Sys. Dept.	Burlington	VT	MIL	36620
GE	GE Astrospace	Princeton	NJ	MIL	37612
GE	GE Astrospace Division	Hightstown	NJ	MIL	37612
GE	GE Corporate Research & Dev.	Schenectady	NY	MIL	38110
GE	GE Defense Systems	Pittsfield	MA	MIL	36620
GE	GE Direct Current Motor & Gen.	Erie	PA	IND	35690
GE	GE Drive Systems	Salem	VA	IND	38230
GE	GE Electrical Distrib. & Comp.	Bloomington	IL	IND	35690
GE	GE FANUC Automation	Charlottsville	VA	IND	35694
GE	GE Govt. Electronic Sys. Dept.	Syracuse	NY	MIL	36625
GE	GE Lighting Business Group	Cleveland	OH	IND	35690
GE	GE Locomotive Products Division	Erie	PA	TRAN	0
GE	GE Major Appliance Division	Louisville	KY	CON	36394
GE	GE Medical Systems Group	Milwaukee	WI	IND	36931
GE	GE Meter Business Department	Somersworth	NH	IND	38326
GE	GE Military & Data Systems Dv.	Philadelphia	PA	MIL	36010
GE	GE Mobile Communications Dv.	Lynchburg	VA	COMM	36621
GE	GE Neutron Devices	Largo	FL	MIL	38110
GE	GE Power Supply Operation Dv.	Fort Wayne	IN	IND	36795
GE	GE RCA Corporation	Camden	NJ	MIL	36620
GE	GE RCA Electronic Services	Moorestown	NJ	MIL	36625
GE	GE Rentry Systems Operation	Philadelphia	PA	MIL	37612
GE	GE Simulation & Control Sys.	Daytona Beach	FL	MIL	38229
GE	GE Wiring Device Department	Warwick	RI	IND	35690
GI	GI Government Systems Division	Hicksville	NY	MIL	36625
GI	GI Jerrold Division	Tucson	AZ	COMM	36622
GI	GI Jerrold Division (PA)	Hatboro	PA	COMM	36622
GI	GI Sytek, Inc. (Procurement)	Mountain View	CA	COMM	36612
GI	GI Tocom Division	Irving	TX	COMM	36622
GI	GI Tocum Division (Procurement)	Dallas	TX	COMM	36622
GM	GM Delco Electronics	Oak Creek	WI	MIL	35731
GM	GM Delco Electronics	Kokomo	IN	TRAN	36947
GM	GM Hughes Electro Optical & DS	El Segundo	CA	MIL	36625

(Continued)

Table 2 (Continued)

Electronic Business 200 Purchasing Locations

Parent Company Code	Location Name	City	State	Bus. Segment	SIC Code
GM	GM Hughes Electron Dynamics	Torrance	CA	MIL	38110
GM	GM Hughes Ground Systems Grp.	Fullerton	CA	MIL	36625
GM	GM Hughes Industrial Prod. Dv.	Carlsbad	CA	IND	38252
GM	GM Hughes Microelec. Sys. Grp.	Rancho Santa Mg	CA	MIL	36620
GM	GM Hughes Network Systems	San Diego	CA	MIL	36620
GM	GM Hughes Santa Barbara Res. Ctr.	Goleta	CA	MIL	37611
GM	GM Hughes Space & Comm. Group	Los Angeles	CA	MIL	37612
GM	GM Hughes-Missile Systems Grp.	Canoga Park	CA	MIL	37611
GM	GM Hughes-Radar Systems Group	Los Angeles	CA	MIL	36625
GTE	GTE Communication Systems	Phoenix	AZ	COMM	36611
GTE	GTE Communication Systems Corp.	Phoenix	AZ	COMM	36611
GTE	GTE Corporation	Stamford	CT	COMM	36611
GTE	GTE Government Systems	Needham Heights	MA	MIL	36620
GSIG	Gen Sig Thin Film Company	Fremont	CA	IND	35595
GSIG	Gen Sig-Advanced Mechanization	Horsham	PA	IND	35595
GSIG	Gen Sig-Cardion Electronics	Woodbury	NY	MIL	36625
GSIG	Gen Sig-Circuit Processing App.	Fremont	CA	IND	35595
GSIG	Gen Sig-Leeds & Northup	North Wales	PA	IND	38230
GSIG	Gen Sig-Solar Electric	Elk Grove Vil.	IL	IND	35694
GSIG	Gen Sig-Stock Equipment Co.	Chagrin Falls	OH	IND	35340
GSIG	Gen Sig-Tau Tron, Inc.	Waterford	MA	COMM	36621
GSIG	Gen Sig-Telecom. Technology Dv.	Milpitas	CA	COMM	36621
GSIG	Gen Sig-Ultratech Stepper	Santa Clara	CA	IND	35595
GSIG	Gen Sig-Warren-Die Electric	Littleton	MA	IND	36795
GD	Gen. Dynamics (Ft. Worth)	Fort Worth	TX	MIL	37211
GD	Gen. Dynamics Electronics Dv.	San Diego	CA	MIL	37211
GD	Gen. Dynamics-Pomona Division	Pomona	CA	MIL	36620
GD	Gen. Dynamics -Datagraphix	San Diego	CA	DP	35732
GENRAD	GenRad Service Products Dv.	Phoenix	AZ	IND	38252
GENRAD	GenRad Structural Test Prod.	Milpitas	CA	IND	38252
GENRAD	GenRad-Electronic Mfg. Test	Concord	MA	IND	38252
GENCORP	Gencorp Aerojet Division	Azusa	CA	MIL	37612
GDCI	General DataCom Industries	Naugatuck	CT	COMM	36612
GI	General Instrument Corporation	Lyndhurst	NJ	COMM	36622
GSIG	General Railway Signal	Rochester	NY	IND	36626
GENI	Genicom Corporation	Waynesboro	VA	DP	35732
GERBER	Gerber Garment Technology, Inc.	Tolland	CT	IND	35401

(Continued)

Table 2 (Continued)

Electronic Business 200 Purchasing Locations

Parent Company Code	Location Name	City	State	Bus. Segment	SIC Code
GERBER	Gerber Scientific Instrument	S. Windsor	CT	DP	35731
GERBER	Gerber Scientific Products	Manchester	CT	IND	35401
GOULD	Gould, Inc.	Pocatello	ID	IND	38252
GRUM	Grumman Electronics Division	Bethpage	NY	MIL	36625
HP	HP Andover Division	Andover	MA	MIL	35731
HP	HP Avondale Division	Avondale	PA	IND	38326
HP	HP Bar Code Operation	San Jose	CA	DP	35732
HP	HP Boise Printer Division	Boise	ID	DP	35732
HP	HP Colorado Springs Division	Colorado Springs	CO	IND	38252
HP	HP Colorado Telecom. Division	Colorado Springs	CO	IND	38252
HP	HP Computer Systems Division	Cupertino	CA	DP	35731
HP	HP Corporate Materials Mgt.	Palo Alto	CA	DP	35731
HP	HP Corvallis Division	Corvallis	OR	DP	35731
HP	HP Disc Memory Division	Boise	ID	DP	35732
HP	HP Greeley Storage Division	Greele	CO	DP	35732
HP	HP Lake Stevens Instrument Dv.	Everett	WA	IND	38252
HP	HP Logic Systems Division	Colorado Springs	CO	DP	35731
HP	HP Loveland Instrument (Proc.)	Loveland	CO	IND	38252
HP	HP Loveland Instrument Division	Loveland	CO	IND	38252
HP	HP McMinnville Division	McMinnville	OR	IND	36933
HP	HP Network Management Division	Santa Rosa	CA	COMM	36621
HP	HP New Jersey Division	Rockaway	NJ	IND	36795
HP	HP Office & Computer Division	Sunnyvale	CA	DP	35731
HP	HP Personal Computer Group	Sunnyvale	CA	DP	35731
HP	HP Roseville Manufacturing Op.	Roseville	CA	COMM	36621
HP	HP Roseville Terminals Division	Roseville	CA	DP	35732
HP	HP San Diego Division	San Diego	CA	DP	35732
HP	HP Santa Clara Division	Santa Clara	CA	IND	38252
HP	HP Scientific Instruments Dv.	Palo Alto	CA	IND	38326
HP	HP Signal Analyzer Division	Rohnert Park	CA	IND	38252
HP	HP Stanfd Park Microw Test Eqp.	Palo Alto	CA	COMM	36621
HP	HP Stanford Park Instrument	Palo Alto	CA	COMM	36621
HP	HP Technical Computer Group	Sunnyvale	CA	DP	35731
HP	HP Technical Systems Sector	Fort Collins	CO	DP	35731
HP	HP Vancouver Division	Camas	WA	DP	35732
HP	HP Waltham Division	Waltham	MA	IND	36933
SINGER	HRB-Singer	State College	PA	MIL	36625

(Continued)

Table 2 (Continued)

Electronic Business 200 Purchasing Locations

Parent Company Code	Location Name	City	State	Bus. Segment	SIC Code
HARRIS	Harris Computer Systems Division	Ft. Lauderdale	FL	DP	35731
HARRIS	Harris Corporation (CA)	San Carlos	CA	MIL	36620
HARRIS	Harris Corporation (FLA)	Melbourne	FL	MIL	36620
HONEY	Honeywell Bull (Procurement)	Brighton	MA	DP	35731
HONEY	Honeywell Bull Phoenix Opertns	Phoenix	AZ	DP	35731
HONEY	Honeywell Comml. Aviation Dv.	St. Louis Park	MN	IND	38111
HONEY	Honeywell Commercial Buildings	Arlington Hghts	IL	IND	38220
HONEY	Honeywell Comml. Flight Systems	Phoenix	AZ	IND	38111
HONEY	Honeywell Comml. Flight Systems	Phoenix	AZ	IND	38111
HONEY	Honeywell Defense Comm. & Prod.	Tampa	FL	MIL	36620
HONEY	Honeywell Defense Comm./Prod. Dv.	Tampa	FL	MIL	36620
HONEY	Honeywell Defense Systems Dv.	New Brighton	MN	MIL	36620
HONEY	Honeywell Inc.-Defense Systems	New Brighton	MN	MIL	36620
HONEY	Honeywell Ind. Automation Sys.	Phoeniz	AZ	IND	38230
HONEY	Honeywell Indust. Controls Dv.	Fort Washington	PA	IND	38230
HONEY	Honeywell Industrial Controls	Ft. Washington	PA	IND	38230
HONEY	Honeywell Keyboard Division	El Paso	TX	DP	35732
HONEY	Honeywell Marine Systems Dv.	Everett	WA	MIL	37312
HONEY	Honeywell Microswitch Division	Freeport	IL	IND	35340
HONEY	Honeywell Protection Services	Irvine	CA	IND	36624
HONEY	Honeywell Residential Division	Golden Valley	MN	IND	36624
HONEY	Honeywell Test Instruments Dv.	Denver	CO	IND	38326
HONEY	Honeywell Training/Control Sys.	W. Covina	CA	MIL	38229
HONEY	Honeywell Underseas Division	Hopkins	MN	MIL	36620
CHRY	Huntsville Electronics Division	Huntsville	AL	TRAN	36947
IBM	IBM	Hopewell Junctn	NY	DP	35731
IBM	IBM	Research Tri.Pk.	NC	DP	35731
IBM	IBM	Colorado Springs	CO	COMM	36611
ITT	ITT Aerospace	Fort Wayne	IN	MIL	37612
ITT	ITT Avionics	Nutley	NJ	MIL	36625
ITT	ITT Avionics Division (Proc.)	Clifton	NJ	MIL	36625
ITT	ITT Barton Instruments	City of Industy.	CA	IND	38242
ITT	ITT Defense Comm. Division	Nutley	NJ	MIL	36620
ITT	ITT Defense Comm. (Proc.)	Clifton	NJ	MIL	36620
ITT	ITT Electro Optical Products	Roanoke	VA	MIL	38110
ITT	ITT Gilfillan Division	Van Nuys	CA	MIL	36625
ITT	ITT Gilfillan Division	Van Nuys	CA	MIL	36625

(Continued)

Table 2 (Continued)

Electronic Business 200 Purchasing Locations

Parent Company Code	Location Name	City	State	Bus. Segment	SIC Code
ITT	ITT McDonnell-Miller	Chicago	IL	IND	35690
ITT	ITT Pomona Electronics Division	Pomona	CA	IND	38252
ITT	ITT Standard	Cheektowaga	NY	IND	35690
BELLS	Illuminated Displays Division	Redmond	WA	MIL	37213
ROCK	Industrial Computer Group	Highland Hts.	OH	IND	35401
WANG	InteCom, Inc.	Allen	TX	COMM	36611
INTEL	Intel Pers. Computer Enh. Oper.	Hillsboro	OR	DP	35731
INTEL	Intel Systems Group	Hillsboro	OR	DP	35731
INTER	Intergraph Corporation	Huntsville	AL	DP	35731
FIGGIE	Interstate Electronics Corp.	Anaheim	CA	MIL	85120
GI	Jerrold Distribution Systems	Hatboro	PA	COMM	36622
FLUKE	John Fluke Mfg. Co., Inc.	Everette	WA	IND	38252
JCI	Johnson Systems and Services	Milwaukee	WI	IND	38220
KODAK	Kodak Apparatus Division	Rochester	NY	DP	35793
KODAK	Kodak Company	Columbia	SC	IND	35690
KODAK	Kodak Datatape Division	Pasadena	CA	DP	35732
KODAK	Kodak Electronic Prepress Sys.	Billerica	MA	DP	35731
KODAK	Kodak-Spin Physics, Inc.	San Diego	CA	CON	36516
LTV	LTV Aircraft Products Division	Dallas	TX	MIL	37211
LTV	LTV Missiles (Proc.)	Dallas	TX	MIL	37611
LTV	LTV Missiles Division	Dallas	TX	MIL	37611
LTV	LTV Sierra Research Division	Buffalo	NY	MIL	36625
LTX	LTX Corporation	Westwood	MA	IND	38252
LANDIS	Landis & Gyr Metering	Lafayette	IN	IND	38252
LANDIS	Landis & Gyr Powers	Buffalo Grove	IL	IND	38220
LANDIS	Landis & Gyr Systems	San Jose	CA	IND	38230
SPEC	Laser Analytics Division	Bedford	MA	IND	38112
DYNATECH	Lea Dynatech, Inc.	Santa Fe Springs	CA	IND	36795
LITTON	Litton Aerospace Products	Moorpark	CA	MIL	37612
LITTON	Litton Amecon Division	College Park	MD	MIL	36625
LITTON	Litton Applied Technology	San Jose	CA	MIL	36625
LITTON	Litton Automated Mfg. Systems	Hebron	KY	IND	35340
LITTON	Litton Data Systems	Van Nuys	CA	MIL	35731
LITTON	Litton Data Systems (LDS)	Pascagoula	MI	TRAN	37313
LITTON	Litton Electron Devices	San Carlos	CA	IND	38112
LITTON	Litton Encoder	Chatsworth	CA	MIL	36620
LITTON	Litton Engineered Systems	Florence	KY	MIL	37211

(Continued)

Table 2 (Continued)

Electronic Business 200 Purchasing Locations

Parent Company Code	Location Name	City	State	Bus. Segment	SIC Code
LITTON	Litton Guidance & Control Sys.	Woodland Hills	CA	MIL	37611
LITTON	Litton Guidance & Control Sys.	Grants Pass	OR	MIL	37211
LITTON	Litton IAS	Holland	MI	IND	35340
LITTON	Litton Itek Optical Systems	Lexington	MA	MIL	37211
LITTON	Litton Laser Systems	Apopka	FL	MIL	37211
LITTON	Litton Microwave Cooking Prod.	Memphis	TN	CON	36311
LITTON	Litton Potentiometer Division	Mount Vernon	NY	IND	36624
LITTON	Litton-Clifton Prec/Spec. Devs.	Springfield	PA	MIL	37211
LITTON	Litton-Clifton Precision/Iowa	Davenport	IA	MIL	37211
LOCK	Lockheed Aeronautical Systems	Marietta	GA	MIL	37211
LOCK	Lockheed Defense Info Sys. Dv.	Nashua	NH	MIL	36625
LOCK	Lockheed Defense Info Sys. Dv.	Nashua	NH	DP	35731
LOCK	Lockheed Electronics Co., Inc.	Plainfield	NJ	MIL	36625
LOCK	Lockheed Missiles & Space Co.	Sunnyvale	CA	MIL	37612
LORAL	Loral Conic	San Diego	CA	MIL	37611
LORAL	Loral Conic	San Diego	CA	MIL	36620
LORAL	Loral Electro-Optical Systems	Pasadena	CA	MIL	38229
LORAL	Loral Electronic Systems-Proc.	Yonkers	NY	MIL	36625
LORAL	Loral Information Display Sys.	Atlanta	GA	MIL	38110
LORAL	Loral Instrumentation	San Diego	CA	MIL	38110
LORAL	Loral Narda Microwave	Hauppauge	NY	MIL	36620
LORAL	Loral Terracom	San Diego	CA	MIL	36620
MACOM	M/A COM Active Assemblies Dv.	Chandler	AZ	MIL	36625
MACOM	M/A COM, Inc.	Burlington	MA	MIL	36620
MAIBASIC	MAI Basic Four Inc.	Tustin	CA	DP	35731
MARKCON	Mark /Powers Process Controls	Skokie	IL	IND	38230
MARK	Mark IV Altec Lansing	Oklahoma City	OK	CON	36629
MARK	Mark IV Automatic Signal Dv.	Clinton	MA	IND	36626
MARK	Mark IV Display Products	Duarte	CA	DP	35732
MARK	Mark IV Eagle Signal Controls	Austin	TX	IND	35401
MARK	Mark IV Electro Voice	Redmond	WA	CON	36629
MARK	Mark IV FCD	Hamden	CT	MIL	38110
MARK	Mark IV FEMCO	High Point	NC	COMM	36621
MARK	Mark IV Graphic Instruments	East Greenwich	RI	DP	35732
MARK	Mark IV Gulton Data Systems	Albuquerque	NM	MIL	37611
MARK	Mark IV Industrial Systems	Clinton	MA	IND	38230
MARK	Mark IV Instruments Dv. of LFE	Chesterland	OH	IND	38253

(Continued)

Table 2 (Continued)

Electronic Business 200 Purchasing Locations

Parent Company Code	Location Name	City	State	Bus. Segment	SIC Code
MARK	Mark IV Plasma Systems	Clinton	MA	IND	35595
MARK	Mark IV SCD	Duarte	CA	MIL	35731
MARK	Mark IV Servonic	Costa Mesa	CA	MIL	38110
MM	Martin Mar. Aero & Naval Sys.	Baltimore	MD	MIL	37211
MM	Martin Mar. Elect. & Missiles	Orlando	FL	MIL	37611
MM	Martin Mar. Elect. & Missiles	Orlando	FL	MIL	37211
MM	Martin Marietta Aerospace Dv.	Denver	CO	MIL	37612
MAXTOR	Maxtor Corporation	San Jose	CA	DP	35732
MCDD	McDonnell Dougl. Astronautics	Huntington Bch.	CA	MIL	37612
MCDD	McDonnell Douglas Aeronautics	St. Louis	MO	MIL	37211
MCDD	McDonnell Douglas Computer Sys.	Irvine	CA	DP	35731
MCDD	McDonnell Douglas Electronics	St. Charles	MO	MIL	37211
MCDD	McDonnell Douglas Electronics	St. Charles	MO	MIL	37211
MCDD	McDonnell-Vitek Systems, Inc.	Hazelwood	MO	MIL	35731
MEAS	Measurex Corporation	Cupertino	CA	IND	38230
MEDTI	Medtronic Micro-Rel. Division	Tempe	AZ	IND	36933
MEDTI	Medtronic, Inc.	Minneapolis	MN	IND	36933
MEMTEL	Memorex Telex Corporation	Raleigh	NC	DP	35732
MICOM	Micom Systems, Inc.	Simi Valley	CA	COMM	36611
MICROP	Micropolis Corporation	Chatsworth	CA	DP	35732
MINISCR	MiniScribe Corporation	Longmont	CO	DP	35732
PB	Monarch Marking	Dayton	OH	DP	35732
MOTO	Motorola Auto & Ind Elect. Dv.	Northbrook	IL	TRAN	38252
MOTO	Motorola Cellular Group	Schaumberg	IL	COMM	36621
MOTO	Motorola Cellular Group (Proc.)	Arlington Hgts.	IL	COMM	36621
MOTO	Motorola Codex Products	Mansing	MA	COMM	36612
MOTO	Motorola Communications Sector	Ft. Lauderdale	FL	COMM	36621
MOTO	Motorola Communications Sector	Schaumberg	IL	COMM	36621
MOTO	Motorola Computer Systems	Cupertino	CA	DP	35731
MOTO	Motorola Corp. Materials Mgt.	Schaumberg	IL	DP	35731
MOTO	Motorola Microcomputer Division	Tempe	AZ	IND	38230
MOTO	Motorola Micrographic Sys. Dv.	Mountain View	CA	DP	35793
MOTO	Motorola Mil. & Aerospace Elec.	Chandler	AZ	MIL	37612
MOTO	Motorola Universal Data Sys. Prod.	Huntsville	AL	COMM	36612
NBI	NBI, Inc.	Boulder	CO	DP	35731
NCR	NCR Applied Digital Data Sys.	Hauppauge	NY	DP	35731
NCR	NCR Comten (Procurement)	Blaine	MN	COMM	35730

(Continued)

Table 2 (Continued)

Electronic Business 200 Purchasing Locations

Parent Company Code	Location Name	City	State	Bus. Segment	SIC Code
NCR	NCR Corporation (Headquarters)	Dayton	OH	DP	35731
NCR	NCR Micrographic Sys. Dv.-Proc.	Mountain View	CA	DP	35793
NORTHROP	Northrop Aircraft Division	Hawthorne	CA	MIL	37211
NORTHROP	Northrop Defense Systems Dv.	Rolling Meadows	IL	MIL	37211
NORTHROP	Northrop Defense Systems Dv.	Warner Robbins	GA	MIL	36625
NORTHROP	Northrop Electro-Mechanical Dv.	Anaheim	CA	MIL	37211
NORTHROP	Northrop Precision Products Dv.	Norwood	MA	MIL	37211
NORTHROP	Northrop-Wilcox Electric Inc.	Kansas City	MO	MIL	37211
OLIN	Olin-Pacific Electrodynamic	Redmond	WA	MIL	38110
CIPHER	Optimem	Mountain View	CA	DP	35732
PARA	Paradyne Corporation	Largo	FL	COMM	36612
PENNCEN	Penn Central-Vitro Corporation	Silver Spring	MD	MIL	37611
PENNCEN	Penn Central-Vitro Services	Ridgecrest	CA	MIL	36620
BALL	Penn Video	Akron	OH	IND	35694
PENNCEN	Penn-Vitro Serv Co-Elec. Sys.	Ft. Walton Bch.	FL	MIL	36625
PENNCEN	Penn-Vitro Servs. Corp-IRSP	Ft. Walton Bch.	FL	MIL	36625
PERK	Perkin-El. Concurrent Computer	Oceanport	NJ	DP	35731
PERK	Perkin-El. Connecticut Inst.	Norwalk	CT	IND	35595
PERK	Perkin-El. Physical Elects. Dv.	Eden Prairie	MN	IND	38292
PERK	Perkin-Elmer Applied Optics Dv.	Garden Grove	CA	MIL	36625
PERK	Perkin-Elmer Applied Science	Pomona	CA	MIL	36625
PERK	Perkin-Elmer Elec. Beam Tech.	Hayward	CA	IND	35595
PHILIPS	Phil-Magnavox Govt. & Ind Elec.	Fort Wayne	IN	MIL	36620
PHILIPS	Philips-Airpax Corporation	Cheshire	CN	IND	35690
PHILIPS	Philips-Genie Company	Alliance	OH	CON	36994
PHILIPS	Philips Advanced Transformers	Chicago	IL	IND	35690
PHILIPS	Philips Consumer Electronics	Knoxville	TN	CON	36512
PHILIPS	Philips Electronic Instruments	Mahwah	NJ	IND	36931
PHILIPS	Philips Grenada Hospital Grp.	Burlington	MA	CON	36512
PHILIPS	Philips Magnavox CATV Systems	Manlius	NY	COMM	36622
PHILIPS	Philips Medical Systems, Inc.	Shelton	CT	IND	36931
PERK	Physcial Electronics Division	Eden Prairie	MN	IND	38292
PB	Pitney Bowes Dictaphone Corp.	Stratford	CN	COMM	36621
PB	Pitney Bowes Inc.	Stamford	CT	DP	35795
POLAROID	Polaroid Corporation	Norwood	MA	CON	38611
PRIME	Prime Computer, Inc.	Framingham	MA	DP	35731
PRIME	Prime-Computervision	Bedford	MA	DP	35731

(Continued)

Table 2 (Continued)

Electronic Business 200 Purchasing Locations

Parent Company Code	Location Name	City	State	Bus. Segment	SIC Code
INTELSYS	Princeton Graphics	Princeton	NJ	DP	35732
INTELSYS	Quadram	Norcross	GA	DP	35732
QUANTUM	Quantum Corporation	Milpitas	CA	DP	35732
RAYTHEON	Raytheon Co.	Lexington	MA	MIL	37611
RECOG	Recognition Equipment, Inc.	Irving	TX	DP	35732
REYN	Reynolds & Reynolds Co.	Dayton	OH	IND	35690
ROCK	Rockwell-Allen-Bradley Co.	Twinsburg	OH	IND	35694
ROCK	Rockwell-Satellite Systems	Seal Beach	CA	MIL	37612
ROCK	Rockwell Allen-Bradley Comms.	Ann Arbor	MI	COMM	36612
ROCK	Rockwell Avionics Group	Melbourne	FL	MIL	37213
ROCK	Rockwell Collins Air Trans Dv.	Cedar Rapids	IA	MIL	37211
ROCK	Rockwell Collins Air Transport	Cedar Rapids	IA	MIL	37211
ROCK	Rockwell Collins Defense Comm.	Cedar Rapids	IA	MIL	36620
ROCK	Rockwell Commercial Electronic	Richardson	TX	MIL	37213
ROCK	Rockwell Defense Electronics	Anaheim	CA	MIL	37211
ROCK	Rockwell Electronic Components	Greensboro	NC	IND	35340
ROCK	Rockwell Fireye Division	Derry	NH	IND	36624
ROCK	Rockwell Government Avionics	Cedar Rapids	IA	IND	38111
ROCK	Rockwell Graphic Systems Dv.	Chicago	IL	IND	35690
ROCK	Rockwell Industrial Computer	Twinsburg	OH	IND	38230
ROCK	Rockwell Industrial Control Dv.	Milwaukee	WI	IND	35694
ROCK	Rockwell Industrial Control Dv.	Fairfield	NJ	DP	35732
ROCK	Rockwell Meas. & Flow Control	Pittsburg	PA	IND	38242
ROCK	Rockwell Meas. & Flow Control	Uniontown	PA	IND	38242
ROCK	Rockwell Missile Systems Dv.	Duluth	GA	MIL	37611
ROCK	Rockwell No. Amer. Aircraft Op.	Los Angeles	CA	MIL	37211
PROCK	Rockwell No. Amer. Aircraft Op.	McAlester	OK	MIL	37211
ROCK	Rockwell Quality & Prod. Sys.	Highland Hgts.	OH	IND	35340
ROCK	Rockwell Rocketdyne Division	Canoga Park	CA	MIL	37612
ROCK	Rockwell Space Trans. Systems	Downey	CA	MIL	37612
ROCK	Rockwell Switching Systems Dv.	Downers Grove	IL	COMM	36611
ROCK	Rockwell Transmission Systems	Richardson	TX	COMM	36621
ROCK	Rockwell Wescom Telephone Prod.	Downers Grove	IL	COMM	36611
SCISI	SCI Systems Inc.	Huntsville	AL	MIL	36620
SCISI	SCI Unitronics	Sunnyvale	CA	IND	36933
SCIATL	Sci-Atl Broadband Communications	Norcross	GA	COMM	36622
SCIATL	Sci-Atl Control Systems Division	Atlanta	GA	IND	38220

(Continued)

Table 2 (Continued)

Electronic Business 200 Purchasing Locations

Parent Company Code	Location Name	City	State	Bus. Segment	SIC Code
SCIATL	Sci-Atl Electro Products Dv.	Atlanta	GA	MIL	36620
SCIATL	Sci-Atl Network Systems Group	Norcross	GA	COMM	36621
SCIATL	Scientific-Atl Instrumentation	Norcross	GA	IND	38326
SEAGATE	Seagate Technology	Scotts Valley	CA	DP	35732
SEQUA	Sequa-Kollsman Medical Dv.	Amherst	NH	IND	36933
SEQUA	Sequa-Kollsman Military Dv.	Nashua	NH	MIL	36625
SINGER	Singer-Kearfott Guid. & Nav.	Black Mountain	NC	MIL	37211
SINGER	Singer Company (NJ)	Little Falls	NJ	MIL	37211
SINGER	Singer Electronics Division	San Marcos	CA	MIL	38110
SINGER	Singer Librascope Division	Glendale	CA	MIL	37312
SKB	SmithKline Beckman Corporation	Philadelphia	PA	IND	36933
SKB	SmithKline Beckman Instruments	Fullerton	CA	IND	36933
SKB	SmithKline Beckman Instruments	Porterville	CA	IND	36933
HONEY	Space & Strategic Avionics Dv.	Clearwater	FL	MIL	37612
SPEC	Spectra-Phy. Retail Systems Dv.	Eugene	OR	DP	35732
SPEC	Spectra-Physics Autolab Division	San Jose	CA	IND	38230
SPEC	Spectra-Physics Laser Prod. Dv.	Mountain View	CA	IND	36795
HONEY	Sperry Space Systems Division	Glendale	AZ	MIL	37612
SQUARE	Square D-Engineered Systems	Tempe	AZ	DP	35731
SQUARE	Square D-K.B. Denver	Loveland	CO	MIL	38110
SQUARE	Square D-Ramsey Controls	Pinellas Park	FL	IND	35401
WATK	Stewart Division	Scotts Valley	CA	IND	35595
STC	Storage Tech. Printer Operation	Palm Bay	FL	DP	35732
STC	Storage Technology Corporation	Louisville	CO	DP	35732
STRATUS	Stratus Computer	Marlborough	MA	DP	35731
SUNECORP	Sun Electric Corporation	Crystal Lake	IL	TRAN	38252
SUNMIC	Sun Microsystems Inc.	Mountain View	CA	DP	35731
SUNDSC	Sundstrand Corporation	Redmond	WA	IND	38291
SUNDSC	Sundstrand Trans. Com. Division	Costa Mesa	CA	CON	36516
TI	TI Consumer Products Division	Lubbock	TX	CON	39447
TRW	TRW-ESL Inc.	Sunnyvale	CA	MIL	36625
TRW	TRW-ESL Inc.	Sunnyvale	CA	MIL	36625
TRW	TRW Dynalco Controls Division	Fort Lauderdale	FL	IND	38230
TRW	TRW Electronic Products, Inc.	Colorado Springs	CO	MIL	36620
TRW	TRW Electronics & Defense Sec.	Redondo Beach	CA	MIL	37612
TRW	TRW High Reliability Elec. Proc.	Redondo Beach	CA	MIL	37612
TRW	TRW Information Network Division	Torrance	CA	COMM	36612

(Continued)

Table 2 (Continued)

Electronic Business 200 Purchasing Locations

Parent Company Code	Location Name	City	State	Bus. Segment	SIC Code
TRW	TRW Transporation Elec. Division	Farmington Hill	MI	TRAN	36947
TRW	TRW Transportation Electronic	Farmington Hill	MI	TRAN	36947
TANDEM	Tandem Computers Corporation	Austin	TX	DP	35732
TANDEM	Tandem Computers Inc.	Cupertino	CA	DP	35731
TANDON	Tandon-NNA Corporation	Scotts Valley	CA	DP	35731
TANDY	Tandy Electronics	Fort Worth	TX	DP	35731
TEK	Tektronix Comm. Network Anlyzs.	Redmond	OR	COMM	36621
TEK	Tektronix Display Devices Oper.	Beaverton	OR	DP	35732
TEK	Tektronix Freq. Dm. Inst. Dv.	Beaverton	OR	IND	38252
TEK	Tektronix Graphic Prtng/Img. Dv.	Wilsonville	OR	DP	35732
TEK	Tektronix Graphic Workstations	Wilsonville	OR	DP	35732
TEK	Tektronix Graphics Terminals	Wilsonville	OR	DP	35732
TEK	Tektronix Lab. Instruments Dv.	Beaverton	OR	IND	38252
TEK	Tektronix Logic Analyzers Dv.	Beaverton	OR	IND	38252
TEK	Tektronix Modular Products Dv.	Grass Valley	CA	COMM	36622
TEK	Tektronix Murdock Park Division	Vancouver	WA	IND	38252
TEK	Tektronix Port. Instrument Dv.	Vancouver	WA	IND	38252
TEK	Tektronix Port. Test Inst. Dv.	Vancouver	WA	IND	38252
TEK	Tektronix Professional Video	Grass Valley	CA	COMM	36622
TEK	Tektronix Semic. Test Sys. Dv.	Beaverton	OR	IND	38252
TEK	Tektronix Switching Prdts. Dv.	Nevada City	CA	COMM	36622
TEK	Tektronix Telecom. Systems Grp.	Grass Valley	CA	COMM	36621
TEK	Tektronix Televis. Wavefm. Dsp.	Beaverton	OR	COMM	36622
TEK	Tektronix Television Division	Beaverton	OR	COMM	36622
TELEDY	Teledyne Analytical Instrument	City of Industy.	CA	IND	38326
TELEDY	Teledyne Avionics	Charlottesville	VA	MIL	37211
TELEDY	Teledyne Brown Engineering	Huntsville	AL	MIL	37211
TELEDY	Teledyne Controls	W. Los Angeles	CA	MIL	37211
TELEDY	Teledyne Hastings-Raydist	Hampton	VA	IND	38111
TELEDY	Teledyne Lewisburg	Lewisburg	TN	MIL	36620
TELEDY	Teledyne Microwave	Mountain View	CA	MIL	36625
TELEDY	Teledyne Ryan Electronics	San Diego	CA	MIL	36625
TELEDY	Teledyne Systems	Northridge	CA	MIL	37612
MEMTEL	Telex Communications	Lincoln	NE	COMM	36621
MEMTEL	Telex Communications	Rochester	MN	IND	36933
MEMTEL	Telex Communications	Glencoe	MN	CON	36515
MEMTEL	Telex Communications	Blue Earth	MN	CON	36514

(Continued)

Table 2 (Continued)

Electronic Business 200 Purchasing Locations

Parent Company Code	Location Name	City	State	Bus. Segment	SIC Code
TERAD	Teradyne-Zehntel	Walnut Creek	CA	IND	38252
TERAD	Teradyne Connection Systems Dv.	Nashua	NH	IND	38252
TERAD	Teradyne Industrial/Consum. Dv.	Boston	MA	IND	38252
TERAD	Teradyne Manufact. Systems Dv.	Boston	MA	IND	38252
TERAD	Teradyne Telecommunications Dv.	Deerfield	IL	COMM	36621
HONEY	Test Instruments Division	Littleton	CO	IND	38252
TI	Texas In. Geophysical Services	Dallas	TX	IND	36625
TI	Texas Instr Industrial Systems	Johnson City	TN	IND	38230
TI	Texas Instruments Defense Sys.	Dallas	TX	MIL	37611
TI	Texas Instruments Defense Sys.	Plano	TX	MIL	36625
TEXTRON	Textron Opto-Electronics	Petaluma	CA	IND	38292
TBCORP	Thomas & Betts Corporation	Bridgewater	NJ	IND	38252
TRACOR	Tracor Aerospace Inc.	Austin	TX	MIL	37211
TRACOR	Tracor Applied Sciences Inc.	Austin	TX	MIL	36625
TRACOR	Tracor Northern	Middleton	WI	IND	38252
UTC	UTC-Hamilton Standard Division	Windsor Locks	CT	MIL	37211
UNISYS	Unisys Corporation (Colorado)	Pueblo	CO	DP	35731
UNISYS	Unisys Corporation-California	San Diego	CA	DP	35731
UNISYS	Unisys Peripherals Group	Santa Clara	CA	DP	35732
UICORP	United Indust.-AAI Corporation	Cockeysville	MD	MIL	38229
UICORP	United Indust.-AAI Corporation	Maitland	FL	MIL	38229
UTC	United Tech-Norden Systems Dv.	Westport	CT	MIL	37211
UTC	United Tech-Power Systems Dv.	S. Windsor	CT	IND	36292
UTC	United Tech-Pratt Whitney	Hartford	CT	IND	38291
DYNATECH	Utah Sci.-Advanced Devel. Ctr.	Ft. Lauderdale	FL	COMM	36622
DYNATECH	Utah Scientific, Inc.	Salt Lake City	UT	COMM	36622
VAR	Varian Extrion Division (Proc.)	Gloucester	MA	IND	35595
VAR	Varian Instrument Division	Walnut Creek	CA	IND	38242
VAR	Varian Palo Alto Instrument Dv.	Palo Alto	CA	IND	38252
VAR	Varian Radiation Division	Palo Alto	CA	IND	36933
VAR	Varian Solid State Microwave	Santa Clara	CA	MIL	38110
VAR	Varian Thin Film Division (Proc.)	Palo Alto	CA	IND	35690
VAR	Varian Thin Film Division	Palo Alto	CA	IND	35690
VAR	Varian-Beverly Microwave Dv.	Beverly	MA	MIL	36625
VEECO	Veeco-Industrial Equipment Dv.	Plainview	NY	IND	38252
INTELSYS	Video Seven	Fremont	CA	DP	35732
WATK	Watkins-Johnson Co.	Palo Alto	CA	MIL	37612

(Continued)

Table 2 (Continued)

Electronic Business 200 Purchasing Locations

Parent Company Code	Location Name	City	State	Bus. Segment	SIC Code
WATK	Watkins-Johnson Comm. Elec. Tech.	Gaithersburg	MD	MIL	36620
WATK	Watkins-Johnson ESM Division	San Jose	CA	MIL	36620
WATK	Watkins-Johnson Steward Division	Scotts Valley	CA	IND	35595
WEC	Wesinghouse Control Division	Oldsmar	FL	IND	38230
WEC	Westinghouse Advanced Ind. Sys.	Pittsburgh	PA	IND	38230
WEC	Westinghouse Automation Division	Pittsburgh	PA	IND	35340
WEC	Westinghouse B & CE Division	Beaver	PA	IND	35690
WEC	Westinghouse Combustn. Control	Orrville	OH	IND	38230
WEC	Westinghouse Def. & Elec. Sys.	Baltimore	MD	MIL	36620
WEC	Westinghouse Defense Unit	Baltimore	MD	MIL	36625
WEC	Westinghouse Int. Logistics Sup.	Hunt Valley	MD	MIL	36625
WEC	Westinghouse Material Acq. Ctr.	Baltimore	MD	MIL	36625
WEC	Westinghouse Meas. & Controls	Raleigh	NC	IND	38326
WEC	Westinghouse Oceanic Division	Annapolis	MD	MIL	37312
WYSE	Wyse Technology	San Jose	CA	DP	35731
XEROX	Xerox Corporation	El Segundo	CA	DP	35732
XEROX	Xerox Special Info. Systems Dv.	Pasadena	CA	DP	35731
ZEN	Zenith Electronics Corporation	Glenview	IL	CON	36512
ZEN	Zenith-Heath Co.	St. Joseph	MI	DP	35731
ZEN	Zenith-Rauland Division	Melrose	IL	CON	36512

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Table 3

Data Processing Purchasing Locations

Parent Company Code	Location Name	City	State	SIC Code
MMM	3M	St. Paul	MN	35732
AM	AM Int.-Multigraphics Division	Mount Prospect	IL	35795
AST	AST Research Inc.	Irvine	CA	35731
ALTO	Altos Computer Systems	San Jose	CA	35731
AMDH	Amdahl Corporate Procurement	Sunnyvale	CA	35731
AMETEK	Ametek Houston Instrument Dv.	Austin	TX	35732
APOL	Apollo Computer Inc.	Chelmsford	MA	35731
APOL	Apollo Computer Inc. (NH)	Exeter	NH	35731
APPLE	Apple Computer, Inc.	Cupertino	CA	35731
APPLE	Apple Computer, Inc.	Fremont	CA	35731
ALLIED	Aquatech Systems Division	Warren	NJ	35731
ATARI	Atari Corporation	Sunnyvale	CA	35731
AYDIN	Aydin Controls	Fort Washington	PA	35731
BRIN	BRIntec-Gary Electronics	Langhorn	PA	35731
BELLHO	Bell & Howell-Microfilm Products	Chicago	IL	35732
AM	Bruning Computer Graphics	Martinez	CA	35732
BELLHO	Business Data Products Division	Baldwin Park	CA	35732
LOCK	CalComp Communications	Anaheim	CA	35732
LOCK	CalComp Digitizer Division	Scottsdale	AZ	35732
CHERRY	Cherry Display Products	El Paso	TX	35732
CHERRY	Cherry Electrical Prdts. Corp.	Waukegan	IL	35732
CIPHER	Cipher Data Products (Mt. View)	Mountain View	CA	35732
CIPHER	Cipher Data Products, Inc.	San Diego	CA	35732
COMPAQ	Compaq Computer Corporation	Plano	TX	35731
COMPAQ	Compaq Computer Corporation	Houston	TX	35731
COMPUGR	Compugraphic Corporation	Wilmington	MA	35731
COMPCONS	Computer Consoles, Inc.	Rochester	NY	35731
CONTEL	Contel Business Systems	Torrance	CA	35731
CONTEL	Contel Business Systems	Torrance	CA	35731
CONTEL	Contel Federal Systems	Fairfax	VA	35731
CONTEL	Contel IPC	Westbrook	CT	35732
CD	Control Data Corporation	Bloomington	MN	35731
UNISYS	Convergent Technologies, Inc.	Roseville	CA	35731
CRAY	Cray Research, Inc.	Chippewa Falls	WI	35731
CUBIC	Cubic Western Data	San Diego	CA	35732
DGC	Data General Corporation	Westborough	MA	35731

(Continued)

Table 3 (Continued)

Data Processing Purchasing Locations

Parent Company Code	Location Name	City	State	SIC Code
DGC	Data General Corporation	Southborough	MA	35731
DGC	Data General Corporation	Sunnyvale	CA	35731
DATACARD	DataCard Corporation	Minneapolis	MN	35732
DATACARD	DataCard Datatrol Division	Hudson	MA	35732
ROCK	DataMyte Corporation	Minnetonka	MN	35743
NSC	Datachecker Systems Division	Santa Clara	CA	35743
DPOC	Datapoint Corporation	San Antonio	TX	35732
DPRC	Dataproducts Corporation (Calif)	Woodland Hills	CA	35732
INTELSYS	Datavue	Norcross	GA	35731
DECIC	Decision Industries Corporation	Horsham	PA	35732
DIEBOLD	Diebold Inc.	North Canton	OH	35743
DIEBOLD	Diebold Inc.	Hebron	OH	35743
DIEBOLD	Diebold Inc.	Southborough	MA	35743
DCAI	Digital Communications-Forte	San Jose	CA	35732
DEC	Digital Equipment Corp. (Ariz)	Phoenix	AZ	35731
DEC	Digital Equipment Corporation	Marlboro	MA	35731
TEK	Dubner Computer Systems	Paramus	NJ	35732
DYNATECH	Dynatech-Colorgraphics Systems	Madison	WI	35732
EATON	Eaton Printer Products	Riverton	WY	35732
GD	Gen. Dynamics.-Datagraphix	San Diego	CA	35732
GENI	Genicom Corporation	Waynesboro	VA	35732
GERBER	Gerber Scientific Instrument	S. Windsor	CT	35731
HP	HP Bar Code Operation	San Jose	CA	35732
HP	HP Boise Printer Division	Boise	ID	35732
HP	HP Computer Systems Division	Cupertino	CA	35731
HP	HP Corporate Materials Mgt.	Palo Alto	CA	35731
HP	HP Corvallis Division	Corvallis	OR	35731
HP	HP Disc Memory Division	Boise	ID	35732
HP	HP Greeley Storage Division	Greeley	CO	35732
HP	HP Logic Systems Division	Colorado Springs	CO	35731
HP	HP Office & Computer Division	Sunnyvale	CA	35731
HP	HP Personal Computer Group	Sunnyvale	CA	35731
HP	HP Roseville Terminals Division	Roseville	CA	35732
HP	HP San Diego Division	San Diego	CA	35732
HP	HP Technical Computer Group	Sunnyvale	CA	35731
HP	HP Technical Systems Sector	Fort Collins	CO	35731

(Continued)

Table 3 (Continued)

Data Processing Purchasing Locations

Parent Company Code	Location Name	City	State	SIC Code
HP	HP Vancouver Division	Camas	WA	35732
HARRIS	Harris Computer Systems Division	Ft. Lauderdale	FL	35731
HONEY	Honeywell Bull (Procurement)	Brighton	MA	35731
HONEY	Honeywell Bull Phoenix Opertns.	Phoenix	AZ	35731
HONEY	Honeywell Keyboard Division	El Paso	TX	35732
IBM	IBM	Hopewell Junctn.	NY	35731
IBM	IBM	Research Tri. Pk.	NC	35731
RINTEL	Intel Pers. Computer Enh. Oper.	Hillsboro	OR	35731
INTEL	Intel Systems Group	Hillsboro	OR	35731
INTER	Intergraph Corporation	Huntsville	AL	35731
KODAK	Kodak Apparatus Division	Rochester	NY	35793
KODAK	Kodak Datatape Division	Pasadena	CA	35732
KODAK	Kodak Electronic Prepress Sys.	Billerica	MA	35731
LOCK	Lockheed Defense Info. Sys. Dv.	Nashua	NH	35731
MAIBASIC	MAI Basic Four Inc.	Tustin	CA	35731
MARK	Mark IV Display Products	Duarte	CA	35732
MARK	Mark IV Graphic Instruments	East Greenwich	RI	35732
MAXTOR	Maxtor Corporation	San Jose	CA	35732
MCDD	McDonnell Douglas Computer Sys.	Irvine	CA	35731
MEMTEL	Memorex Telex Corporation	Raleigh	NC	35732
MICROP	Micropolis Corporation	Chatsworth	CA	35732
MINISCR	MiniScribe Corporation	Longmont	CO	35732
PB	Monarch Marking	Dayton	OH	35732
MOTO	Motorola Computer Systems	Cupertino	CA	35731
MOTO	Motorola Corp. Materials Mgt.	Schaumberg	IL	35731
MOTO	Motorola Micrographic Sys. Dv.	Mountain View	CA	35793
NBI	NBI, Inc.	Boulder	CO	35731
NCR	NCR Applied Digital Data Sys.	Hauppauge	NY	35731
NCR	NCR Corporation (Headquarters)	Dayton	OH	35731
NCR	NCR Micrographic Sys. Dv.-Proc.	Mountain View	CA	35793
CIPHER	Optimem	Mountain View	CA	35732
PERK	Perkin-El. Concurrent Computer	Oceanport	NJ	35731
PB	Pitney Bowes Inc.	Stamford	CT	35795
PRIME	Prime Computer, Inc.	Framingham	MA	35731
PRIME	Prime-Computervision	Bedford	MA	35731
INTELSYS	Princeton Graphics	Princeton	NJ	35732

(Continued)

Table 3 (Continued)

Data Processing Purchasing Locations

Parent Company Code	Location Name	City	State	SIC Code
INTELSYS	Quadram	Norcross	GA	35732
QUANTUM	Quantum Corporation	Milpitas	CA	35732
RECOG	Recognition Equipment, Inc.	Irving	TX	35732
ROCK	Rockwell Industrial Control Dv.	Fairfield	NJ	35732
SEAGATE	Seagate Technology	Scotts Valley	CA	35732
SPEC	Spectra-Phy Retail Systems Dv.	Eugene	OR	35732
SQUARE	Square D-Engineered Systems	Tempe	AZ	35731
STC	Storage Tech Printer Operation	Palm Bay	FL	35732
STC	Storage Technology Corporation	Louisville	CO	35732
STRATUS	Stratus Computer	Marlboro	MA	35731
SUNMIC	Sun Microsystems Inc.	Mountain View	CA	35731
TANDEM	Tandem Computers Inc.	Austin	TX	35732
TANDEM	Tandem Computers Inc.	Cupertino	CA	35731
TANDON	Tandon-NNA Corporation	Scotts Valley	CA	35731
TANDY	Tandy Electronics	Fort Worth	TX	35731
TEK	Tektronix Display Devices Oper.	Beaverton	OR	35732
TEK	Tektronix Graphic Prtng/Img. Dv.	Wilsonville	OR	35732
TEK	Tektronix Graphic Workstations	Wilsonville	OR	35732
TEK	Tektronix Graphics Terminals	Wilsonville	OR	35732
UNISYS	Unisys Corporation (Colorado)	Pueblo	CO	35731
UNISYS	Unisys Corporation-California	San Diego	CA	35731
UNISYS	Unisys Peripherals Group	Santa Clara	CA	35732
INTELSYS	Video Seven	Fremont	CA	35732
WYSE	Wyse Technology	San Jose	CA	35731
XEROX	Xerox Corporation	El Segundo	CA	35732
XEROX	Xerox Special Info. Systems Dv.	Pasadena	CA	35731
ZEN	Zenith-Heath Co.	St. Joseph	MI	35731

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Table 4

Communications Purchasing Locations

Parent Company Code	Location Name	City	State	SIC Code
MMM	3M Broadcasting & Related Prod.	Huntsville	AL	36622
ADC	ADC Telecommunications, Inc.	Minnesota	MN	36621
PERK	ARK Electronic Products, Inc.	Melbourne	FL	36612
ATT	AT&T Tech-Corp Procurement Ctr.	Allentown	PA	36611
ALLEN	Allen-Antenna Specialists Co.	Solon	OH	36621
AMDH	Amdahl Comm. Systems Division	Richardson	TX	36611
AMDH	Amdahl Comm. Systems Dv.-Proc.	Richardson	TX	36612
ANDR	Andrew Corporation	Richardson	TX	36621
AYDIN	Aydin Monitor Systems Division	Ft. Washington	PA	36612
MICOM	Black Box Corporation	Pittsburgh	PA	36611
CTS	CTS Corporation	Eden Prarie	MN	36612
MOTO	Codex Corporation	Canton	MA	36612
CUBIC	Cubic Communications (Proc.)	Oceanside	CA	36622
CUBIC	Cubic Communications, Inc.	Oceanside	CA	36622
DSC	DSC Comm-Bus. Network Sys. Grp.	Santa Clara	CA	36612
DSC	DSC Comm-Elect Cross Connt Sys.	Santa Clara	CA	36612
DSC	DSC Switching Group	Plano	TX	36611
PB	Dictaphone Corporation	Stratford	CN	36612
DCAI	Digital Comm. Assocs.-Cohesive	Los Gatos	CA	36612
DCAI	Digital Communications Assocs.	Alpharetta	GA	36611
DYNASCO	Dynascan Corporation	Chicago	IL	36621
DYNATECH	Dynatech Data Systems	Springfield	VA	36611
DYNATECH	Dynatech Packet Technology Inc.	Woodbridge	VA	36611
DYNATECH	Dynatech Telecom Techniques Dv.	Gaithersburg	MD	36621
DYNATECH	Dynatech-Advanced Develop. Ctr.	Fort Lauderdale	FL	36622
DYNATECH	Dynatech-Controlonics Corporation	Westford	MA	36621
GE	GE Aerospace & Defense Auto Sys.	Burlington	MA	36628
GE	GE Mobile Communications Dv.	Lynchburg	VA	36621
GI	GI Jerrold Division	Tucson	AZ	36622
GI	GI Jerrold Division (PA)	Hatboro	PA	36622
GI	GI Sytek, Inc. (Procurement)	Mountain View	CA	36612
GI	GI Tocom Division	Irving	TX	36622
GI	GI Tocum Division (Procurement)	Dallas	TX	36622
GTE	GTE Communication Systems	Phoenix	AZ	36611
GTE	GTE Corporation	Stamford	CT	36611
GSIG	Gen Sig-Tau Tron, Inc.	Waterford	MA	36621

(Continued)

Table 4 (Continued)

Communications Purchasing Locations

Parent Company Code	Location Name	City	State	SIC Code
GSIG	Gen Sig-Telecom. Technology Dv.	Milpitas	CA	36621
GDCI	General DataCom Industries	Naugatuck	CT	36612
GI	General Instrument Corporation	Lyndhurst	NJ	36622
MHP	HP Network Management Division	Santa Rosa	CA	36621
HP	HP Roseville Manufacturing Op.	Roseville	CA	36621
HP	HP Stanfd Park Microw. Test Eqp.	Palo Alto	CA	36621
HP	HP Stanford Park Instrument	Palo Alto	CA	36621
IBM	IBM	Colorado Springs	CO	36611
WANG	InteCom, Inc.	Allen	TX	36611
GI	Jerrold Distribution Systems	Hatboro	PA	36622
MARK	Mark IV FEMCO	High Point	NC	36621
MICOM	Micom Systems, Inc.	Simi Valley	CA	36611
MOTO	Motorola Cellular Group	Schaumburg	IL	36621
MOTO	Motorola Cellular Group (Proc.)	Arlington Hgts.	IL	36621
MOTO	Motorola Codex Products	Mansing	MA	36612
MOTO	Motorola Communications Sector	Ft. Lauderdale	FL	36621
MOTO	Motorola Communications Sector	Schaumsburg	IL	36621
MOTO	Motorola Universal Data Sys. Prod.	Huntsville	AL	36612
NCR	NCR Comten (Procurement)	Blaine	MN	35730
PARA	Paradyne Corporation	Largo	FL	36612
PHILIPS	Philips Magnavox CATV Systems	Manlius	NY	36622
PB	Pitney Bowes Dictaphone Corp.	Stratford	CN	36621
ROCK	Rockwell Allen-Bradley Comms.	Ann Arbor	MI	36612
ROCK	Rockwell Switching Systems Dv.	Downers Grove	IL	36611
ROCK	Rockwell Transmission Systems	Richardson	TX	36621
ROCK	Rockwell Wescom Telephone Prod.	Downers Grove	IL	36611
SCIATL	Sci-Atl Broadband Comm.	Norcross	GA	36622
SCIATL	Sci-Atl Network Systems Group	Norcross	GA	36621
TRW	TRW Information Network Division	Torrance	CA	36612
TEK	Tektronix Comm Network Anlyzs.	Redmond	OR	36621
TEK	Tektronix Modular Products Dv.	Grass Valley	CA	36622
TEK	Tektronix Professional Video	Grass Valley	CA	36622
TEK	Tektronix Switching Prdts. Dv.	Nevada City	CA	36622
TEK	Tektronix Telecom. Systems Grp.	Grass Valley	CA	36621
TEK	Tektronix Televis. Wavefm. Dsp.	Beaverton	OR	36622
TEK	Tektronix Television Division	Beaverton	OR	36622

(Continued)

Table 4 (Continued)

Communications Purchasing Locations

Parent Company Code	Location Name	City	State	SIC Code
MEMTEL	Telex Communications	Lincoln	NE	36621
TERAD	Teradyne Telecommunications Dv.	Deerfield	IL	36621
DYNATECH	Utah Sci.-Advanced Devel. Ctr.	Ft. Lauderdale	FL	36622
DYNATECH	Utah Scientific, Inc.	Salt Lake City	UT	36622

Source: Electronic Business
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Table 5

Industrial Purchasing Locations

Parent Company Code	Location Name	City	State	SIC Code
MMM	3M Static Control	Austin	TX	38252
ADT	ADT Inc.	Clifton	NJ	36624
AM	AM Int.-Varityper Division	East Hanover	NJ	35690
ALLEN	Allen Automated Systems Co. Dv.	Livonia	MI	38252
ALLEN	Allen Test Products Division	Kalamazoo	MI	38252
ROCK	Allen-Bradley Drives Dv. (CA)	Fullerton	CA	35690
ROCK	Allen-Bradley Drives Dv. (WIS)	Cedarsburg	WI	35690
ALLIED	Allied-Signal Endevco Division	San Juan Cap.	CA	38253
AMETEK	Ametek Controls Division	Feasterville	PA	38230
AMETEK	Ametek Lamb Electric Division	Kent	OH	35690
AMETEK	Ametek Mansfield & Green Dv.	Largo	FL	38292
AMETEK	Ametek McCrometer Division	Hemet	CA	38242
AMETEK	Ametek Panalarm Division	Skokie	IL	38230
AMETEK	Ametek Process Equipment	Santee	CA	35593
AMETEK	Ametek Thermox Instruments Dv.	Pittsburgh	PA	38252
AMETEK	Ametek U.S. Gauge Division	Sellersville	PA	38292
ANALOGIC	Analogic Corporation	Peabody	MA	38230
ANALOGIC	Analogic Medical Division	Peabody	MA	36931
APMATS	Applied Materials, Inc.	Santa Clara	CA	35595
FIGGIE	Automatic Sprinkler Corporation	Broadview Hghts.	OH	38220
BALL	Ball Industrial Systems Division	Broomfield	CO	38230
ALLIED	Baron-Blakeslee, Inc.	Melrose Park	IL	35492
BECT	Becton, Dickinson FACS Inst.	Mountain View	CA	36933
BECT	Becton-Diagnostic Instruments	Towson	MD	36933
ALLIED	Bendix Electric Power Division	Eatontown	NJ	35690
ALLIED	Bendix Engine Controls Division	Jacksonville	FL	38291
ALLIED	Bendix Environmental Systems	Baltimore	MD	36625
ALLIED	Bendix Guidance Systems Division	Teterboro	NJ	38111
TRW	Brandt Solids Control Division	Conroe	TX	38230
EMER	Branson IPC	Hayward	CA	35595
EMER	Branson Ultrasonic Corporation	Danbury	CN	36629
HONEY	Business Commuter Aviation Sys.	Glendale	AZ	38111
MOTO	CTX International	Sunnyvale	CA	38230
FIGGIE	Chemetron Fire Systems, Inc.	University Park	IL	36624
CINCI	Cincinnati Mil. Electronic Sys.	Lebanon	OH	35694
COHER	Coherent Components Group	Auburn	CA	36795

(Continued)

Table 5 (Continued)

Industrial Purchasing Locations

Parent Company Code	Location Name	City	State	SIC Code
COHER	Coherent Components Group-Proc.	Auburn	CA	36795
COHER	Coherent General, Inc.	Sturbridge	MA	36621
COHER	Coherent General, Inc. (Proc.)	Sturbridge	MA	36621
COHER	Coherent Medical Group	Palo Alto	CA	36621
COHER	Coherent Medical Group	Palo Alto	CA	36621
EMER	Commercial Cam Division	Wheeling	IL	35492
FIGGIE	Consolidated Packaging Machnry.	Alden	NY	35492
SPEC	Construction & Agriculture Dv.	Dayton	OH	36933
CUBIC	Cubic Corp-U.S. Elevator	Spring Valley	CA	35690
DATACARD	DataCard Addressograph	Holmesville	OH	35690
DIAS	Diasonics, Inc.	Milpitas	CA	36933
DYNATECH	Dynatech Frontier Corporation	Albuquerque	NM	38292
DYNATECH	Dynatech Interface Technology	Glendora	CA	38252
DYNATECH	Dynatech Laboratories, Inc.	Chantilly	VA	36933
DYNATECH	Dynatech Nevada, Inc.	Carson City	NV	36933
DYNATECH	Dynatech Prec. Sampling Corp.	Baton Rouge	LA	35690
DYNATECH	Dynatech Trans-Met Engineering	Anaheim	CA	38252
DYNATECH	Dynatech-Computer Power, Inc.	Scotts Valley	CA	36795
DYNATECH	Dynatech-Integra, Inc.	Milpitas	CA	38252
DYNATECH	Dynatech-Lighting Loc. & Prot.	Tucson	AZ	38220
DYNATECH	Dynatech-Trigon Ind., Inc.	Milpitas	CA	35694
EATON	Eaton Controls Division	Carol Stream	IL	35690
EATON	Eaton Elec. Instrumentation Dv.	Los Angeles	CA	38252
EATON	Eaton Electronics Instrument	Los Angeles	CA	38252
EATON	Eaton Ion Beam Systems Division	Beverly	MA	35595
EATON	Eaton Memory Test Division	Irvine	CA	38252
EATON	Eaton Microlithography Division	San Jose	CA	35595
EATON	Eaton-Kenway	Bountiful	UT	38230
UTC	Electro Systems Division	Columbus	MS	35690
MCDD	Electro-Mechanical Division	Grand Rapids	MI	35690
ELI	Eli-Cardiac Pacemakers, Inc.	St. Paul	MN	36933
ELI	Eli-IVAC Corporation	San Diego	CA	36933
ELI	Eli-Physio-Control Corporation	Redmond	WA	36933
EMER	Emerson EMC	Chanhassen	MN	38230
EMER	Emerson Electric-Corp Proc.	St. Louis	MO	38230
EMER	Emerson-ACDC Electronics Dv.	Oceanside	CA	36292

(Continued)

Table 5 (Continued)

Industrial Purchasing Locations

Parent Company Code	Location Name	City	State	SIC Code
EMER	Emerson-Alco Controls Division	St. Louis	MO	38230
EMER	Emerson-Alco Controls Division	Hazelhurst	GA	38230
EMER	Emerson-Brooks Instruments	Hatfield	PA	38230
EMER	Emerson-Chance Load Management	Hazelwood	MO	38230
EMER	Emerson-Commercial Cam Division	Wheeling	IL	35492
EMER	Emerson-Doerr Electrical Dv.	Cedarsburg	WI	35690
EMER	Emerson-Doric Scientific Dv.	San Diego	CA	38230
EMER	Emerson-Industrial Controls Dv.	Santa Ana	CA	36292
EMER	Emerson-Industrial Products	Brea	CA	38253
EMER	Emerson-Rosemont Inc.	Eden Prairie	MN	38230
EMER	Emerson-Rosemont Inc.	Irvine	CA	38242
EMER	Emerson-Rosemont Inc.	La Habra	CA	38230
EMER	Emerson-White Rodgers Division	Harrison	AK	36292
ESTER	Esterline Angus Instrument Corp.	Indianapolis	IN	38326
ESTER	Esterline Excellon Automation	Torrance	CA	35595
ESTER	Esterline-Federal Products Corp.	Providence	RI	38253
FIGGIE	Figgie Intl.-CASI-RUSCO	Glendale	CA	36624
FIGGIE	Figgie Intl. American LaFrance	Bluefield	VA	38230
FOX	Foxboro Analytical Division	Plymouth	MA	38326
FOX	Foxboro Co. (Calif)	Valencia	CA	38230
FOX	Foxboro Company	Foxboro	MA	38230
GE	GE Aircraft Instruments Division	Wilmington	MA	38111
GE	GE Direct Current Motor & Gen.	Erie	PA	35690
GE	GE Drive Systems	Salem	VA	38230
GE	GE Electrical Distrib. & Comp.	Bloomington	IL	35690
GE	GE FANUC Automation	Charlottsville	VA	35694
GE	GE Lighting Business Group	Cleveland	OH	35690
GE	GE Medical Systems Group	Milwaukee	WI	36931
GE	GE Meter Business Dept.	Somersworth	NH	38326
GE	GE Power Supply Operation Dv.	Fort Wayne	IN	36795
GE	GE Wiring Device Dept.	Warwick	RI	35690
GM	GM Hughes Industrial Prod. Dv.	Carlsbad	CA	38252
GSIG	Gen Sig Thin Film Company	Fremont	CA	35595
GSIG	Gen Sig-Advanced Mechanization	Horsham	PA	35595
GSIG	Gen Sig-Circuit Processing App.	Fremont	CA	35595
GSIG	Gen Sig-Leeds & Northup	North Wales	PA	38230

(Continued)

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Table 5 (Continued)

Industrial Purchasing Locations

Parent Company Code	Location Name	City	State	SIC Code
GSIG	Gen Sig-Solar Electric	Elk Grove Vil.	IL	35694
GSIG	Gen Sig-Stock Equipment Co.	Chagrin Falls	OH	35340
GSIG	Gen Sig-Ultratech Stepper	Santa Clara	CA	35595
GSIG	Gen Sig-Warren-Die Electric	Littleton	MA	36795
GENRAD	GenRad Service Products Division	Phoenix	AZ	38252
GENRAD	GenRad Structural Test Prod.	Milpitas	CA	38252
GENRAD	GenRad-Electronic Mfg. Test	Concord	MA	38252
GSIG	General Railway Signal	Rochester	NY	36626
GERBER	Gerber Garment Technology, Inc.	Tolland	CT	35401
GERBER	Gerber Scientific Products	Manchester	CT	35401
GOULD	Gould, Inc.	Pocatello	ID	38252
HP	HP Avondale Division	Avondale	PA	38326
HP	HP Colorado Springs Division	Colorado Springs	CO	38252
HP	HP Colorado Telecom. Division	Colorado Springs	CO	38252
HP	HP Lake Stevens Instrument Dv.	Everett	WA	38252
HP	HP Loveland Instrument (Proc.)	Loveland	CO	38252
HP	HP Loveland Instrument Division	Loveland	CO	38252
HP	HP McMinnville Division	McMinnville	OR	36933
HP	HP New Jersey Division	Rockaway	NJ	36795
HP	HP Santa Clara Division	Santa Clara	CA	38252
HP	HP Scientific Instruments Dv.	Palo Alto	CA	38326
HP	HP Signal Analyzer Division	Rohnert Park	CA	38252
HP	HP Waltham Division	Waltham	MA	36933
HONEY	Honeywell Comml. Aviation Dv.	St. Louis Park	MN	38111
HONEY	Honeywell Commercial Buildings	Arlington Hghts.	IL	38220
HONEY	Honeywell Comml. Flight Systems	Phoenix	AZ	38111
HONEY	Honeywell Ind. Automation Sys.	Phoeniz	AZ	38230
HONEY	Honeywell Indust. Controls Dv.	Fort Washington	PA	38230
HONEY	Honeywell Microswitch Division	Freeport	IL	35340
HONEY	Honeywell Protection Services	Irvine	CA	36624
HONEY	Honeywell Residential Division	Golden Valley	MN	36624
HONEY	Honeywell Test Instruments Dv.	Denver	CO	38326
ITT	ITT Barton Instruments	City of Industry	CA	38242
ITT	ITT McDonnell-Miller	Chicago	IL	35690
ITT	ITT Pomona Electronics Division	Pomona	CA	38252
ITT	ITT Standard	Cheektowaga	NY	35690

(Continued)

Table 5 (Continued)

Industrial Purchasing Locations

Parent Company Code	Location Name	City	State	SIC Code
ROCK	Industrial Computer Group	Highland Hts.	OH	35401
FLUKE	John Fluke Mfg. Co., Inc.	Everett	WA	38252
JCI	Johnson Systems and Services	Milwaukee	WI	38220
KODAK	Kodak Company	Columbia	SC	35690
LTX	LTX Corporation	Westwood	MA	38252
LANDIS	Landis & Gyr Metering	Lafayette	IN	38252
LANDIS	Landis & Gyr Powers	Buffalo Grove	IL	38220
LANDIS	Landis & Gyr Systems	San Jose	CA	38230
SPEC	Laser Analytics Division	Bedford	MA	38112
DYNATECH	Lea Dynatech, Inc.	Santa Fe Springs	CA	36795
LITTON	Litton Automated Mfg. Systems	Hebron	KY	35340
LITTON	Litton Electron Devices	San Carlos	CA	38112
LITTON	Litton IAS	Holland	MI	35340
LITTON	Litton Potentiometer Division	Mount Vernon	NY	36624
MARKCON	Mark /Powers Process Controls	Skokie	IL	38230
MARK	Mark IV Automatic Signal Dv.	Clinton	MA	36626
MARK	Mark IV Eagle Signal Controls	Austin	TX	35401
MARK	Mark IV Industrial Systems	Clinton	MA	38230
MARK	Mark IV Instruments Dv. of LFE	Chesterland	OH	38253
MARK	Mark IV Plasma Systems	Clinton	MA	35595
MEAS	Measurex Corporation	Cupertino	CA	38230
MEDTI	Medtronic Micro-Rel. Division	Tempe	AZ	36933
MEDTI	Medtronic, Inc.	Minneapolis	MN	36933
MOTO	Motorola Microcomputer Division	Tempe	AZ	38230
BALL	Penn Video	Akron	OH	35694
PERK	Perkin-El. Connecticut Inst.	Norwalk	CT	35595
PERK	Perkin-El. Physical Elects. Dv.	Eden Prairie	MN	38292
PERK	Perkin-Elmer Elec. Beam Tech.	Hayward	CA	35595
PHILIPS	Philips-Airpax Corporation	Cheshire	CN	35690
PHILIPS	Philips Advanced Transformers	Chicago	IL	35690
PHILIPS	Philips Electronic Instruments	Mahwah	NJ	36931
PHILIPS	Philips Medical Systems, Inc.	Shelton	CT	36931
PERK	Physcial Electronics Division	Eden Prairie	MN	38292
REYN	Reynolds & Reynolds Co.	Dayton	OH	35690
ROCK	Rockwell-Allen-Bradley Co.	Twinsburg	OH	35694
ROCK	Rockwell Electronic Components	Greensboro	NC	35340

(Continued)

Table 5 (Continued)

Industrial Purchasing Locations

Parent Company Code	Location Name	City	State	SIC Code
ROCK	Rockwell Fireye Division	Derry	NH	36624
ROCK	Rockwell Government Avionics	Cedar Rapids	IA	38111
ROCK	Rockwell Graphic Systems Dv.	Chicago	IL	35690
ROCK	Rockwell Industrial Computer	Twinsburg	OH	38230
ROCK	Rockwell Industrial Control Dv.	Milwaukee	WI	35694
ROCK	Rockwell Meas. & Flow Control	Pittsburgh	PA	38242
ROCK	Rockwell Meas. & Flow Control	Uniontown	PA	38242
ROCK	Rockwell Quality & Prod. Sys.	Highland Hgts.	OH	35340
SCISI	SCI Unitronics	Sunnyvale	CA	36933
SCIATL	Sci-Atl Control Systems Division	Atlanta	GA	38220
SCIATL	Scientific-Atl Instrumentation	Norcross	GA	38326
SEQUA	Sequa-Kollsman Medical Division	Amherst	NH	36933
SKB	SmithKline Beckman Corporation	Philadelphia	PA	36933
SKB	SmithKline Beckman Instruments	Fullerton	CA	36933
SKB	SmithKline Beckman Instruments	Porterville	CA	36933
SPEC	Spectra-Physics Autolab Division	San Jose	CA	38230
SPEC	Spectra-Physics Laser Prod. Dv.	Mountain View	CA	36795
SQUARE	Square D-Ramsey Controls Inc.	Pinellas Park	FL	35401
WATK	Stewart Division	Scotts Valley	CA	35595
SUNDSC	Sundstrand Corporation	Redmond	WA	38291
TRW	TRW Dynalco Controls Division	Fort Lauderdale	FL	38230
TEK	Tektronix Freq. Dom. Inst. Dv.	Beaverton	OR	38252
TEK	Tektronix Lab. Instruments Dv.	Beaverton	OR	38252
TEK	Tektronix Logic Analyzers Dv.	Beaverton	OR	38252
TEK	Tektronix Murdock Park Division	Vancouver	WA	38252
TEK	Tektronix Port. Instrument Dv.	Vancouver	WA	38252
TEK	Tektronix Port. Test Inst. Dv.	Vancouver	WA	38252
TEK	Tektronix Semi. Test Sys. Dv.	Beaverton	OR	38252
TELEDY	Teledyne Analytical Instrument	City of Industry	CA	38326
TELEDY	Teledyne Hastings-Raydist	Hampton	VA	38111
MEMTEL	Telex Communications	Rochester	MN	36933
TERAD	Teradyne-Zehntel	Walnut Creek	CA	38252
TERAD	Teradyne Connection Systems Dv.	Nashua	NH	38252
TERAD	Teradyne Industrial/Consum. Dv.	Boston	MA	38252
TERAD	Teradyne Manufact. Systems Dv.	Boston	MA	38252
HONEY	Test Instruments Division	Littleton	CO	38252

(Continued)

Table 5 (Continued)

Industrial Purchasing Locations

Parent Company Code	Location Name	City	State	SIC Code
TI	Texas Inst. Geophysical Services	Dallas	TX	36625
TI	Texas Inst. Industrial Systems	Johnson City	TN	38230
TEXTRON	Textron Opto-Electronics	Petaluma	CA	38292
TBCORP	Thomas & Betts Corporation	Bridgewater	NJ	38252
TRACOR	Tracor Northern	Middleton	WI	38252
UTC	United Tech-Power Systems Dv.	S. Windsor	CT	36292
UTC	United Tech-Pratt Whitney	Hartford	CT	38291
VAR	Varian Extrion Division (Proc.)	Gloucester	MA	35595
VAR	Varian Instrument Division	Walnut Creek	CA	38242
VAR	Varian Palo Alto Instrument Dv.	Palo Alto	CA	38252
VAR	Varian Radiation Division	Palo Alto	CA	36933
VAR	Varian Thin Film Dv. (Proc.)	Palo Alto	CA	35690
VAR	Varian Thin Film Division	Palo Alto	CA	35690
VEECO	Veeco-Industrial Equipment Dv.	Plainview	NY	38252
WATK	Watkins-Johnson Steward Dv.	Scotts Valley	CA	35595
WEC	Wesinghouse Control Division	Oldsmar	FL	38230
WEC	Westinghouse Advanced Ind. Sys.	Pittsburgh	PA	38230
WEC	Westinghouse Automation Dv.	Pittsburgh	PA	35340
WEC	Westinghouse B & CE Division	Beaver	PA	35690
WEC	Westinghouse Combustn. Control	Orrville	OH	38230
WEC	Westinghouse Meas. & Controls	Raleigh	NC	38326

Source: Electronic Business
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Table 6

Consumer Purchasing Locations

Parent Company Code	Location Name	City	State	SIC Code
BELLHO	Bell & Howell Co.	Garden Grove	CA	36516
EMER	Emerson-Special Products Dv.	Hazelwood	MO	36629
GE	GE Major Appliance Dv.	Louisville	KY	36394
KODAK	Kodak-Spin Physics, Inc.	San Diego	CA	36516
LITTON	Litton Microwave Cooking Prod.	Memphis	TN	36311
MARK	Mark IV Altec Lansing	Oklahoma City	OK	36629
MARK	Mark IV Electro Voice	Redmond	WA	36629
PHILIPS	Philips-Genie Company	Alliance	OH	36994
PHILIPS	Philips Consumer Electronics	Knoxville	TN	36512
PHILIPS	Philips Grenada Hospital Grp.	Burlington	MA	36512
POLAROID	Polaroid Corporation	Norwood	MA	38611
SUNDSC	Sundstrand Trans. Com. Dv.	Costa Mesa	CA	36516
TI	TI Consumer Products Division	Lubbock	TX	39447
MEMTEL	Telex Communications	Glencoe	MN	36515
MEMTEL	Telex Communications	Blue Earth	MN	36514
ZEN	Zenith Electronics Corporation	Glenview	IL	36512
ZEN	Zenith-Rauland Division	Melrose	IL	36512

Source: Electronic Business
Dataquest
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Table 7

Military/Aero Purchasing Locations

Parent Company Code	Location Name	City	State	SIC Code
BBOE	ARGO Systems, Inc.	Sunnyvale	CA	36620
ALLIED	Air Research	Tucson	AZ	37612
ALLIED	Allied Signal Aerospace Co.	Torrance	CA	37612
ALLIED	Allied-Sig. Aerospace Comm. Dv.	Baltimore	MD	36625
ALLIED	Allied-Signal Aerospace Division	Kansas City	MO	36620
ALLIED	Allied-Signal Air Transport Dv.	Fort Lauderdale	FL	37213
ALLIED	Allied-Signal Corporate Proc.	Morristwton	PA	36620
BALL	Ball Corp. Aerospace Systems Dv.	Boulder	CO	37612
BALL	Ball Corporation-Efratom Division	Irvine	CA	37211
BELLS	Bell Ind. Illuminated Displays	Redmond	WA	37213
ALLIED	Bendix Cheshire Corporation	Cheshire	CT	37213
ALLIED	Bendix Electrodynamics Division	North Hollywood	CA	37213
ALLIED	Bendix Engine Controls Division	South Bend	IN	37213
ALLIED	Bendix Engine Controls Division	Jacksonville	FL	37213
ALLIED	Bendix Wheels & Brake Division	South Bend	IN	37213
BOE	Boeing Advanced Systems	Seattle	WA	37612
BOE	Boeing Aerospace Company	Huntsville	AL	37612
BOE	Boeing Commercial Airplanes	Renton	WA	37213
BOE	Boeing Electronics (Texas)	Irving	TX	37211
BOE	Boeing Electronics Co.-Proc.	Seattle	WA	37211
BOE	Boeing Helicopters	Philadelphia	PA	37213
BOE	Boeing Huntsville Division	Huntsville	AL	37612
BOE	Boeing Military Airplane Co.	Wichita	KS	37211
BOLT	Bolt Beranek and Newman Inc.	Billerica	MA	36620
HONEY	Business Commuter Aviation Sys.	Glendale	AZ	37213
ALLIED	Courter Operations	Boyne City	MI	37211
CUBIC	Cubic Defense Systems Division	San Diego	CA	37211
DPRC	Dataproducts (New England)	Wallingford	CT	37612
HONEY	Defense Systems Divison	Albuquerque	NM	37211
ESYS	E-Sys. Communications & Mfg. Dv.	St. Petersburg	FL	36620
ESYS	E-Systems Garland Division	Garland	TX	36620
ESYS	E-Systems Greenville Division	Greenville	TX	36625
ESYS	E-Systems Melpar Division	Falls Church	VA	36625
ESYS	E-Systems Montek Division	Salt Lake City	UT	37211
AMETEK	Eastport International, Inc.	Upper Marlboro	MD	36620
EATON	Eaton Information Mgt. Dv.	Westlake Villge	CA	35731

(Continued)

Table 7 (Continued)

Military/Aero Purchasing Locations

Parent Company Code	Location Name	City	State	SIC Code
EATON	Eaton Microwave Products Dv.	Sunnyvale	CA	36625
EATON	Eaton-MSC Products	Costa Mesa	CA	37211
BALL	Efratom Division	Irvine	CA	38110
HONEY	Electro-Optics Division	Lexington	MA	36620
ESYS	Electronic Communications, Inc.	St. Petersburg	FL	36620
ELECTRO	Electrospace Systems, Inc.	Richardson	TX	37211
ELECTRO	Electrotel, Inc.	W. Ballanger	TX	36625
EMER	Emerson-Beckman Industrial	Fullerton	CA	37611
EMER	Emerson-Computer Power Systems	Carson	CA	35731
EMER	Emerson-Electronic Navigation	Rochester	NY	37211
EMER	Emerson-Electronics & Space Dv.	St. Louis	MO	36625
EMER	Emerson-Rantec Division	Calabasas	CA	36625
EMER	Emerson-Varec, Inc.	Cypress	CA	38110
EMER	Emerson-White Rodgers Dv.	St. Louis	MO	36620
FAIR	Fairchild Communications & Elec.	Germantown	MD	36620
FAIR	Fairchild Space Co.	Germantown	MD	37612
FERRANTI	Ferrant Internat. Signal Inc.	Lancaster	PA	36620
FIGGIE	Figgie-Hartman Systems	Huntington Sta.	NY	37312
FIGGIE	Figgie-Interstate Electronics	Anaheim	CA	36625
FORD	Ford Aero. & Comm. Corp. (Mich)	Dearborn	MI	85120
FORD	Ford Aeronutronic Division	Newport Beach	Ca	37611
FORD	Ford Aerospace & Comm. Corp-CA	Newport Beach	CA	37611
FORD	Ford Aerospace & Comm. Corp-CO	Colorado Springs	CO	36620
FORD	Ford Aerospace & Comm. Corp-TX	Houston	TX	35731
FORD	Ford Aerospace-Space Sys. Dv.	Palo Alto	CA	37612
LORAL	Frequency Sources Inc.-East	S. Chelmsford	MA	36620
LORAL	Frequency Sources Inc.-West	San Jose	CA	36620
GE	GE Aerospace Controls Systems	Binghamton	NY	37211
GE	GE Aerospace Electronic Sys. Mfg.	Utica	NY	37211
GE	GE Armament & Elec. Systems	Erie	PA	38110
GE	GE Armament Electric Sys. Dept.	Burlington	VT	36620
GE	GE Astrospace	Princeton	NJ	37612
GE	GE Astrospace Division	Hightstown	NJ	37612
GE	GE Corporate Research & Dev.	Schenectady	NY	38110
GE	GE Defense Systems	Pittsfield	MA	36620
GE	GE Govt. Electronic Sys. Dept.	Syracuse	NY	36625

(Continued)

Table 7 (Continued)

Military/Aero Purchasing Locations

Parent Company Code	Location Name	City	State	SIC Code
GE	GE Military & Data Systems Dv.	Philadelphia	PA	36010
GE	GE Neutron Devices	Largo	FL	38110
GE	GE RCA Corporation	Camden	NJ	36620
GE	GE RCA Electronic Services	Moorestown	NJ	36625
GE	GE Rentry Systems Operation	Philadelphia	PA	37612
GE	GE Simulation & Control Sys.	Daytona Beach	FL	38229
GI	GI Government Systems Division	Hicksville	NY	36625
GM	GM Delco Electronics	Oak Creek	WI	35731
GM	GM Hughes Electro Optical & DS	El Segundo	CA	36625
GM	GM Hughes Electron Dynamics	Torrance	CA	38110
GM	GM Hughes Ground Systems Grp.	Fullerton	CA	36625
GM	GM Hughes Microelec. Sys. Grp.	Rancho Santa Mg.	CA	36620
GM	GM Hughes Network Systems	San Diego	CA	36620
GM	GM Hughes Santa Barbara Res. Ctr.	Goleta	CA	37611
GM	GM Hughes Space & Comm. Group	Los Angeles	CA	37612
GM	GM Hughes-Missile Systems Grp.	Canoga Park	CA	37611
GM	GM Hughes-Radar Systems Group	Los Angeles	CA	36625
GTE	GTE Government Systems	Needham Heights	MA	36620
GSIG	Gen Sig-Cardion Electronics	Woodbury	NY	36625
GD	Gen. Dynamics (Ft. Worth)	Fort Worth	TX	37211
GD	Gen. Dynamics Electronics Dv.	San Diego	CA	37211
GD	Gen. Dynamics-Pomona Division	Pomona	CA	36620
GENCORP	Gencorp Aerojet Division	Azusa	CA	37612
GRUM	Grumman Electronics Division	Bethpage	NY	36625
HP	HP Andover Division	Andover	MA	35731
SINGER	HRB-Singer	State College	PA	36625
HARRIS	Harris Corporation (CA)	San Carlos	CA	36620
HARRIS	Harris Corporation (FLA)	Melbourne	FL	36620
HONEY	Honeywell Defense Comm. & Prod.	Tampa	FL	36620
HONEY	Honeywell Defense Comm./Prod. Dv.	Tampa	FL	36620
HONEY	Honeywell Defense Systems Dv.	New Brighton	MN	36620
HONEY	Honeywell Inc.-Defense Systems	New Brighton	MN	36620
HONEY	Honeywell Marine Systems Dv.	Everett	WA	37312
HONEY	Honeywell Training/Control Sys.	W. Covina	CA	38229
HONEY	Honeywell Underseas Division	Hopkins	MN	36620
ITT	ITT Aerospace	Fort Wayne	IN	37612

(Continued)

Table 7 (Continued)

Military/Aero Purchasing Locations

Parent Company Code	Location Name	City	State	SIC Code
ITT	ITT Avionics	Nutley	NJ	36625
ITT	ITT Avionics Division (Proc.)	Clifton	NJ	36625
ITT	ITT Defense Comm. Division	Nutley	NJ	36620
ITT	ITT Defense Comm. (Proc.)	Clifton	NJ	36620
ITT	ITT Electro Optical Products	Roanoke	VA	38110
ITT	ITT Gilfillan Division	Van Nuys	CA	36625
BELLS	Illuminated Displays Division	Redmond	WA	37213
FIGGIE	Interstate Electronics Corp.	Anaheim	CA	85120
LTV	LTV Aircraft Products Division	Dallas	TX	37211
LTV	LTV Missiles (Proc.)	Dallas	TX	37611
LTV	LTV Missiles Division	Dallas	TX	37611
LTV	LTV Sierra Research Division	Buffalo	NY	36625
LITTON	Litton Aerospace Products	Moorpark	CA	37612
LITTON	Litton Amecon Division	College Park	MD	36625
LITTON	Litton Applied Technology	San Jose	CA	36625
LITTON	Litton Data Systems	Van Nuys	CA	35731
LITTON	Litton Encoder	Chatsworth	CA	36620
LITTON	Litton Engineered Systems	Florence	KY	37211
LITTON	Litton Guidance & Control Sys.	Woodland Hills	CA	37611
LITTON	Litton Guidance & Control Sys.	Grants Pass	OR	37211
LITTON	Litton Itek Optical Systems	Lexington	MA	37211
LITTON	Litton Laser Systems	Apopka	FL	37211
LITTON	Litton-Clifton Prec/Spec. Devs.	Springfield	PA	37211
LITTON	Litton-Clifton Precision/Iowa	Davenport	IA	37211
LOCK	Lockheed Aeronautical Systems	Marietta	GA	37211
LOCK	Lockheed Defense Info. Sys. Dv.	Nashua	NH	36625
LOCK	Lockheed Electronics Co., Inc.	Plainfield	NJ	36625
LOCK	Lockheed Missiles & Space Co.	Sunnyvale	CA	37612
LORAL	Loral Conic	San Diego	CA	37611
LORAL	Loral Conic	San Diego	CA	36620
LORAL	Loral Electro-Optical Systems	Pasadena	CA	38229
LORAL	Loral Electronic Systems-Proc.	Yonkers	NY	36625
LORAL	Loral Information Display Sys.	Atlanta	GA	38110
LORAL	Loral Instrumentation	San Diego	CA	38110
LORAL	Loral Narda Microwave	Hauppauge	NY	36620
LORAL	Loral Terracom	San Diego	CA	36620

(Continued)

Table 7 (Continued)

Military/Aero Purchasing Locations

Parent Company Code	Location Name	City	State	SIC Code
MACOM	M/A COM Active Assemblies Dv.	Chandler	AZ	36625
MACOM	M/A COM, Inc.	Burlington	MA	36620
MARK	Mark IV FCD	Hamden	CT	38110
MARK	Mark IV Gulton Data Systems	Albuquerque	NM	37611
MARK	Mark IV SCD	Duarte	CA	35731
MARK	Mark IV Servonic	Costa Mesa	CA	38110
MM	Martin Mar. Aero & Naval Systems	Baltimore	MD	37211
MM	Martin Mar. Elec. & Missiles	Orlando	FL	37611
MM	Martin Mar. Elec. & Missiles	Orlando	FL	37211
MM	Martin Marietta Aerospace Dv.	Denver	CO	37612
MCDD	McDonnell Dougl. Astronautics	Huntington Bch.	CA	37612
MCDD	McDonnell Douglas Aeronautics	St. Louis	MO	37211
MCDD	McDonnell Douglas Electronics	St. Charles	MO	37211
MCDD	McDonnell-Vitek Systems, Inc.	Hazelwood	MO	35731
MOTO	Motorola Mil. & Aerospace Elec.	Chandler	AZ	37612
NORTHROP	Northrop Aircraft Division	Hawthorne	CA	37211
NORTHROP	Northrop Defense Systems Dv.	Rolling Meadows	IL	37211
NORTHROP	Northrop Defense Systems Dv.	Warner Robbins	GA	36625
NORTHROP	Northrop Electro-Mechanical Dv.	Anaheim	CA	37211
NORTHROP	Northrop Precision Products Dv.	Norwood	MA	37211
NORTHROP	Northrop-Wilcox Electric Inc.	Kansas City	MO	37211
OLIN	Olin-Pacific Electrodynamic	Redmond	WA	38110
PENNCEN	Penn Central-Vitro Corp.	Silver Spring	MD	37611
PENNCEN	Penn Central-Vitro Services	Ridgecrest	CA	36620
PENNCEN	Penn-Vitro Serv. Co-Elec. Sys.	Ft. Walton Bch.	FL	36625
PENNCEN	Penn-Vitro Serv. Corp-IRSP	Ft. Walton Bch.	FL	36625
PERK	Perkin-Elmer Applied Optics Dv.	Garden Grove	CA	36625
PERK	Perkin-Elmer Applied Science	Pomona	CA	36625
PHILIPS	Phil-Magnavox Govt. & Ind. Elec.	Fort Wayne	IN	36620
RAYTHEON	Raytheon Co.	Lexington	MA	37611
ROCK	Rockwell-Satellite Systems	Seal Beach	CA	37612
ROCK	Rockwell Avionics Group	Melbourne	FL	37213
ROCK	Rockwell Collins Air Trans. Dv.	Cedar Rapids	IA	37211
ROCK	Rockwell Collins Defense Comm.	Cedar Rapids	IA	36620
ROCK	Rockwell Commercial Electronic	Richardson	TX	37213
ROCK	Rockwell Defense Electronics	Anaheim	CA	37211

(Continued)

Table 7 (Continued)

Military/Aero Purchasing Locations

Parent Company Code	Location Name	City	State	SIC Code
ROCK	Rockwell Missile Systems Dv.	Duluth	GA	37611
ROCK	Rockwell No. Amer. Aircraft Op.	Los Angeles	CA	37211
ROCK	Rockwell No. Amer. Aircraft Op.	McAlester	OK	37211
ROCK	Rockwell Rocketdyne Division	Canoga Park	CA	37612
ROCK	Rockwell Space Trans. Systems	Downey	CA	37612
SCISI	SCI Systems Inc.	Huntsville	AL	36620
SCIATL	Sci-Atl Electro Products Dv.	Atlanta	GA	36620
SEQUA	Sequa-Kollsman Military Dv.	Nashua	NH	36625
SINGER	Singer-Kearfott Guidance & Nav.	Black Mountain	NC	37211
SINGER	Singer Company (NJ)	Little Falls	NJ	37211
SINGER	Singer Electronics Division	San Marcos	CA	38110
SINGER	Singer Librascope Division	Glendale	CA	37312
HONEY	Space & Strategic Avionics Dv.	Clearwater	FL	37612
HONEY	Sperry Space Systems Division	Glendale	AZ	37612
SQUARE	Square D-K.B. Denver, Inc.	Loveland	CO	38110
TRW	TRW-ESL Inc.	Sunnyvale	CA	36625
TRW	TRW Electronic Products, Inc.	Colorado Springs	CO	36620
TRW	TRW Electronics & Defense Sec.	Redondo Beach	CA	37612
TRW	TRW High Reliability Elec. Proc.	Redondo Beach	CA	37612
TELEDY	Teledyne Avionics	Charlottesville	VA	37211
TELEDY	Teledyne Brown Engineering	Huntsville	AL	37211
TELEDY	Teledyne Controls	W. Los Angeles	CA	37211
TELEDY	Teledyne Lewisburg	Lewisburg	TN	36620
TELEDY	Teledyne Microwave	Mountain View	CA	36625
TELEDY	Teledyne Ryan Electronics	San Diego	CA	36625
TELEDY	Teledyne Systems	Northridge	CA	37612
TI	Texas Instruments Defense Sys.	Dallas	TX	37611
TI	Texas Instruments Defense Sys.	Plano	TX	36625
TRACOR	Tracor Aerospace Inc.	Austin	TX	37211
TRACOR	Tracor Applied Sciences Inc.	Austin	TX	36625
UTC	UTC-Hamilton Standard Dv.	Windsor Locks	CT	37211
UICORP	United Indust.-AAI Corporation	Cockeysville	MD	38229
UICORP	United Indust.-AAI Corporation	Maitland	FL	38229
UTC	United Tech.-Norden Systems Dv.	Westport	CT	37211
VAR	Varian Solid State Microwave	Santa Clara	CA	38110
VAR	Varian-Beverly Microwave Dv.	Beverly	MA	36625

(Continued)

Table 7 (Continued)

Military/Aero Purchasing Locations

Parent Company Code	Location Name	City	State	SIC Code
WATK	Watkins-Johnson Co.	Palo Alto	CA	37612
WATK	Watkins-Johnson Comm. Elec. Tech.	Gaithersburg	MD	36620
WATK	Watkins-Johnson ESM Division	San Jose	CA	36620
WEC	Westinghouse Def. & Elec. Sys.	Baltimore	MD	36620
WEC	Westinghouse Defense Unit	Baltimore	MD	36625
WEC	Westinghouse Int. Logistics Sup.	Hunt Valley	MD	36625
WEC	Westinghouse Material Acq. Ctr.	Baltimore	MD	36625
WEC	Westinghouse Oceanic Division	Annapolis	MD	37312

Source: Electronic Business
Dataquest
November 1988

Table 8

Transportation Purchasing Locations

Parent Company Code	Location Name	City	State	SIC Code
ALLIED	Bendix Automotive Brakes Dv.	South Bend	IN	36947
CHRY	Chrysler Huntsville Elec. Dv.	Huntsville	AL	36510
DYNATECH	Dynatech-Sensors, Inc.	Saline	MI	36947
FORD	Ford Electrical/Electronics Dv.	Ypsilanti	MI	36947
GE	GE Appliance Control Dept.	Morrison	IL	36947
GM	GM Delco Electronics	Kokomo	IN	36947
CHRY	Huntsville Electronics Dv.	Huntsville	AL	36947
LITTON	Litton Data Systems (LDS)	Pascagoula	MI	37313
MOTO	Motorola Auto & Ind. Elec. Dv.	Northbrook	IL	38252
SUNECORP	Sun Electric Corporation	Crystal Lake	IL	38252
TRW	TRW Transporation Elec. Dv.	Farmington Hill	MI	36947

Source: Electronic Business
Dataquest
November 1988

Table 9

Cross-Index: SICs to Lines of Business (LOBs)

SIC Code	Semiconductor Application Market	Line of Business
0	TRAN	Railway & High-Speed Train
0	TRAN	Other
35340	IND	Mfg. Systems/Auto. Material Handling/Guided Vehicles
35340	IND	Mfg. Systems/Auto. Material Handling/Prog. Conveyors
35340	IND	Mfg. Systems/Auto. Material Handling/Strg./ Retriev. Sys.
35340	IND	Mfg. Systems/Auto. Material Handling/Prog. Monorails
35340	IND	Mfg. Systems/Auto. Material Handling/ Warehousing
35340	IND	Mfg. Systems/Auto. Material Handling/Other
35401	IND	Mfg. Systems/Programmable Machine Tools
35492	IND	Mfg. Systems/Mechanical Assembly Equipment
35593	IND	Mfg. Systems/Plastic Processing Machinery
35595	IND	Mfg. Systems/Semiconductor Production
35690	IND	Other/Gen. Ind. Eqp./N.E.C.
35694	IND	Mfg. Systems/Robot Systems/Assembly
35694	IND	Mfg. Systems/Robot Systems/Material Handling/Loading
35694	IND	Mfg. Systems/Robot Systems/Painting

(Continued)

Table 9 (Continued)

Cross-Index: SICs to Lines of Business (LOBs)

SIC Code	Semiconductor Application Market	Line of Business
35694	IND	Mfg. Systems/Robot Systems/Spot Welding
35694	IND	Mfg. Systems/Robot Systems/Arc Welding
35694	IND	Mfg. Systems/Robot Systems/Machining--Other
35730	COMM	Cust. Premises/Data Comm. Equip./Front-End Proc.
35731	DP	Comp./Single-User PCs
35731	DP	Comp./Corp. Res. (>$1M)
35731	DP	Comp./Bus. Unit ($250K-$1M)
35731	DP	Comp./Large Dept. ($75K-$250K)
35731	DP	Comp./Small Dept. ($25K-$75K)
35731	DP	Comp./Work Group (<$25K)
35731	DP	Comp./Single-User Enhanced (<$75K)
35731	MIL	Procurement/Computers/Periphs./Military
35732	DP	Term./Alphanumeric (CRT)
35732	DP	Term./Graphics Terminals
35732	DP	Input/Output/Remote Batch, Job Entry and Output
35732	DP	Input/Output/Key Entry Equipment
35732	DP	Input/Output/Media to Media Data Conv.
35732	DP	Input/Output/Magnetic Ink Recognition

(Continued)

Table 9 (Continued)

Cross-Index: SICs to Lines of Business (LOBs)

SIC Code	Semiconductor Application Market	Line of Business
35732	DP	Input/Output/Opt. Scanning Equip.
35732	DP	Input/Output/Computer Plotters
35732	DP	Input/Output/Ser. Prts./Impact, Dot Matrix
35732	DP	Input/Output/Ser. Prts./Impact, Fully Formed
35732	DP	Input/Output/Ser. Prts./Nonimp., Dir. Thermal
35732	DP	Input/Output/Ser. Prts./Nonimp., Therm. Trans.
35732	DP	Input/Output/Ser. Prts./Nonimp., Ink Jet
35732	DP	Input/Output/Line Prts./Impact, Dot Matrix
35732	DP	Input/Output/Line Prts./Impact, Fully Formed
35732	DP	Input/Output/Line Prts./Nonimp., Dir. Therm.
35732	DP	Input/Output/Line Prts./Nonimp., Therm. Trans.
35732	DP	Input/Output/Page Prts.
35732	DP	Dedicated Sys./Other Specialized Term.
35732	DP	Data Stor. Subsys./Rigid Drives
35732	DP	Data Stor. Subsys./Tape Drives
35732	DP	Data Stor. Subsys./Optical
35743	DP	Dedicated Sys./Banking Sys./Funds Trans. Term.

(Continued)

Table 9 (Continued)

Cross-Index: SICs to Lines of Business (LOBs)

SIC Code	Semiconductor Application Market	Line of Business
35743	DP	Dedicated Sys./Point of Sale Terminals
35744	DP	Dedicated Sys./Off. Auto./Elec. Calc.
35745	DP	Dedicated Sys./Cash Registers
35792	DP	Dedicated Sys./Off. Auto./Word Processors
35793	DP	Dedicated Sys./Off. Auto./Copiers and Dupl.
35795	DP	Dedicated Sys./Mail, Letter Hndlng., Addrng.
35799	DP	Dedicated Sys./Off. Auto./Dictating, Trnscrib.
35799	DP	Dedicated Sys./Off. Auto./Electronic Typewriters
35799	DP	Dedicated Sys./Banking Sys./Check Handling Sys.
35811	IND	Other/Vending Machines
36010	MIL	Procurement/Electronics
36292	IND	Other/Power Supplies/Uninterruptible
36311	CON	Appliances/Air Conditioners
36311	CON	Appliances/Microwave Ovens
36321	CON	Appliances/Refrigerators
36331	CON	Appliances/Washers & Dryers
36345	CON	Appliances/Ranges & Ovens

(Continued)

Table 9 (Continued)

Cross–Index: SICs to Lines of Business (LOBs)

SIC Code	Semiconductor Application Market	Line of Business
36394	CON	Appliances/Dishwashers, Disposals
36510	TRAN	Auto & Light Truck/Entertainment
36511	CON	Audio/Radio
36512	CON	Video/Color TVs
36512	CON	Video/B&W TVs
36514	CON	Audio/Stereo Sets
36514	CON	Audio/Tape Recorders
36515	CON	Audio/Audio Amplifiers
36515	CON	Audio/Compact Disk Players
36515	CON	Audio/Stereo Headphones
36516	CON	Video/Video Cameras
36516	CON	Video/VCRs
36516	CON	Video/Video Disk Players
36610	COMM	Cust. Premises/Videoteleconferencing
36611	COMM	Cust. Premises/Bus. Comm. Sys./PBX
36611	COMM	Cust. Premises/Data PBX
36611	COMM	Cust. Premises/Auto. Call Distrib.
36611	COMM	Cust. Premises/Call Accounting
36611	COMM	Public Telcom./Switching Equip./Central Office

(Continued)

Table 9 (Continued)

Cross-Index: SICs to Lines of Business (LOBs)

SIC Code	Semiconductor Application Market	Line of Business
36611	COMM	Public Telcom./Switching Equip./Other Common Carrier
36611	COMM	Public Telcom./Switching Equip./Priv. Packet Data Net.
36611	COMM	Radio/Mobile Base Stations
36612	COMM	Cust. Premises/Term. Equip./Single Line Tele.
36612	COMM	Cust. Premises/Term. Equip./Teleprinter
36612	COMM	Cust. Premises/Data Comm. Equip./Modems
36612	COMM	Cust. Premises/Data Comm. Equip./Stat. Multiplexers
36612	COMM	Cust. Premises/Data Comm. Equip./T1 Multiplexers
36612	COMM	Cust. Premises/Local Area Networks
36612	COMM	Cust. Premises/Bus. Comm. Sys./Key Tele. Sys.
36612	COMM	Cust. Premises/Attached Network Func./Protocol Conv.
36612	COMM	Cust. Premises/Attached Network Func./Voice Mess.
36612	COMM	Public Telcom./Transmission Equip./Multiplex
36612	COMM	Public Telcom./Transmission Equip./Carrier Sys.

(Continued)

Table 9 (Continued)

Cross-Index: SICs to Lines of Business (LOBs)

SIC Code	Semiconductor Application Market	Line of Business
36620	MIL	Procurement/Ordnance & Weapons
36620	MIL	Procurement/Vehicles
36620	MIL	Procurement/Communications
36621	COMM	Cust. Premises/Term. Equip./Intgrtd. Voice/Data Wrkstn.
36621	COMM	Public Telcom./Transmission Equip./Microwave Radio
36621	COMM	Public Telcom./Transmission Equip./Satellite Earth Sta.
36621	COMM	Radio/Mobile Radio Stations
36621	COMM	Radio/Mobile Vehicular
36621	COMM	Radio/Cellular Rad/Tel/Base Station
36621	COMM	Radio/Cellular Radio Telephones
36621	COMM	Radio/Amateur Radio
36621	COMM	Radio/Citizen's Band/Mobile & Base
36621	COMM	Radio/Portable Receivers, Transmitters
36621	COMM	Radio/Checkout, Monitor, Evaluation
36621	COMM	Radio/Communications Antenna <890 MHz
36621	COMM	Radio/Microwave Antenna >890 MHz
36621	COMM	Other/Transmitters, Receivers, RF Amplifiers

(Continued)

Table 9 (Continued)

Cross-Index: SICs to Lines of Business (LOBs)

SIC Code	Semiconductor Application Market	Line of Business
36621	COMM	Other/Light Comm. Systems/Fiber Optic
36621	COMM	Other/Light Comm. Systems/Other
36621	COMM	Other/Telemetering Systems
36621	IND	Other/Laser Systems (excluding Communication)
36621	COMM	Cust. Premises/Data Comm. Equip./Network Management
36622	COMM	Radio/Broadcast Receivers, Transmitters
36622	COMM	Broadcast & Studio/Audio Equipment
36622	COMM	Broadcast & Studio/Video Equipment
36622	COMM	Broadcast & Studio/Transmitters, RF Power Amplifier
36622	COMM	Broadcast & Studio/Studio Transmitter Links
36622	COMM	Broadcast & Studio/Cable TV Broadcast Equipment
36622	COMM	Broadcast & Studio/CCTV
36622	COMM	Broadcast & Studio/Broadcast Transmitter Antenna
36622	COMM	Broadcast & Studio/Other (Studio, Theater)
36624	IND	Security/Energy Mgmt./Alarm Systems
36625	IND	Instrumentation/Geophysical

(Continued)

Table 9 (Continued)

Cross-Index: SICs to Lines of Business (LOBs)

SIC Code	Semiconductor Application Market	Line of Business
36625	MIL	Procurement/Radar/Sonar
36625	MIL	Procurement/Electronic Warfare Systems
36626	IND	Other/Traffic Control
36628	COMM	Other/Intercom. Eqp., Electronically Amplified
36629	IND	Instrumentation/Ultrasonic Cleaners, Drills
36629	IND	Other/Particle Accelerator Electronics
36629	IND	Other/Trainers & Simulators
36629	IND	Other/Scientific Not Elsewhere Classified (N.E.C.)
36629	CON	Other/Consumer Elec. Eqp. Not Elsewhere Classified
36791	DP	Dedicated Sys./Smart Cards
36795	IND	Other/Power Supplies (except Uninterruptible)
36931	IND	Medical Eqp./Diagnostic/CAT Scanners
36931	IND	Medical Eqp./Diagnostic/Digital Radiography
36931	IND	Medical Eqp./Diagnostic/X-Ray
36931	IND	Other/Industrial & Scientific X-Ray
36933	IND	Medical Eqp./Diagnostic/Automatic Blood Analyzer

(Continued)

Table 9 (Continued)

Cross-Index: SICs to Lines of Business (LOBs)

SIC Code	Semiconductor Application Market	Line of Business
36933	IND	Medical Eqp./Diagnostic/Electrocardiographs
36933	IND	Medical Eqp./Diagnostic/Electroencephalographs
36933	IND	Medical Eqp./Diagnostic/Nuclear Magnetic Resonance
36933	IND	Medical Eqp./Diagnostic/Respiratory Analysis
36933	IND	Medical Eqp./Diagnostic/Ultrasonic Scanners
36933	IND	Medical Eqp./Diagnostic/Other Diagnostic
36933	IND	Medical Eqp./Patient-Monitoring
36933	IND	Medical Eqp./Prosthetic/Hearing Aids
36933	IND	Medical Eqp./Surgical Support
36933	IND	Medical Eqp./Therapeutic/Defibrillators
36933	IND	Medical Eqp./Therapeutic/Dialysis, Diathermy
36933	IND	Medical Eqp./Therapeutic/Electrosurgical
36933	IND	Medical Eqp./Therapeutic/Pacemakers
36933	IND	Medical Eqp./Therapeutic/Ultrasonic Generators
36933	IND	Medical Eqp./Therapeutic/Other Therapeutic
36947	TRAN	Auto & Light Truck/Body Controls
36947	TRAN	Auto & Light Truck/Powertrain
36947	TRAN	Auto & Light Truck/Safety & Convenience

(Continued)

Table 9 (Continued)

Cross-Index: SICs to Lines of Business (LOBs)

SIC Code	Semiconductor Application Market	Line of Business
36994	CON	Other/Automatic Garage Door Openers
37211	MIL	Procurement/Aircraft/Military
37213	MIL	Procurement/Aircraft/Commercial
37312	MIL	Procurement/Military Ships
37313	TRAN	Commercial Ships
37611	MIL	Procurement/Missiles
37612	MIL	Procurement/Space/Military
37612	MIL	Procurement/Space/Commercial & Govt. (Non-Mil.)
38110	MIL	Procurement/Other
38111	IND	Comm'l. Aviation/Aeronautical, Nautical & Nav. Inst.
38112	IND	Other/Scientific & Lab Apparatus
38113	IND	Instrumentation/Surveying & Drafting Instruments
38220	IND	Security/Energy Mgmt./Discrete Devices
38220	IND	Security/Energy Mgmt./MPU Load Programmers
38220	IND	Security/Energy Mgmt./Computerized Energy Control Sys.
38220	IND	Security/Energy Management/Automatic Sprinkler Systems

(Continued)

Table 9 (Continued)

Cross-Index: SICs to Lines of Business (LOBs)

SIC Code	Semiconductor Application Market	Line of Business
38229	MIL	Procurement/Simulators
38230	IND	Mfg. Systems/Process Control Systems
38242	IND	Instrument./Integrating & Totaling Meters for Gas & Liq.
38242	IND	Instrumentation/Flow Meters
38243	IND	Instrumentation/Counting Devices
38252	IND	Mfg. Systems/Test Equipment/ATE
38252	IND	Mfg. Systems/Test Equipment/General
38252	TRAN	Auto & Light Truck/Driver Information
38253	IND	Instrumentation/Digital Panel Meters
38253	IND	Instrumentation/Analog Panel Meters
38253	IND	Instrumentation/Panel Type
38253	IND	Instrumentation/Elapsed-Time Meters
38253	IND	Instrumentation/Portable Elec. Measuring Instruments
38291	IND	Comm'l. Aviation/Aircraft Engine Inst. (except Flight)
38292	IND	Instrumentation/Phys. Property Test, Insp., Measurement
38293	IND	Instrumentation/Commercial Meteorological & Gen. Purp.

(Continued)

Table 9 (Continued)

Cross-Index: SICs to Lines of Business (LOBs)

SIC Code	Semiconductor Application Market	Line of Business
38294	IND	Instrumentation/Nuclear Radiation Detection/Monitoring
38326	IND	Instrumentation/Elec. Recording Instruments
38326	IND	Instrumentation/Analytical & Scientific Instruments
38611	CON	Personal Electronics/Cameras
38731	CON	Personal Electronics/Clocks
38736	CON	Personal Electronics/Watches
39314	CON	Audio/Musical Instruments
39447	CON	Personal Electronics/Games
85120	MIL	Procurement/R&D, Testing, & Evaluation

Source: *Electronic Business*
Dataquest
November 1988

Overview

INTRODUCTION

This section forms the first major data base on which the methodology of this product is based. The other data base, located behind the next tab, provides forecasts of electronic equipment production. The year in common, 1983, forms a transition in which to view history, while simultaneously extrapolating material that is necessary for understanding the future. The purpose of the electronic equipment revenue data base is threefold:

- To provide concrete historical information on specific companies—The section provides a data base of the electronic equipment revenue of 50 U.S. equipment manufacturers. We estimate that this electronic revenue accounts for a significant percentage of U.S. electronic equipment shipments and forms a good base for examining trends in the electronic equipment marketplace. This data base is a tool for analyzing growth by application market segment or the activities of individual companies.

- To offer a check on other summary data--The information complements a historical view of semiconductor consumption with an equipment viewpoint rather than simply a product-shipment analysis.

- To serve as a basis for developing input/output ratios--Tracking the actual semiconductor consumption (both merchant and captive) and the actual electronic equipment revenue of given users allows an analysis of the input/output (I/O) ratio: the relationship between semiconductor dollar value and the dollar value of the equipment in which the semiconductors are used.

Dataquest has developed I/O ratios by interviewing procurement, contract, and materials managers who are experts in knowing their individual companies' merchant and captive use of semiconductors. We have interviewed more than 200 leading electronics manufacturers that have given us proprietary information on their semiconductor procurement, their captive production, and their relationships to the equipment or divisions in which the devices are used.

Dataquest has agreed to use this information only for internal purposes and to report these ratios only on an aggregate basis. The I/O ratios that we develop are applied to the forecasts for electronic equipment (in the next tab). Information in those I/O ratios are available to clients that subscribe to our on-line services and can also be solicited from our analysts by using their inquiry privilege. The result is a series of forecasts of semiconductor consumption by application market presented in the "Semiconductor Consumption Analysis" section.

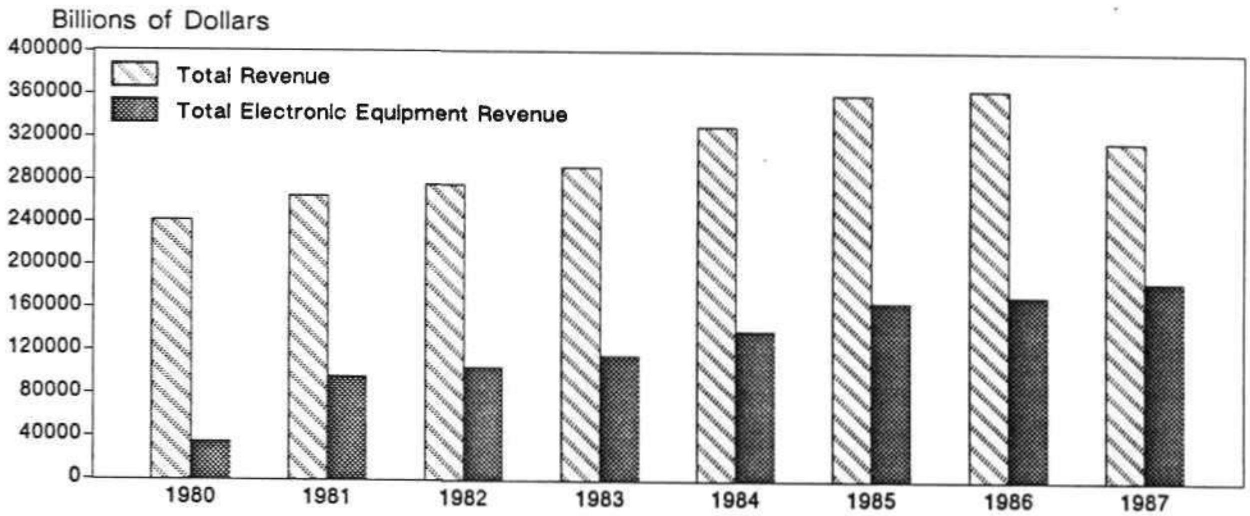
OVERVIEW

The information that follows is the result of a comprehensive data base that tracks and analyzes the electronic equipment revenue of a sample of U.S. manufacturing companies. Major companies' revenue is listed, segmented, and presented in this section in various ways. Accordingly, the data, covering a seven-year span (1980 through 1987), are presented as follows:

- The combined total revenue of all companies in the data base in relation to the combined total electronic equipment revenue of those same companies (see Figure 1 and Table 1)
- The combined total electronic equipment revenue broken out by the six standard application markets that consume semiconductors: data processing, communications, industrial, consumer, military, and transportation (see Figure 2 and Table 2)
- The combined total electronic equipment revenue plotted against total North American semiconductor consumption for the same historical seven-year period (see Figure 3, Figure 4, and Table 3)
- The individual application markets broken out by year, company, and revenue for that market

Figure 1

Total Company Revenue versus Total Company Electronic Equipment Revenue



Source: Dataquest
October 1988

Table 1

Total Company Revenue versus Total Company Electronic Equipment Revenue (Millions of Dollars)

	1980	1981	1982	1983	1984	1985	1986	1987	CAGR 1980-1984	CAGR 1985-1987
Total Revenue*	$242,056	$265,274	$275,993	$293,162	$330,674	$360,252	$365,303	$397,040	8.1%	5.0%
Electronic Equipment Revenue*	$ 84,601	$ 95,812	$105,042	$116,249	$138,877	$165,719	$171,836	$185,671	13.2%	5.8%
Electronic Percent of Total	35.0%	36.1%	38.1%	39.7%	42.0%	46.0%	47.0%	46.8%		

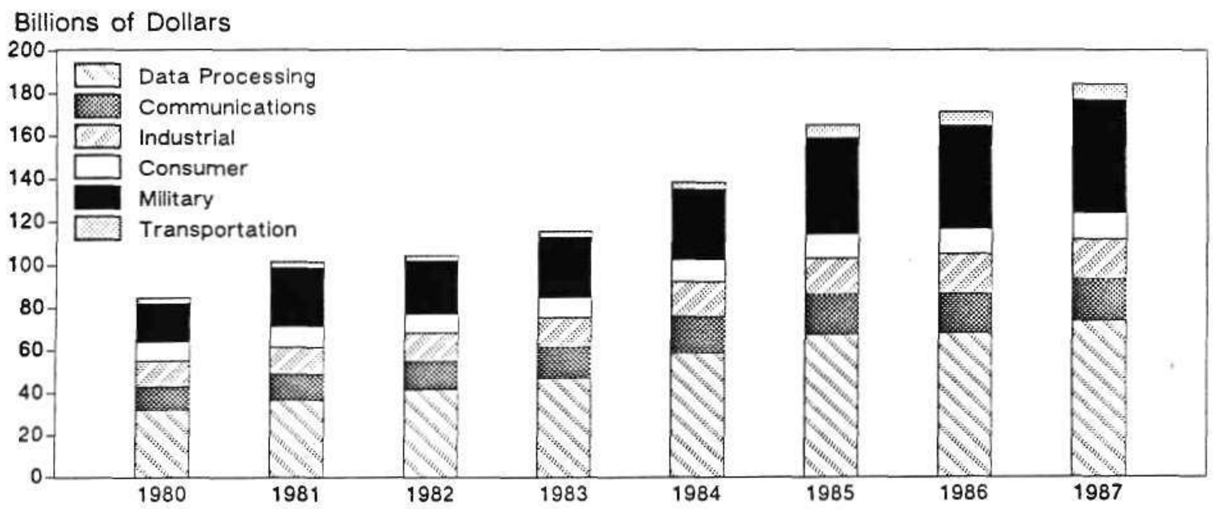
*Starting in 1985, revenue includes GM Hughes Electronics' revenue:

- 1985 $ 9,504 Million
- 1986 $10,440 Million
- 1987 $10,481 Million

Source: Dataquest
October 1988

Figure 2

Total Electronic Equipment Revenue by Application Market



Source: Dataquest
October 1988

Overview

Table 2

Total Electronic Equipment Revenue by Application Market (Millions of Dollars)

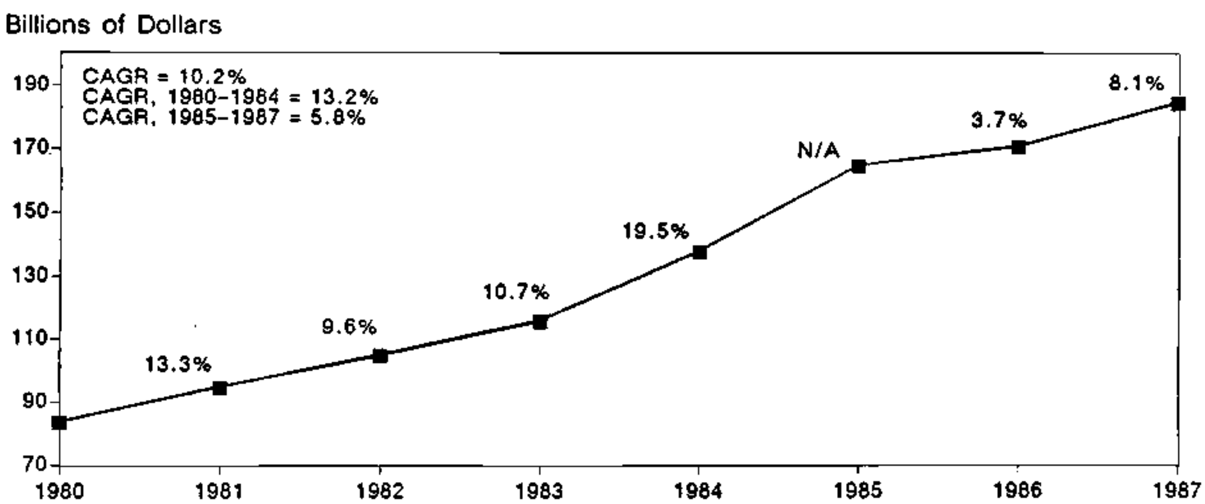
	1980	1981	1982	1983	1984	1985	1986	1987	CAGR 1980-1984	CAGR 1985-1987
Data Processing	$31,946	$36,612	$ 41,664	$ 47,130	$ 58,834	$ 67,404	$ 68,007	$ 74,711	16.5%	5.3%
Communications	10,934	12,339	13,458	14,705	17,357	19,087	18,862	19,620	12.2	1.4
Industrial*	11,934	12,842	13,468	13,939	16,201	17,140	18,835	18,808	7.9	4.8
Consumer	9,019	9,801	8,931	9,397	10,632	11,446	11,612	12,228	4.2	3.4
Military*	18,225	21,651	25,037	28,343	32,788	44,742	48,044	53,283	15.8	9.1
Transportation*	2,543	2,567	2,484	2,735	3,065	5,900	6,476	7,021	4.8	9.1
Total	$84,601	$95,812	$105,042	$116,249	$138,877	$165,719	$171,836	$185,671	13.2%	5.8%

*Starting in 1985, Industrial, Military, and Transportation applications include GM Hughes Electronics' revenue.

Source: Dataquest
October 1988

Figure 3

Total Company Electronic Equipment Revenue

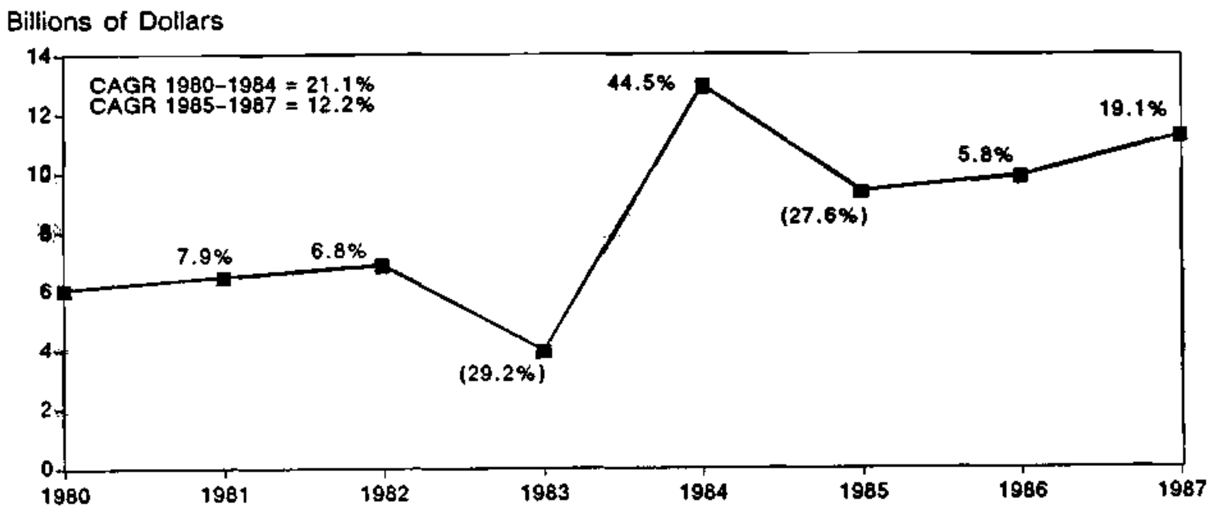


N/A = Not Available
Note: Starting in 1985, total company electronic equipment revenues include GM Hughes Electronics revenue.

Source: Dataquest
October 1988

Figure 4

North American Semiconductor Consumption



Source: Dataquest
October 1988

Table 3

Total Company Electronic Equipment Revenue versus North American Semiconductor Consumption (Millions of Dollars)

	1980	1981	1982	1983	1984	1985	1986	1987	CAGR 1980-1984	CAGR 1985-1987
Electronic Equipment Revenue*	$84,601	$95,812	$105,042	$116,249	$138,877	$165,719	$171,836	$185,671	13.2%	5.8%
North American Semiconductor Consumption	$ 6,053	$ 6,529	$ 6,970	$ 9,002	$ 13,006	$ 9,420	$ 9,968	$ 11,869	21.1%	12.2%
Semiconductor Consumption as a Percent of Electronic Equipment Revenue (Overall Input/ Output Ratio)	7.2	6.8	6.6	7.7	9.4	5.7	5.8	6.4		

*Beginning in 1985, electronic equipment revenue includes GM Hughes Electronics.

Source: Dataquest
October 1988

METHODOLOGY

Most of the companies included in the data base were originally chosen because of their classification as a "large or leading" electronic equipment manufacturer in one or more of the six application markets. We determine which companies are major players by consulting with other Dataquest industry services. In those industries that Dataquest does not analyze, we refer to such listings as the "Electronic Business 200" feature of Electronic Business.

We have also included companies whose size or market share may not be as great as many of the larger, multi-interest corporations. However, the importance of including these companies in the data base must not be minimized. For the most part, the smaller companies are "pureplay" companies—companies that are involved in single or highly related lines of business. These companies' revenue can be traced to very specific equipment types. Their semiconductor consumption is equally specific. The I/O ratios generated for these companies are important because they tend to reflect a narrower product range than those of the larger companies. In addition, these pureplay companies are usually active in fast-growing markets that will affect future semiconductor consumption.

Company annual reports provided the main source of information on equipment shipments. (I/O ratios were developed with subsequent detailed analysis.) Virtually every annual report lists a company's revenue by line of business, each line of business usually being referred to as a segment. Descriptions of each segment are also reported. Dataquest used these descriptions to determine whether a segment's revenue should be added to the data base.

Given that the information in some annual reports is limited, Dataquest developed the following protocols to provide continuity to the data base:

- The latest annual report was always used. For example, a typical 1986 report might have historical segment data for a three- or five-year period. If only three years were reported, the 1985 report was examined for 1983 information and the data for 1985 and 1984 were simply checked against the information in the 1986 report to ensure that a company hadn't reorganized its reporting structure. Using the latest annual report provided continuity in the segments and their revenue.

- Some large companies' segments included nonelectronic equipment. If electronic equipment made up the majority of the segment, or if there was a heavy technical influence in the description, the entire revenue was added to the data base. Unless specifically detailed or additional information was obtainable, percentages were not applied to segment revenue based on the proportion or type of electronic equipment in that segment.

- Despite the name a company gave to a given segment, a description of the equipment in a segment was used to determine in which of the six Dataquest application market segments the revenue belonged. Some of the larger companies' segments had such a varied product mix that they crossed over the Dataquest segmentation. In such cases, the major product influence in that segment's description mandated which of our categories the revenue went into.

- In segments where there was little or no clear evidence of electronic equipment, the revenue was not added to the data base. Nonelectronic lines of business were also not included.

- Service, interest, supply, rentals, and other additional or product-support revenue were eliminated from the data base if they were listed in the report. Most companies in the data base separated such revenue. Software revenue was also eliminated when it was broken out as a separate line item, or if additional information indicated a percentage.

These gray areas appeared in only a portion of the companies in the data base. Since Dataquest dealt with them using the standards just described, we believe that this history of sample companies provides a thorough snapshot of what transpired in the six application market segments that affect semiconductor consumption. The strength of this data base lies in its power to identify and examine trends. As more years are included, we can examine the link between electronic equipment and semiconductor consumption more closely and analyze their historical effects on each other.

ANALYSIS

As indicated by Figure 1 and Table 1, combined total revenue grew at a compound annual growth rate (CAGR) of 8.1 percent from 1980 through 1984, and 5.0 percent from 1985 through 1987. By comparison, combined electronic equipment revenue grew at a CAGR of 13.2 percent from 1980 through 1984, and 5.8 percent from 1985 through 1987. Dataquest believes that the relatively quicker pace of growth of electronic equipment revenue supports the trend of the increasing pervasiveness of semiconductor devices.

We have split the 1980 through 1987 period analysis into two separate periods due to the inclusion of GM Hughes Electronics Corporation (GMHE), beginning in 1985. General Motors Corporation acquired the Hughes Aircraft Company (Hughes) December 31, 1985. Also on that date, GMC formed Delco Electronics Corporation (Delco Electronics). Prior to this date, Hughes was a privately held concern of the Howard Hughes Medical Institute. As a result, Hughes' revenue is unavailable prior to 1985. Delco Electronics, a leading designer and producer of automotive electronic components and systems, comprises the following former GM units: Delco Electronics Division; the Instrumentation and Display business unit of AC Spark Plug Division; and Delco Systems Operations. These operations' revenue were not segmented prior to Delco Electronics' formation, and so are also unavailable. GMHE is the holding company that owns both Hughes and the newly formed Delco Electronics Corporation.

Figure 2 and Table 2 show that the fastest-growing application markets during the 1980 through 1984 period were data processing, with a CAGR of 16.5 percent, and military, with a CAGR of 15.8 percent. During the 1985 through 1987 period, however, data processing dropped to a CAGR of 5.3 percent, while military and transportation tied for leading growth at 9.1 percent. The change in applications' growth rankings is an artifact of the two separate periods of analysis. Indeed, if GMHE is excluded, then military and data processing applications lead 1980 through 1987 compound annual growth at 14.4 percent and 12.9 percent, respectively, followed by communications at 8.7 percent, industrial at 6.2 percent, transportation at 5.9 percent, and consumer at 4.4 percent.

In 1987, military and data processing applications grew the fastest at 10.9 percent and 9.9 percent respectively, followed closely by transportation at 8.4 percent. Data processing's growth in 1987 represents a significant recovery from 0.9 percent growth in 1986, and was fueled by 29.2 percent growth in PC sales. Transportation's recent accelerated growth indicates the increasing use of electronics in automobiles.

Finally, the relationship of electronics revenue to semiconductor consumption is shown in Figure 3, Figure 4, and Table 3. In 1981, despite growth in the electronic equipment market, excess semiconductor supply and price erosion left semiconductor consumption with a relatively flat growth rate of 7.9 percent. In 1982, equipment growth grew at a slower rate, 9.6 percent, down from 13.3 percent in 1981, thereby moderately slowing semiconductor industry growth. In 1983 and 1984, however, when the equipment industry returned to a slightly faster rate of growth, semiconductor capacity was far short of demand. Semiconductor prices increased and remained firm, constraining semiconductor consumption growth. In 1985, excluding GMHE, electronic equipment revenue grew 12.5 percent, down from 19.5 percent in 1984, while semiconductor consumption dropped 27.6 percent. Large semiconductor inventories, excess capacity, and slower than expected growth in the computer industry contributed to the decrease in semiconductor industry revenue. In 1986, slow growth in the electronics industry translated into moderate growth in the semiconductor industry. A similar situation that occurred in 1983 and 1984, when semiconductor consumption growth exceeded electronic equipment growth, occurred in 1987: Semiconductor consumption and electronics equipment grew 19.1 percent and 8.1 percent, respectively, from 1986 levels.

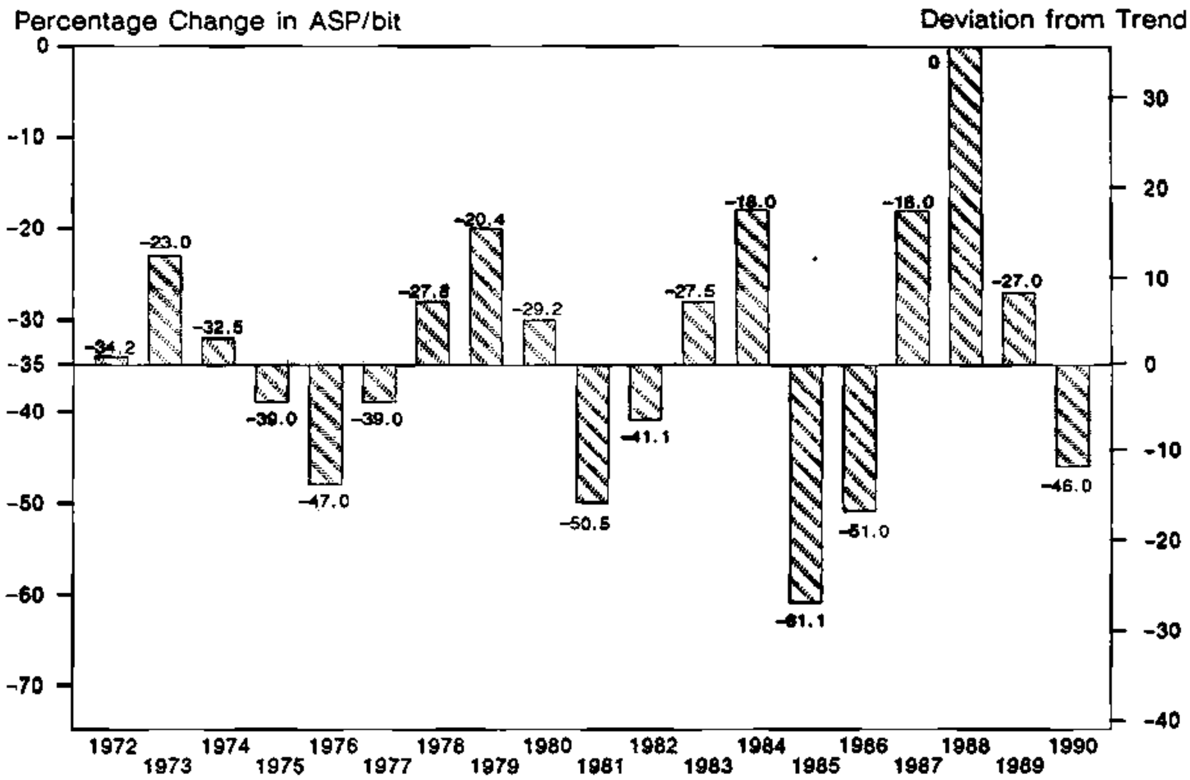
Another way to examine price pressures and confirm the results presented above is shown in Figure 5, which depicts MOS memory annual average selling prices (ASPs) per bit per year. Dataquest uses price per bit as a measure for the following reasons:

- Price per bit offers a means of tracking the price level of a function and the real cost to the user. The continual increase in functional density renders other methods ineffective.

- Package prices are not a good measure because they stay relatively constant despite this increase in functionality. A 256K DRAM's price may be similar to that of its older counterpart, the 64K DRAM, after several years in the market. For this reason, Dataquest believes that price per bit is much more useful than the average selling price per unit. It is easiest to examine ASP per bit in the MOS memory market.

Figure 5

MOS Memory Annual ASP Per Bit



Source: Dataquest
October 1988

Accordingly, in Figure 5, the years in which the average decline in memory ASP per bit exceeds the trend (34 percent per year) are those in which there is greater than normal downward price pressure. Similarly, those years in which the price decline is below normal indicate that firmer prices characterized the market. The figure clearly shows that in 1981 the MOS memory market experienced tremendous downward price pressure (less in 1982), whereas, in 1983 and 1984, downward price pressure was below average. In 1985, the downward price pressure was exceedingly high (61 percent reduction) due to the strong dollar, foreign competition, excess capacity, and excess inventories, all of which are responsible for our general semiconductor industry recession. Comparison of Figure 5 with Figure 3, Figure 4, and Table 3 shows that semiconductor shipments grew more slowly than equipment shipments in 1981 (when there was above average downward price pressure) and more rapidly than equipment shipments in 1983 (when downward price pressure was below average). This trend was true again in 1985, when semiconductor shipments dropped as electronic equipment revenue grew slowly and semiconductor prices decreased at a higher than average rate. In 1987, the ASP per bit began to increase due to trade pressure and, during the second half of the year, the shortage of 256K DRAMS. The 256K DRAM shortage carried over into 1988 giving rise to the forecast of zero growth in ASP per bit for the year.

Throughout the eight-year period, we can see that the severe price pressures—either positive or negative—that the semiconductor industry is so susceptible to are not nearly as visible to the industries that consume these devices. Despite the dramatic swings that prevail in semiconductor consumption estimates, for the most part, it is clear that electronic equipment growth experiences more moderate variations from the long-term average.

Despite year-to-year differences, however, both groups grew over the long term, with a semiconductor consumption on average growing faster than electronic equipment. Dataquest believes that a significant finding of this analysis is that while the semiconductor industry experienced severe highs and lows, the long-term relationship between semiconductor consumption as a percentage of electronic equipment revenue remained fairly steady between 1979 and 1986, with some fluctuation from year to year because of inordinate pricing that characterizes extreme changes (growth or decline) in the value of a given year's overall semiconductor consumption.

Application Market Revenue

Data Processing Revenue
(Millions of Dollars)

Company	1980	1981	1982	1983	1984	1985	1986	1987
Allied-Signal	0	0	0	0	0	0	0	0
Apollo	0	$ 3	$ 15	$ 65	$ 194	$ 228	$ 335	467
Apple	$ 113	$ 325	$ 533	$ 873	$ 1,301	$ 1,668	$ 1,807	$ 2,645
Applied Materials	0	0	0	0	0	0	0	0
AT&T	0	0	0	0	$ 96	$ 592	$ 721	$ 459
Burroughs	$ 896	$ 1,142	$ 1,450	$ 1,610	$ 2,057	$ 2,214	0	0
Commodore	$ 96	$ 144	$ 241	$ 609	$ 1,159	$ 708	$ 711	$ 645
Compaq Computer	0	0	0	$ 111	$ 329	$ 504	$ 625	$ 1,224
Control Data	$ 1,473	$ 1,660	$ 1,699	$ 1,916	$ 2,128	$ 2,246	$ 1,880	$ 1,870
Data General	$ 549	$ 589	$ 617	$ 596	$ 884	$ 912	$ 868	$ 850
Digital Equipment	$ 1,779	$ 2,384	$ 2,794	$ 2,854	$ 3,796	$ 4,266	$ 4,753	$ 5,479
Eastman Kodak	$ 652	$ 681	$ 767	$ 721	$ 857	$ 788	$ 932	$ 1,204
Eaton Corporation	0	0	0	0	0	0	0	0
E-Systems	0	0	0	0	0	0	0	0
GCA	0	0	0	0	0	0	0	0
General Electric	0	0	0	0	0	0	0	0
GM Hughes Electronics	0	0	0	0	0	0	0	0
GTE	0	0	0	0	0	0	0	0
Harris	$ 464	$ 556	$ 622	$ 656	$ 679	$ 802	$ 715	$ 638
Hewlett-Packard	$ 1,208	$ 1,386	$ 1,694	$ 1,936	$ 2,234	$ 2,405	$ 2,809	$ 3,199
Honeywell	$ 828	$ 895	$ 788	$ 778	$ 936	$ 1,081	$ 940	0
Honeywell Bull	0	0	0	0	0	0	0	1,297
IBM	$14,124	$15,808	$18,850	$21,164	$28,341	$34,690	$32,954	$33,909
ITT	0	0	0	0	0	0	0	0
Litton	0	0	0	0	0	0	0	0
Lockheed	0	0	0	0	0	0	0	0
3M	$ 772	$ 797	$ 808	$ 854	$ 946	$ 906	$ 929	$ 918
Martin Marietta	0	0	0	0	0	0	0	0
McDonnell Douglas	$ 107	$ 129	$ 178	$ 205	$ 329	$ 300	$ 387	$ 292
Motorola	$ 296	$ 371	$ 437	$ 463	$ 558	$ 598	$ 496	$ 427
NCR	$ 1,683	$ 1,696	$ 1,703	$ 1,710	$ 1,972	$ 2,158	$ 2,410	$ 2,983
Northern Telecom	$ 571	$ 686	$ 966	$ 986	$ 1,162	$ 1,257	$ 1,285	$ 1,302
Polaroid	0	0	0	0	0	0	0	0
Raytheon	0	0	0	0	0	0	0	0
RCA	0	0	0	0	0	0	0	0
Rockwell	0	0	0	0	0	0	0	0
Singer	0	0	0	0	0	0	0	0
Sperry	$ 1,809	$ 2,111	$ 2,066	$ 1,959	$ 1,950	$ 2,065	0	0
Sun Microsystems	0	0	0	$ 9	$ 39	$ 115	$ 200	$ 430
Tandy	$ 165	$ 370	$ 550	$ 771	$ 864	$ 802	$ 953	$ 1,046
Tektronix	$ 326	$ 391	$ 441	$ 455	$ 529	$ 567	$ 534	$ 501
Teradyne	0	0	0	0	0	0	0	0
Texas Instruments	$ 888	$ 958	$ 1,024	$ 962	$ 963	$ 862	$ 789	$ 767
TRW	0	0	0	0	0	0	0	0
Unisys	0	0	0	0	0	0	$ 4,604	$ 5,421
United Technologies	0	0	0	0	0	0	0	0
Varian	0	0	0	0	0	0	0	0
Westinghouse	0	0	0	0	0	0	0	0
Xerox	$ 3,043	$ 3,410	$ 3,289	$ 3,695	$ 4,282	$ 4,318	$ 4,822	$ 5,702
Zenith	$ 104	$ 120	$ 132	$ 172	$ 249	$ 352	$ 548	$ 1,036

Source: Dataquest
October 1988

Application Market Revenue

Communications Revenue
(Millions of Dollars)

Company	1980	1981	1982	1983	1984	1985	1986	1987
Allied-Signal	0	0	0	0	0	0	0	0
Apollo	0	0	0	0	0	0	0	0
Apple	0	0	0	0	0	0	0	0
Applied Materials	0	0	0	0	0	0	0	0
AT&T	$6,467	$7,306	$7,770	$8,429	$10,093	$10,002	$8,676	$ 8,875
Burroughs	0	0	0	0	0	0	0	0
Commodore	0	0	0	0	0	0	0	0
Compaq Computer	0	0	0	0	0	0	0	0
Control Data	0	0	0	0	0	0	0	0
Data General	0	0	0	0	0	0	0	0
Digital Equipment	0	0	0	$ 14	$ 38	$ 86	$ 177	$ 207
Eastman Kodak	0	0	0	0	0	0	0	0
Eaton Corporation	0	0	0	0	0	0	0	0
E-Systems	0	0	0	0	0	0	0	0
GCA	0	0	0	0	0	0	0	0
General Electric	$ 160	$ 164	$ 220	$ 218	$ 228	$ 239	$ 771	$ 828
GM Hughes Electronics	0	0	0	0	0	0	0	0
GTE	$1,006	$1,066	$1,185	$1,298	$ 1,178	$ 1,289	$1,212	$ 562
Harris	$ 245	$ 306	$ 397	$ 391	$ 369	$ 384	$ 351	$ 335
Hewlett-Packard	0	0	0	0	0	0	0	0
Honeywell	0	0	0	0	0	0	0	0
Honeywell Bull	0	0	0	0	0	0	0	0
IBM	0	0	0	0	0	$ 600	$ 900	$ 1,100
ITT	0	0	0	0	0	0	0	0
Litton	0	0	0	0	0	0	0	0
Lockheed	0	0	0	0	0	0	0	0
3M	0	0	0	0	0	0	0	0
Martin Marietta	0	0	0	0	0	0	0	0
McDonnell Douglas	0	0	0	0	0	0	0	0
Motorola	$1,156	$1,328	$1,405	$1,490	$ 1,891	$ 2,118	$2,637	$ 2,981
NCR	0	0	0	0	0	0	0	0
Northern Telecom	$ 879	$1,073	$1,261	$1,419	$ 1,897	$ 2,633	$2,751	$ 3,143
Polaroid	0	0	0	0	0	0	0	0
Raytheon	0	0	0	0	0	0	0	0
RCA	$ 464	$ 446	$ 458	$ 421	$ 453	$ 431	0	0
Rockwell	$ 342	$ 363	$ 379	$ 488	$ 579	$ 733	$ 761	$ 860
Singer	0	0	0	0	0	0	0	0
Sperry	0	0	0	0	0	0	0	0
Sun Microsystems	0	0	0	0	0	0	0	0
Tandy	$ 78	$ 110	$ 148	$ 223	$ 264	$ 283	$ 352	$ 401
Tektronix	$ 129	$ 150	$ 171	$ 192	$ 221	$ 236	$ 216	$ 255
Teradyne	0	0	0	0	0	0	0	0
Texas Instruments	0	0	0	0	0	0	0	0
TRW	0	0	0	0	0	0	0	0
Unisys	0	0	0	0	0	0	0	0
United Technologies	0	0	0	0	0	0	0	0
Varian	0	0	0	0	0	0	0	0
Westinghouse	0	0	0	0	0	0	0	0
Xerox	0	0	0	0	0	0	0	0
Zenith	$ 8	$ 27	$ 64	$ 122	$ 146	$ 53	$ 58	$ 73

Source: Dataquest
October 1988

Industrial Revenue
(Millions of Dollars)

Company	1980	1981	1982	1983	1984	1985	1986	1987
Allied-Signal	$ 426	$ 487	$ 576	$ 784	$ 950	$ 893	$1,517	0
Apollo	0	0	0	0	0	0	0	0
Apple	0	0	0	0	0	0	0	0
Applied Materials	$ 71	$ 79	$ 91	$ 106	$ 168	$ 175	$ 149	$ 174
AT&T	0	0	0	0	0	0	0	0
Burroughs	0	0	0	0	0	0	0	0
Commodore	0	0	0	0	0	0	0	0
Compaq Computer	0	0	0	0	0	0	0	0
Control Data	0	0	0	0	0	0	0	0
Data General	0	0	0	0	0	0	0	0
Digital Equipment	0	0	0	0	0	0	0	0
Eastman Kodak	$ 861	$ 899	$ 973	$ 882	$ 885	$ 901	$ 933	$ 1,058
Eaton Corporation	$1,169	$1,214	$1,043	$1,029	$1,189	$1,251	$1,256	$ 1,411
E-Systems	0	0	0	0	0	0	0	0
GCA	$ 170	$ 203	$ 128	$ 185	$ 294	$ 228	$ 116	$ 76
General Electric	$ 895	$1,127	$1,467	$1,586	$2,303	$2,564	$3,356	$ 3,854
GM Hughes Electronics	0	0	0	0	0	$ 821	$ 769	$ 647
GTE	0	0	0	0	0	0	0	0
Harris	0	0	0	0	0	0	0	0
Hewlett-Packard	$1,589	$1,795	$2,072	$2,290	$2,504	$2,529	$2,651	$ 2,983
Honeywell	$2,239	$2,384	$2,444	$2,452	$2,628	$2,736	$2,878	$ 3,071
Honeywell Bull	0	0	0	0	0	0	0	0
IBM	0	0	0	0	0	0	0	0
ITT	$1,869	$1,877	$1,754	$1,657	$1,813	$ 983	$ 748	$ 790
Litton	$ 933	$ 988	$ 992	$ 952	$1,054	$ 861	$ 940	$ 997
Lockheed	0	0	0	0	0	0	0	0
3M	$ 265	$ 292	$ 300	$ 305	$ 319	$ 323	$ 353	$ 398
Martin Marietta	0	0	0	0	0	0	0	0
McDonnell Douglas	0	0	0	0	0	0	0	0
Motorola	$ 21	$ 22	$ 25	$ 32	$ 39	$ 40	$ 42	$ 44
NCR	0	0	0	0	0	0	0	0
Northern Telecom	0	0	0	0	0	0	0	0
Polaroid	0	0	0	0	0	0	0	0
Raytheon	0	0	0	0	0	0	0	0
RCA	0	0	0	0	0	0	0	0
Rockwell	$ 369	$ 384	$ 403	$ 424	$ 455	$1,184	$1,668	$ 1,735
Singer	$ 75	$ 80	$ 85	$ 72	$ 89	$ 108	$ 113	$ 104
Sperry	0	0	0	0	0	0	0	0
Sun Microsystems	0	0	0	0	0	0	0	0
Tandy	0	0	0	0	0	0	0	0
Tektronix	$ 504	$ 508	$ 568	$ 527	$ 564	$ 615	$ 583	$ 618
Teradyne	$ 151	$ 145	$ 178	$ 253	$ 403	$ 338	$ 291	$ 317
Texas Instruments	0	0	0	0	0	0	0	0
TRW	0	0	0	0	0	0	0	0
Unisys	0	0	0	0	0	0	0	0
United Technologies	0	0	0	0	0	0	0	0
Varian	$ 327	$ 358	$ 369	$ 403	$ 544	$ 590	$ 472	$ 531
Westinghouse	0	0	0	0	0	0	0	0
Xerox	0	0	0	0	0	0	0	0
Zenith	0	0	0	0	0	0	0	0

Source: Dataquest
October 1988

Consumer Revenue
(Millions of Dollars)

Company	1980	1981	1982	1983	1984	1985	1986	1987
Allied-Signal	0	0	0	0	0	0	0	0
Apollo	0	0	0	0	0	0	0	0
Apple	0	0	0	0	0	0	0	0
Applied Materials	0	0	0	0	0	0	0	0
AT&T	0	0	0	0	0	0	0	0
Burroughs	0	0	0	0	0	0	0	0
Commodore	$ 11	$ 8	$ 4	0	0	0	0	0
Compaq Computers	0	0	0	0	0	0	0	0
Control Data	0	0	0	0	0	0	0	0
Data General	0	0	0	0	0	0	0	0
Digital Equipment	0	0	0	0	0	0	0	0
Eastman Kodak	$1,069	$1,117	$1,180	$1,042	$1,023	$1,126	$1,242	$1,386
Eaton Corporation	0	0	0	0	0	0	0	0
E-Systems	0	0	0	0	0	0	0	0
GCA	0	0	0	0	0	0	0	0
General Electric	$4,274	$4,460	$3,973	$4,246	$4,853	$5,549	$7,144	$7,746
GM Hughes Electronics	0	0	0	0	0	0	0	0
GTE	0	0	0	0	0	0	0	0
Harris	0	0	0	0	0	0	0	0
Hewlett-Packard	0	0	0	0	0	0	0	0
Honeywell	0	0	0	0	0	0	0	0
Honeywell Bull	0	0	0	0	0	0	0	0
IBM	0	0	0	0	0	0	0	0
ITT	0	0	0	0	0	0	0	0
Litton	$ 173	$ 189	$ 166	$ 167	$ 248	$ 240	$ 190	0
Lockheed	0	0	0	0	0	0	0	0
3M	0	0	0	0	0	0	0	0
Martin Marietta	0	0	0	0	0	0	0	0
McDonnell Douglas	0	0	0	0	0	0	0	0
Motorola	$ 9	$ 9	$ 11	$ 13	$ 16	$ 17	$ 18	$ 19
NCR	0	0	0	0	0	0	0	0
Northern Telecom	0	0	0	0	0	0	0	0
Polaroid	$ 290	$ 284	$ 259	$ 251	$ 254	$ 259	$ 326	$ 330
Raytheon	$ 129	$ 128	$ 113	$ 142	$ 159	$ 157	$ 175	$ 181
RCA	$1,180	$1,580	$1,390	$1,630	$1,950	$1,850	0	0
Rockwell	0	0	0	0	0	0	0	0
Singer	0	0	0	0	0	0	0	0
Sperry	0	0	0	0	0	0	0	0
Sun Microsystems	0	0	0	0	0	0	0	0
Tandy	$ 881	$ 985	$ 896	$ 983	$1,067	$1,186	$1,363	$1,540
Tektronix	0	0	0	0	0	0	0	0
Teradyne	0	0	0	0	0	0	0	0
Texas Instruments	0	0	0	0	0	0	0	0
TRW	0	0	0	0	0	0	0	0
Unisys	0	0	0	0	0	0	0	0
United Technologies	0	0	0	0	0	0	0	0
Varian	0	0	0	0	0	0	0	0
Westinghouse	0	0	0	0	0	0	0	0
Xerox	0	0	0	0	0	0	0	0
Zenith	$1,003	$1,041	$ 939	$ 923	$1,062	$1,062	$1,154	$1,026

Source: Dataquest
October 1988

Military Revenue
(Millions of Dollars)

Company	1980	1981	1982	1983	1984	1985	1986	1987
Allied-Signal	$ 641	$ 734	$ 745	$ 815	$ 850	$1,250	$1,888	$1,999
Apollo	0	0	0	0	0	0	0	0
Apple	0	0	0	0	0	0	0	0
Applied Materials	0	0	0	0	0	0	0	0
AT&T	0	0	0	0	0	0	420	460
Burroughs	0	0	0	0	0	0	0	0
Commodore	0	0	0	0	0	0	0	0
Compaq Computer	0	0	0	0	0	0	0	0
Control Data	0	0	0	0	0	0	0	0
Data General	0	0	0	0	0	0	0	0
Digital Equipment	0	0	0	0	0	0	0	0
Eastman Kodak	0	0	0	0	0	0	0	0
Eaton Corporation	$ 197	$ 201	$ 300	$ 420	$ 615	$ 979	$1,052	$ 917
E-Systems	$ 362	$ 489	$ 623	$ 705	$ 733	$ 819	$1,011	$1,067
GCA	0	0	0	0	0	0	0	0
General Electric	$1,549	$1,878	$2,079	$2,237	$2,509	$3,085	$4,318	$5,262
GM Hughes Electronics	0	0	0	0	0	0	0	0
GTE	$ 597	$ 634	$ 707	$ 736	$ 719	$ 750	$ 795	$1,050
Harris	$ 263	$ 307	$ 399	$ 529	$ 630	$ 790	$ 828	$ 793
Hewlett-Packard	0	0	0	0	0	0	0	0
Honeywell	$ 997	$1,103	$1,258	$1,463	$1,530	$1,807	$2,037	$3,105
Honeywell Bull	0	0	0	0	0	0	0	0
IBM	$ 555	$ 617	$ 737	$1,110	$1,412	$1,766	$1,821	$1,925
ITT	$ 703	$ 797	$ 992	$1,020	$1,213	$1,414	$1,279	$1,279
Litton	$ 741	$ 977	$ 996	$1,338	$1,588	$1,666	$1,736	$2,007
Lockheed	$1,802	$2,196	$2,673	$2,776	$3,735	$4,783	$5,188	$5,717
3M	0	0	0	0	0	0	0	0
Martin Marietta	$1,062	$1,474	$1,668	$1,775	$2,156	$2,453	$2,775	$2,960
McDonnell Douglas	$ 459	$ 559	$ 556	$ 618	$ 736	$ 871	$1,115	$1,338
Motorola	$ 227	$ 236	$ 245	$ 369	$ 441	$ 496	$ 526	$ 540
NCR	0	0	0	0	0	0	0	0
Northern Telecom	0	0	0	0	0	0	0	0
Polaroid	0	0	0	0	0	0	0	0
Raytheon	$1,649	$1,946	$2,160	$2,614	$2,959	$3,355	$3,888	$4,312
RCA	$ 748	$ 896	$1,048	$1,299	$1,442	$1,597	0	$ 0
Rockwell	$1,243	$1,267	$1,331	$1,458	$1,678	$2,041	$2,188	$2,175
Singer	$ 661	$ 781	$ 892	$1,011	$1,111	$1,211	$1,370	$1,509
Sperry	$ 695	$ 885	$ 913	$ 831	$ 985	$1,571	0	$ 0
Sun Microsystems	0	0	0	0	0	0	0	0
Tandy	0	0	0	0	0	0	0	0
Tektronix	0	0	0	0	0	0	0	0
Teradyne	0	0	0	0	0	0	0	0
Texas Instruments	$ 738	$ 876	$1,059	$1,204	$1,392	$1,458	$1,698	$1,967
TRW	$1,003	$1,202	$1,253	$1,479	$1,551	$1,642	$1,780	$2,019
Unisys	0	0	0	0	0	0	0	0
United Technologies	$ 523	$ 684	$ 879	$ 975	$1,163	$1,283	$1,479	$1,701
Varian	0	0	0	0	0	0	0	0
Westinghouse	$ 810	$ 912	$1,524	$1,561	$1,640	$2,033	$2,361	$2,563
Xerox	0	0	0	0	0	0	0	0
Zenith	0	0	0	0	0	0	0	0

Source: Dataquest
October 1988

Transportation Revenue
(Millions of Dollars)

Company	1980	1981	1982	1983	1984	1985	1986	1987
Allied-Signal	$ 200	$ 218	$ 225	$ 237	$ 263	$ 205	$ 287	$ 555
Apollo	0	0	0	0	0	0	0	0
Apple	0	0	0	0	0	0	0	0
Applied Materials	0	0	0	0	0	0	0	0
AT&T	0	0	0	0	0	0	0	0
Burroughs	0	0	0	0	0	0	0	0
Commodore	0	0	0	0	0	0	0	0
Compaq Computers	0	0	0	0	0	0	0	0
Control Data	0	0	0	0	0	0	0	0
Data General	0	0	0	0	0	0	0	0
Digital Equipment	0	0	0	0	0	0	0	0
Eastman Kodak	0	0	0	0	0	0	0	0
Eaton Corporation	0	0	0	0	0	0	$ 15	$ 17
E-Systems	0	0	0	0	0	0	0	0
GCA	0	0	0	0	0	0	0	0
General Electric	0	0	0	0	0	0	0	0
GM Hughes Electronics	0	0	0	0	0	$3,061	$3,180	$3,216
GTE	0	0	0	0	0	0	0	0
Harris	0	0	0	0	0	0	0	0
Hewlett-Packard	0	0	0	0	0	0	0	0
Honeywell	0	0	0	0	0	0	0	0
Honeywell Bull	0	0	0	0	0	0	0	0
IBM	0	0	0	0	0	0	0	0
ITT	$ 735	$ 735	$ 730	$ 786	$ 823	$ 784	$1,014	$1,219
Litton	0	0	0	0	0	0	0	0
Lockheed	0	0	0	0	0	0	0	0
3M	0	0	0	0	0	0	0	0
Martin Marietta	0	0	0	0	0	0	0	0
McDonnell Douglas	0	0	0	0	0	0	0	0
Motorola	$ 201	$ 203	$ 223	$ 250	$ 294	$ 288	$ 302	$ 314
NCR	0	0	0	0	0	0	0	0
Northern Telecom	0	0	0	0	0	0	0	0
Polaroid	0	0	0	0	0	0	0	0
Raytheon	0	0	0	0	0	0	0	0
RCA	0	0	0	0	0	0	0	0
Rockwell	0	0	0	0	0	0	0	0
Singer	0	0	0	0	0	0	0	0
Sperry	0	0	0	0	0	0	0	0
Sun Microsystems	0	0	0	0	0	0	0	0
Tandy	0	0	0	0	0	0	0	0
Tektronix	0	0	0	0	0	0	0	0
Teradyne	0	0	0	0	0	0	0	0
Texas Instruments	0	0	0	0	0	0	0	0
TRW	$ 920	$ 888	$ 806	$ 837	$ 935	$ 977	$1,077	$1,224
Unisys	0	0	0	0	0	0	0	0
United Technologies	$ 487	$ 523	$ 500	$ 625	$ 750	$ 585	$ 601	$ 676
Varian	0	0	0	0	0	0	0	0
Westinghouse	0	0	0	0	0	0	0	0
Xerox	0	0	0	0	0	0	0	0
Zenith	0	0	0	0	0	0	0	0

Source: Dataquest
October 1988

Forecast

Electronic Equipment Forecast

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

- Overview--Electronic Equipmnt Forecast
- Electronic Equipment Forecast

NOTE: The arrow symbol indicates the latest document(s) correct location behind this subject tab.

Overview—Electronic Equipment Forecast

This section presents the methodology used in structuring the forecast data on North American electronic equipment production, describes the organization of the tables, and provides the complete equipment database.

METHODOLOGY

The Electronic Equipment Forecast provides detailed information on the estimated production of electronic equipment in North America for the years 1983 through 1994. This set of tables is the second of two major databases upon which the forecast of semiconductor consumption by application market is based.

The equipment shipment data presented here are used in conjunction with input/output ratios to generate semiconductor consumption estimates by application market. (For a more in-depth discussion on this subject, see the Input/Output Ratios section behind the tab entitled "Introduction.")

The first database, located behind the tab entitled "Company Electronic Equipment Revenue" presents the electronic equipment revenue of various electronic equipment manufacturers. These data provide historical trend information on North American equipment manufacturers and serve as an important input for developing the I/O ratios that we use in our analysis.

Within SAM, Dataquest uses the term "North American shipments" to refer to the value of equipment *produced* in North America. In this context, "shipments" does not refer to the value of products consumed or purchased within the U.S. market.

Data reflecting production in North America are used in this database on the assumption that North American regional semiconductor consumption is more accurately forecast based on the current production of North American electronic equipment and the forecast growth rates of individual equipment types. Much of the currently available data on semiconductor consumption by application market were obtained through surveys of semiconductor manufacturers, and this tends to give a view one step removed from the geographic markets. These latter data indicate the percentage of a semiconductor manufacturer's sales by application area, such as data processing or industrial, but do not indicate in what geographical areas the sales were made, or if they were to North American, Far Eastern, or Western European equipment manufacturers.

For example, typical breakouts of semiconductor consumption obtained from U.S. semiconductor manufacturers often indicate as much as 20 percent of the semiconductors going to consumer applications. When one looks at the percentage of North American-manufactured electronic equipment that is of a consumer type, one sees a very different picture. Dataquest estimates that, although there is a large and volatile consumer electronic equipment market in the United States, consumer electronics account for less than 10 percent of the total electronic equipment produced by North American manufacturers.

North American production statistics are gathered from a variety of sources. The major components of the database are Dataquest's Industry Services and the U.S. Department of Commerce Current Industrial Reports. Other sources include industry contacts, trade association data, and foreign government data.

Dataquest's Industry Services report equipment revenue in terms of factory revenue. Because many of the I/O ratios are developed from information on North American manufacturers' equipment revenue and semiconductor consumption, they may not reflect actual end-user cost due to the variety of potential distribution channels and distributor discounts. For example, revenue reported by a small computer manufacturer that sells to a retailer such as Computerworld may not reflect the actual end-user cost of the equipment, and the I/O ratios derived for that company would be overstated. At present, an informal look into this area indicates that the actual differences in I/Os developed when taking into account the range of companies that have lengthy distribution channels balanced compared with those that sell direct did not significantly impact the long-term forecast of semiconductors consumed.

ORGANIZATION OF THE ELECTRONIC EQUIPMENT FORECAST TABLES

The equipment forecast section contains a series of tables presenting the current and forecast shipments of electronic equipment produced in North America, by application market segment and by individual type of equipment. The first table in the series is an application market segment overview. The overview table presents a condensed version of each of the six segments: data processing, communications, industrial, consumer, military, and transportation. For each segment, the major equipment subcategories are shown. For example, communications has five subsegments: customer premises, public telecommunication, radio, broadcast and studio, and other.

The segment overview is followed by detailed tables—one for each of the six segments. For example, the communications segment has its own table, with the subsegments broken down into detailed equipment types and accompanied by their respective forecasts. To provide flexibility, all equipment types are presented as line items. Where possible, as in the case of medical electronic equipment in the industrial segment, we have supplied subtotals that make it easy to extract and relocate particular equipment types. Line-item values and subtotals are provided for the convenience of notebook users who may require more than six segments, or who need to reconfigure any of the segments to meet individual market segmentation requirements.

The percent growth in equipment in 1990 as well as the CAGR from 1989 through 1994 are calculated in the detail tables. A discussion of the overall assumptions made in developing Dataquest's entire analysis of semiconductor consumption by application market, including segmentation and definitions of specific equipment types, is located behind the Introduction tab of this binder.

Electronic Equipment Forecast

Table 1a

North American Electronic Equipment Production
Segment Overview History
(Millions of Dollars)

Equipment Type	1983	1984	1985	1986	1987	1988	1989
Computers	37,365	49,449	55,563	56,479	62,788	68,769	74,757
Data Storage/ Subsystems (Total)	5,711	7,388	9,598	11,792	11,882	16,120	17,998
Data Storage/Subsystems (Net)	5,711	7,338	9,598	11,792	11,082	13,200	14,940
Terminals	3,247	3,662	6,781	3,607	3,448	3,110	2,584
Input/Output	7,112	7,649	7,348	7,543	9,216	10,541	11,336
Dedicated Systems	4,836	5,546	5,829	5,404	5,315	5,375	5,324
Data Processing	58,271	73,644	85,119	84,825	91,849	100,995	108,941
Premise Telecom Equipment	6,513	7,681	8,623	9,124	9,940	11,046	12,517
Public Telecommunications	4,511	5,117	5,886	6,144	6,336	6,887	7,175
Mobile Communications Equip.	3,118	4,073	4,399	4,712	5,392	5,985	6,418
Broadcast & Studio	1,415	1,436	1,467	1,492	1,780	1,965	2,145
Other Telecom	892	1,174	1,544	1,442	1,541	1,600	1,660
Communications	16,449	19,481	21,919	22,914	24,989	27,483	29,915
Security/Energy Management	1,997	1,960	1,967	2,069	2,211	2,393	2,506
Manufacturing Systems	10,027	12,712	13,182	12,781	13,380	15,200	16,286
Instrumentation	5,607	6,461	6,571	6,570	7,180	7,774	8,122
Medical Equipment	4,740	4,880	4,759	5,002	5,345	5,785	6,117
Civil Aerospace	1,764	5,763	6,454	6,906	6,930	7,116	8,149
Other Industrial	3,456	3,889	4,102	4,364	4,777	5,356	5,719
Industrial	27,591	35,665	37,035	37,692	39,823	43,624	46,899
Audio	270	246	252	269	269	279	285
Video	4,969	5,308	5,284	5,232	5,522	5,628	5,749
Personal Electronics	1,048	473	331	235	249	241	239
Appliances	8,942	10,172	10,889	11,673	12,672	12,830	13,147
Other Consumer	509	647	810	897	945	992	1,037
Consumer	15,738	16,846	17,566	18,306	19,657	19,970	20,457
Military	0	0	47,300	49,370	50,932	51,063	51,727
Transportation	5,547	7,441	8,480	9,580	10,199	10,744	11,292
Total	123,596	153,077	217,419	222,687	237,449	253,879	269,231

Source: Dataquest March 1990

Table 1b

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

Equipment Type	Actual 1989	1990	1991	Estimated 1992	1993	1994	CAGR 1989-1990	CAGR 1989-1994
Computers	74,757	80,892	88,073	96,980	105,998	115,910	8.2%	9.2%
Data Storage/ Subsystems (Total)	17,998	19,736	20,254	21,262	23,077	24,144	9.7%	6.1%
Data Storage/ Subsystems (Net)	14,940	16,410	16,545	16,913	17,979	18,273	9.8%	4.1%
Terminals	2,584	2,081	1,712	1,446	1,238	1,173	(19.5%)	(14.6%)
Input/Output	11,336	12,281	13,287	14,339	15,560	17,034	8.3%	8.5%
Dedicated Systems	5,324	5,333	5,481	5,194	5,137	5,159	0.2%	(0.6%)
Data Processing	108,941	116,997	125,098	134,872	145,912	157,549	7.4%	7.7%
Premise Telecom Equipment	12,517	13,866	15,102	16,116	17,137	19,530	10.8%	9.3%
Public Telecommunications	7,175	7,590	8,019	8,870	9,666	10,328	5.8%	7.6%
Mobile Communications Equipment	6,418	6,748	7,083	7,400	7,746	8,092	5.1%	4.7%
Broadcast & Studio	2,145	2,315	2,465	2,615	2,765	2,915	7.9%	6.3%
Other Telecom	1,660	1,720	1,790	1,860	1,930	2,000	3.6%	3.8%
Communications	29,915	32,239	34,459	36,861	39,244	42,865	7.8%	7.5%
Security/Energy Management	2,506	2,639	2,822	3,020	3,203	3,397	5.3%	6.3%
Manufacturing Systems	16,286	16,965	18,538	20,106	21,484	22,976	4.2%	7.1%
Instrumentation	8,122	8,436	9,142	9,683	10,136	10,614	3.9%	5.5%
Medical Equipment	6,117	6,485	6,896	7,171	7,530	7,916	6.0%	5.3%
Civil Aerospace	8,149	9,411	10,807	12,228	13,694	15,347	15.5%	13.5%
Other Industrial	5,719	6,053	6,537	6,991	7,467	7,980	5.8%	6.9%
Idustrial	46,899	49,989	54,742	59,199	63,514	68,230	6.6%	7.8%
Audio	285	292	299	306	311	318	2.5%	2.2%
Video	5,749	5,864	6,014	6,206	6,432	6,708	2.0%	3.1%
Personal Electronics	239	240	241	239	239	239	0.4%	0
Appliances	13,147	13,512	13,918	14,317	14,650	14,950	2.8%	2.6%
Other Consumer	1,037	1,078	1,126	1,171	1,157	1,157	4.0%	2.2%
Consumer	20,457	20,986	21,598	22,239	22,789	23,372	2.6%	2.7%
Military	51,727	52,918	54,263	55,845	57,866	59,998	2.3%	3.0%
Transportation	11,292	11,828	12,897	13,952	14,836	15,449	4.7%	6.5%
Total	269,231	284,957	303,057	322,968	344,161	367,463	5.8%	6.4%

Source: Dataquest March 1990

Table 2a

North American Electronic Equipment Production Data Processing History (Millions of Dollars)

ESTIMATE

Equipment Type	1983	1984	1985	1986	1987	1988	1989
Corporate Resource	11,664	12,956	12,968	13,530	15,168	15,718	16,540
Business Unit	5,184	5,682	6,155	7,121	7,369	7,811	8,372
Large Department	6,287	7,030	7,475	7,139	6,970	8,033	8,456
Work Group & Small Dept.	7,019	10,061	11,708	12,303	13,391	14,346	15,216
Workstation	193	558	1,116	1,835	2,850	3,900	5,398
Personal Computer	7,018	13,162	16,141	14,551	17,040	18,961	20,775
Computers	37,365	49,449	55,563	56,479	62,788	68,769	74,757
14 Inch	2,248	3,139	3,223	3,891	4,239	4,680	4,593
8-10 Inch	943	1,188	1,630	1,927	2,220	2,623	3,060
5.25 Inch	681	1,299	1,760	2,611	2,783	3,185	3,192
3-4 Inch	7	48	96	322	969	1,805	2,990
Fixed Disk (Total)	3,879	5,674	6,709	8,751	10,211	12,293	13,835
Fixed Disk (Sold to OEMs)	0	0	0	0	(2,800)	(2,920)	(3,058)
Fixed Disk (Net)	3,879	5,674	6,709	8,751	7,411	9,373	10,777
WORM Optical Disk Drive	0	0	21	56	88	96	101
Erasable Optical Disk Drive	0	0	0	0	0	5	19
Optical Disk	0	0	21	56	88	101	120
Tape Drive	1,832	1,664	2,868	2,985	3,583	3,726	4,043
Data Storage/Subsystems (Total)	5,711	7,338	9,598	11,792	13,882	16,120	17,998
Data Storage/Subsystems (Net)	5,711	7,338	9,598	11,792	11,082	13,200	14,940

Source: Dataquest March 1990

Table 2b

North American Electronic Equipment Production Data Processing Forecast (Millions of Dollars)

Equipment Type	Actual 1989	1990	1991	Estimated 1992	1993	1994	CAGR 1989-1990	CAGR 1989-1994
Corporate Resource	16,540	17,335	18,420	19,617	21,030	22,481	4.8%	6.3%
Business Unit	8,372	8,966	9,712	10,528	11,454	12,428	7.1%	8.2%
Large Department	8,456	8,972	9,501	10,052	10,575	11,135	6.1%	5.7%
Work Group & Small Dept.	15,216	15,946	16,696	17,464	18,232	18,943	4.8%	4.5%
Workstation	5,398	7,160	9,030	11,155	13,322	16,653	32.6%	25.3%
Personal Computer	20,775	22,513	24,714	28,164	31,385	34,270	8.4%	10.5%
Computers	74,757	80,892	88,073	96,980	105,998	115,910	8.2%	9.2%
14 Inch	4,593	4,427	4,106	3,861	3,920	3,854	(3.6%)	(3.4%)
8-10 Inch	3,060	3,325	3,305	3,031	2,702	2,390	8.7%	(4.8%)
5.25 Inch	3,192	3,146	2,788	2,662	2,608	2,486	(1.4%)	(4.9%)
3-4 Inch	2,990	4,209	5,156	6,033	7,195	7,696	40.8%	20.8%
Fixed Disk (Total)	13,835	15,107	15,355	15,587	16,425	16,426	9.2%	3.5%
Fixed Disk (Sold to OEMs)	(3,058)	(3,326)	(3,709)	(4,349)	(5,098)	(5,871)	8.8%	13.9%
Fixed Disk (Net)	10,777	11,781	11,646	11,238	11,327	10,555	9.3%	(0.4%)
WORM Optical Disk Drive	101	141	198	363	552	707	39.6%	47.6%
Erasable Optical Disk Drive	19	81	194	407	808	1,349	326.3%	134.6%
Optical Disk	120	222	392	770	1,360	2,056	85.0%	76.5%
Tape Drive	4,043	4,407	4,507	4,905	5,292	5,662	9.0%	7.0%
Data Storage/ Subsystems (Total)	17,998	19,736	20,254	21,262	23,077	24,144	9.7%	6.1%
Data Storage/ Subsystems (Net)	14,940	16,410	16,545	16,913	17,979	18,273	9.8%	4.1%

Source: Dataquest March 1990

Table 2c

North American Electronic Equipment Production
Data Processing History
(Millions of Dollars)

Equipment Type	1983	1984	1985	1986	1987	1988	1989
Minicomputer-Based	1,357	1,490	1,237	928	954	1,098	835
Non-IBM, Protocol Specific	172	202	171	95	85	99	73
IBM 3270	810	909	1,042	873	802	414	358
Host/Vendor-Independent	421	437	431	447	480	474	402
Alphanumeric	2,760	3,038	2,881	2,343	2,321	2,085	1,668
Graphics Terminals	487	624	3,900	1,264	1,127	1,025	916
Terminals	3,247	3,662	6,781	3,607	3,448	3,110	2,584
Remote Batch, Job Entry and Output	60	122	275	276	270	290	301
Key Entry Equipment	102	80	70	57	43	30	15
Media-to-Media Data Conversion	102	135	143	140	147	165	180
Magnetic Ink Regcognition	91	79	60	33	28	18	12
Optical Scanning Equipment	195	253	253	274	320	368	412
Computer Plotters	232	241	466	477	525	588	592
Impact, Dot Matrix	2,790	2,299	2,171	2,262	3,016	3,090	3,127
Impact, Fully Formed	1,044	1,033	381	46	162	124	100
Nonimpact, Direct Thermal	120	175	70	46	32	24	17
Nonimpact, Thermal Transfer	0	33	214	116	120	53	52
Nonimpact, Ink-Jet	32	109	97	71	115	281	354
Serial Printers	3,986	3,649	2,933	2,541	3,445	3,572	3,650
Impact, Dot Matrix	332	420	521	611	599	632	660
Impact, Fully Formed	1,423	1,471	1,439	1,370	1,024	976	899
Nonimpact, Direct Thermal	13	5	2	1	0	0	0
Nonimpact, Thermal Transfer	3	7	12	18	29	44	55
Line Printers	1,771	1,903	1,974	2,000	1,652	1,652	1,614
Nonimpact, Plain Paper	573	1,187	1,174	1,745	2,786	3,858	4,560
Page Printers	573	1,187	1,174	1,745	2,786	3,858	4,560
Input/Output	7,112	7,649	7,348	7,543	9,216	10,541	11,336

Source: Dataquest March 1990

Table 2d

North American Electronic Equipment Production Data Processing Forecast (Millions of Dollars)

Equipment Type	Actual 1989	1990	1991	Estimated 1992	1993	1994	CAGR 1989-1990	CAGR 1989-1994
Minicomputer-Based	835	602	431	291	176	162	(27.9%)	(28.0%)
Non-IBM, Protocol Specific	73	46	29	18	8	6	(37.0%)	(39.3%)
IBM 3270	358	318	212	170	136	116	(11.2%)	(20.2%)
Host/Vendor-Independent	402	254	203	163	122	107	(36.8%)	(23.3%)
Alphanumeric	1,668	1,220	875	642	442	391	(26.9%)	(25.2%)
Graphics Terminals	916	861	837	804	796	782	(6.0%)	(3.1%)
Terminals	2,584	2,081	1,712	1,446	1,238	1,173	(19.5%)	(14.6%)
Remote Batch, Job Entry and Output	301	312	335	350	366	370	3.7%	4.2%
Key Entry Equipment	15	10	8	5	3	2	(33.3%)	(33.2%)
Media-to-Media Data Conversion	180	175	169	162	155	152	(2.8%)	(3.3%)
Magnetic Ink Regcognition	12	10	8	6	4	3	(16.7%)	(24.2%)
Optical Scanning Equipment	412	466	531	616	708	794	13.1%	14.0%
Computer Plotters	592	603	614	622	628	631	1.9%	1.3%
Impact, Dot Matrix	3,127	3,063	2,910	2,650	2,355	2,070	(2.0%)	(7.9%)
Impact, Fully Formed	100	80	54	51	43	36	(20.0%)	(18.5%)
Nonimpact, Direct Thermal	17	11	10	9	7	4	(35.3%)	(25.1%)
Nonimpact, Thermal Transfer	52	51	50	49	48	46	(1.9%)	(2.4%)
Nonimpact, Ink-Jet	354	489	695	986	1,344	1,765	38.1%	37.9%
Serial Printers	3,650	3,694	3,719	3,745	3,797	3,921	1.2%	1.4%
Impact, Dot Matrix	660	669	669	654	621	595	1.4%	(2.1%)
Impact, Fully Formed	899	833	781	716	665	630	(7.3%)	(6.9%)
Nonimpact, Direct Thermal	0	0	0	0	0	0	N/M	N/M
Nonimpact, Thermal Transfer	55	59	58	63	68	71	7.3%	5.2%
Line Printers	1,614	1,561	1,508	1,433	1,354	1,296	(3.3%)	(4.3%)
Nonimpact, Plain Paper	4,560	5,450	6,395	7,400	8,545	9,865	19.5%	16.7%
Page Printers	4,560	5,450	6,395	7,400	8,545	9,865	19.5%	16.7%
Input/Output	11,336	12,281	13,287	14,339	15,560	17,034	8.3%	8.5%

N/M = Not Meaningful

Source: Dataquest March 1990

Table 2e

North American Electronic Equipment Production
Data Processing History
(Millions of Dollars)

Equipment Type	1983	1984	1985	1986	1987	1988	1989
PC	0	0	0	0	0	0	19
Segment 1	150	141	90	137	153	142	129
Segment 2	20	49	120	86	83	102	113
Segment 3	90	173	155	187	191	177	163
Segment 4	48	52	22	229	259	280	302
Segment 5	836	951	957	498	677	681	697
Segment 6	199	208	313	546	586	618	643
Copiers and Duplicators	1,343	1,574	1,657	1,683	1,949	2,000	2,066
Electronic Calculators	188	174	151	149	152	158	155
Dictating, Transcribing	33	19	15	12	9	8	6
Portable and Compact	0	86	162	398	440	462	501
Low-End, Full-Size	40	85	189	162	155	126	100
Midrange, Full-Size	36	40	45	44	4	4	0
Hign-End, Full-Size	141	252	292	355	320	265	253
Display & Monitor Display	0	39	64	70	83	88	81
Electronic Typewriters	217	502	752	1,029	1,002	945	935
Standalone	515	551	400	137	17	6	2
Shared Systems	888	963	754	232	42	18	3
WP File Servers	0	0	384	108	22	8	1
Word Processors	1,403	1,514	1,538	477	81	32	6
Office Automation	3,184	3,783	4,113	3,350	3,193	3,143	3,168
Check-Handling Systems	58	68	111	137	152	170	180
Funds Transfer Terminals	307	373	307	288	321	343	338
Banking Systems	365	441	418	425	473	513	518
Point-of-Sale Terminals	454	491	414	510	515	530	478
Cash Registers	77	27	45	16	13	11	9
Mailing, Letter Handling, Addressing	508	562	596	793	809	858	818
Other Specialized Terminals	248	242	243	310	312	320	333
Dedicated Systems	4,836	5,546	5,829	5,404	5,315	5,375	5,324
Data Processing	58,271	73,644	85,119	84,825	91,849	100,995	108,941

Source: Dataquest
March 1990

Table 2f

North American Electronic Equipment Production
Data Processing Forecast
(Millions of Dollars)

Equipment Type	Actual 1989	1990	1991	Estimated 1992	1993	1994	CAGR 1989-1990	CAGR 1989-1994
PC	19	22	26	29	36	39	15.8%	15.5%
Segment 1	129	117	113	108	110	113	(9.3%)	(2.6%)
Segment 2	113	128	153	149	147	146	13.3%	5.3%
Segment 3	163	149	139	131	125	118	(8.6%)	(6.3%)
Segment 4	302	324	338	370	405	436	7.3%	7.6%
Segment 5	697	642	600	525	450	411	(7.9%)	(10.0%)
Segment 6	643	687	700	525	480	455	6.8%	(6.7%)
Copiers and Duplicators	2,066	2,069	2,069	1,837	1,753	1,718	0.1%	(3.6%)
Electronic Calculators	155	152	149	146	144	143	(1.9%)	(1.6%)
Dictating, Transcribing	6	5	4	4	3	3	(16.7%)	(12.9%)
Portable and Compact	501	487	458	441	427	414	(2.8%)	(3.7%)
Low-End, Full-Size	100	77	51	44	38	34	(23.0%)	(19.4%)
Midrange, Full-Size	0	0	0	0	0	0	N/M	N/M
Hign-End, Full-Size	253	216	180	112	70	53	(14.6%)	(26.8%)
Display & Monitor Display	81	69	66	50	40	32	(14.8%)	(17.0%)
Electronic Typewriters	935	849	755	647	575	533	(9.2%)	(10.6%)
Standalone	2	0	0	0	0	0	(100.0%)	(100.0%)
Shared Systems	3	0	0	0	0	0	(100.0%)	(100.0%)
WP File Servers	1	0	0	0	0	0	(100.0%)	(100.0%)
Word Processors	6	0	0	0	0	0	(100.0%)	(100.0%)
Office Automation	3,168	3,075	2,977	2,634	2,475	2,397	(2.9%)	(5.4%)
Check-Handling Systems	180	198	209	215	219	228	10.0%	4.8%
Funds Transfer Terminals	338	365	390	415	448	476	8.0%	7.1%
Banking Systems	518	563	599	630	667	704	8.7%	6.3%
Point-of-Sale Terminals	478	497	574	620	687	742	4.0%	9.2%
Cash Registers	9	5	3	2	1	1	(44.4%)	(35.6%)
Mailing, Letter Handling, Addressing	818	857	988	950	922	904	4.8%	2.0%
Other Specialized Terminals	333	336	340	358	385	411	0.9%	4.3%
Dedicated Systems	5,324	5,333	5,481	5,194	5,137	5,159	0.2%	(0.6%)
Data Processing	108,941	116,997	125,098	134,872	145,912	157,549	7.4%	7.7%

N/M = Not Meaningful

Source: Dataquest March 1990

Table 3a

North American Electronic Equipment Production Communications History (Millions of Dollars)

Equipment Type	1983	1984	1985	1986	1987	1988	1989
Facsimile	0	0	0	0	0	0	0
Video Teleconferencing	0	0	18	27	32	44	54
Telex	0	0	0	0	0	0	0
Videotex	0	0	0	0	0	0	0
Image & Text Communication Eqp.	0	0	18	27	32	44	54
300/1200 bps	203	242	258	205	88	70	58
2400 bps	165	191	230	283	207	226	238
4800 bps	170	190	210	220	145	113	96
9600 bps	277	303	339	401	650	622	597
14.4 Kbps	101	110	111	110	133	148	140
16.8 Kbps	0	4	8	10	13	13	14
19.2 Kbps	0	6	10	14	63	76	94
Modems	916	1,046	1,166	1,243	1,299	1,268	1,237
Statistical Multiplexers	245	289	303	319	258	193	184
Time-Division Multiplexers	0	0	0	0	0	0	0
T-1 Multiplexers	30	61	158	241	309	403	469
Front-End Processors	383	426	474	527	477	488	502
Data PBX	77	119	143	86	82	80	78
Data Network Management Sys.	0	0	0	43	61	0	0
DSU/CSU	36	70	72	86	101	119	136
Protocol Converters	75	140	154	160	161	164	164
Local Area Networks	150	326	593	913	1,630	2,580	3,774
Response	0	36	34	28	30	32	33
Modem Network Management	0	53	60	66	71	75	79
Matrix	0	50	58	62	64	68	71
Switch/Path	0	72	74	75	78	80	81
Analyers	0	91	96	102	106	108	113
Nodes	63	112	149	201	238	297	340
PADs	19	30	42	42	47	43	47
Switch Concentrator	2	6	11	19	27	0	0
Private Packet Data Switching	84	148	202	262	312	340	387
Public Packet Data Switching	0	0	0	0	0	0	0
Data Communication Equipment	1,996	2,927	3,587	4,213	5,039	5,998	7,308

Source: Dataquest March 1990

Table 3b

North American Electronic Equipment Production Communications Forecast (Millions of Dollars)

Equipment Type	Actual 1989	1990	1991	Estimated 1992	1993	1994	CAGR 1989-1990	CAGR 1989-1994
Facsimile	0	0	0	0	0	0	N/M	N/M
Video Teleconferencing	54	78	109	131	141	150	44.4%	22.7%
Telex	0	0	0	0	0	0	N/M	N/M
Videotex	0	0	0	0	0	0	N/M	N/M
Image & Text Communication Eqp.	54	78	109	131	141	150	44.4%	22.7%
300/1200 bps	58	43	26	17	12	12	(25.9%)	(27.0%)
2400 bps	238	240	215	190	184	184	0.8%	(5.0%)
4800 bps	96	84	74	63	54	54	(12.5%)	(10.9%)
9600 bps	597	546	510	459	431	431	(8.5%)	(6.3%)
14.4 Kbps	140	124	96	71	49	49	(11.4%)	(18.9%)
16.8 Kbps	14	13	10	7	5	5	(7.1%)	(18.6%)
19.2 Kbps	94	89	81	71	60	60	(5.3%)	(8.6%)
Modems	1,237	1,139	1,012	878	795	795	(7.9%)	(8.5%)
Statistical Multiplexers	184	169	150	130	110	90	(8.2%)	(13.3%)
Time-Division Multiplexers	0	0	0	0	0	0	N/M	N/M
T-1 Multiplexers	469	554	627	694	750	800	18.1%	11.3%
Front-End Processors	502	548	578	598	637	666	9.2%	5.8%
Data PBX	78	76	75	70	68	68	(2.6%)	(2.7%)
Data Network Management Sys.	0	0	0	0	0	0	N/M	N/M
DSU/CSU	136	156	178	200	234	265	14.7%	14.3%
Protocol Converters	164	153	143	140	135	130	(6.7%)	(4.5%)
Local Area Networks	3,774	4,959	6,084	7,020	7,857	9,828	31.4%	21.1%
Response	33	32	30	29	28	27	(3.0%)	(3.9%)
Modem Network Management	79	76	71	66	61	56	(3.8%)	(6.7%)
Matrix	71	74	76	78	80	82	4.2%	2.9%
Switch/Path	81	78	72	65	60	55	(3.7%)	(7.5%)
Analyers	113	119	126	136	144	153	5.3%	6.2%
Nodes	340	386	425	465	505	556	13.5%	10.3%
PADs	47	44	42	38	33	28	(6.4%)	(9.8%)
Switch Concentrator	0	0	0	0	0	0	N/M	N/M
Private Packet Data Switching	387	430	467	503	538	584	11.1%	8.6%
Public Packet Data Switching	0	0	0	0	0	0	N/M	N/M
Data Communication Equipment	7,308	8,563	9,689	10,607	11,497	13,599	17.2%	13.2%

N/M = Not Meaningful

Source: Dataquest March 1990

Table 3c

North American Electronic Equipment Production
Communications History
(Millions of Dollars)

Equipment Type	1983	1984	1985	1986	1987	1988	1989
1-40 Lines	93	97	97	130	139	147	150
41-100 Lines	425	447	461	495	529	536	551
101-400 Lines	703	732	727	800	777	800	792
401-1,000 Lines	495	548	564	553	546	535	522
>1,000 Lines	643	769	797	741	769	758	727
PBX Telephone Systems	2,359	2,593	2,646	2,719	2,760	2,776	2,742
Key Telephone Systems	1,304	1,293	1,101	984	866	810	808
Premise Switching Equipment	3,663	3,886	3,747	3,703	3,626	3,586	3,550
Voice Messaging	37	82	117	182	284	472	675
Interactive Voice Response Sys.	0	0	0	0	0	0	0
Call Accounting	182	193	201	243	243	268	282
Automatic Call Distributors	207	224	222	233	265	299	334
Call Processing Equipment	426	499	540	658	792	1,039	1,291
Telephones	0	0	285	200	168	126	82
Integrated Services Digital Network	0	0	0	0	0	0	0
Asynchronous	33	55	73	25	24	20	17
Synchronous	2	6	14	11	9	8	6
PC	6	6	62	23	1	1	0
Add-On	0	8	25	6	4	4	4
Integrated Voice/Data Workstations	41	75	174	65	38	33	27
Teleprinters	387	294	272	258	245	220	205
Answering Machines	0	0	0	0	0	0	0
Desktop Terminal Equipment	428	369	731	523	451	379	314
Premise Telecom Equipment	6,513	7,681	8,623	9,124	9,940	11,046	12,517

Source: Dataquest
March 1990

Table 3d

North American Electronic Equipment Production Communications Forecast (Millions of Dollars)

Equipment Type	Actual 1989	1990	1991	Estimated 1992	1993	1994	CAGR 1989-1990	CAGR 1989-1994
1-40 Lines	150	151	149	152	157	162	0.7%	1.6%
41-100 Lines	551	545	548	565	623	678	(1.1%)	4.2%
101-400 Lines	792	767	764	772	787	792	(3.2%)	0
401-1,000 Lines	522	519	502	502	502	502	(0.6%)	(0.8%)
>1,000 Lines	727	6 99	6 96	702	702	702	(3.9%)	(0.7%)
PBX Telephone Systems	2,742	2,681	2,659	2,693	2,771	2,836	(2.2%)	0.7%
Key Telephone Systems	808	780	754	731	710	690	(3.5%)	(3.1%)
Premise Switching Equipment	3,550	3,461	3,413	3,424	3,481	3,526	(2.5%)	(0.1%)
Voice Messaging	675	825	897	917	926	1,093	22.2%	10.1%
Interactive Voice Response System	0	0	0	0	0	0	N/M	N/M
Call Accounting	282	301	332	365	395	425	6.7%	8.5%
Automatic Call Distributors	334	383	431	488	548	620	14.7%	13.2%
Call Processing Equipment	1,291	1,509	1,660	1,770	1,869	2,138	16.9%	10.6%
Telephones	82	40	37	34	34	34	(51.2%)	(16.1%)
Integrated Services Digital Network	0	0	0	0	0	0	N/M	N/M
Asynchronous	17	15	13	11	9	7	(11.8%)	(16.3%)
Synchronous	6	5	4	3	2	1	(16.7%)	(30.1%)
PC	0	0	0	0	0	0	N/M	N/M
Add-On	4	5	5	6	6	7	25.0%	11.8%
Integrated Voice/Data Workstations	27	25	22	20	17	15	(7.4%)	(11.1%)
Teleprinters	205	190	172	130	98	68	(7.3%)	(19.8%)
Answering Machines	0	0	0	0	0	0	N/M	N/M
Desktop Terminal Equipment	314	255	231	184	149	117	(18.8%)	(17.9%)
Premise Telecom Equipment	12,517	13,866	15,102	16,116	17,137	19,530	10.8%	9.3%

N/M = Not Meaningful

Source: Dataquest March 1990

Table 3e

North American Electronic Equipment Production
Communications History
(Millions of Dollars)

Equipment Type	1983	1984	1985	1986	1987	1988	1989
Multiplex	658	727	812	912	942	1,377	1,507
Carrier System	1,088	1,217	1,372	1,431	1,555	1,689	1,843
Microwave Radio	339	368	404	438	482	480	482
Satellite Earth Station Eqp.	500	560	574	563	592	651	693
Satellite Communication Eqp.	500	560	574	563	592	651	693
Transmission Equipment	2,585	2,872	3,162	3,344	3,571	4,197	4,525
Central Office Switching Eqp.	1,926	2,245	2,724	2,800	2,765	2,690	2,650
Digital Access Cross-Connect System	0	0	0	0	0	0	0
Public Switching Equipment	1,926	2,245	2,724	2,800	2,765	2,690	2,650
Public Telecommunications	4,511	5,117	5,886	6,144	6,336	6,887	7,175
Cellular Telephones	114	326	422	499	723	890	923
Paging Equipment	0	0	0	0	0	0	0
PMR	641	895	908	793	1,160	1,415	1,650
Cordless Telephony	755	1,221	1,330	1,292	1,883	2,305	2,573
Mobile Radio Base Station Eqp.	188	199	217	354	327	350	375
Mobile Radio System Equipment	943	1,420	1,547	1,646	2,210	2,655	2,948
Broadcast Radio Receivers, Transmitter	1,391	1,678	1,953	2,001	1,927	1,925	1,900
Amateur Radio	3	3	5	5	9	10	10
Citizen's Band; Mobile & Base	3	3	5	5	9	10	10
Portable Radio Receivers, Transmitters	536	717	648	779	921	1,050	1,200
Radio Checkout Monitor, Evaluation, etc.	242	252	241	277	317	335	350
Comm. Antenna <890 MHz	0	0	0	0	0	0	0
Microwave Antenna >890 MHz	0	0	0	0	0	0	0
Mobile Communication Equipment	3,118	4,073	4,399	4,712	5,392	5,985	6,418

Source: Dataquest March 1990

Table 3f

North American Electronic Equipment Production
Communications Forecast
(Millions of Dollars)

Equipment Type	Actual 1989	1990	1991	Estimated 1992	1993	1994	CAGR 1989-1990	CAGR 1989-1994
Multiplex	1,507	1,577	1,653	1,757	1,998	2,144	4.6%	7.3%
Carrier System	1,843	2,010	2,200	2,415	2,664	2,912	9.1%	9.6%
Microwave Radio	482	491	505	527	539	550	1.9%	2.7%
Satellite Earth Station Eqp.	693	752	801	993	1,150	1,265	8.5%	12.8%
Satellite Communication Equipment	693	752	801	993	1,150	1,265	8.5%	12.8%
Transmission Equipment	4,525	4,830	5,159	5,692	6,351	6,871	6.7%	8.7%
Central Office Switching Equipment	2,650	2,760	2,860	3,178	3,315	3,457	4.2%	5.5%
Digital Access Cross-Connect System	0	0	0	0	0	0	N/M	N/M
Public Switching Equipment	2,650	2,760	2,860	3,178	3,315	3,457	4.2%	5.5%
Public Telecommunications	7,175	7,590	8,019	8,870	9,666	10,328	5.8%	7.6%
Cellular Telephones	923	953	988	1,005	1,051	1,097	3.3%	3.5%
Paging Equipment	0	0	0	0	0	0	N/M	N/M
PMR	1,650	1,800	1,950	2,100	2,250	2,400	9.1%	7.8%
Cordless Telephony	2,573	2,753	2,938	3,105	3,301	3,497	7.0%	6.3%
Mobile Radio Base Station Eqp.	375	400	425	450	475	500	6.7%	5.9%
Mobile Radio System Equipment	2,948	3,153	3,363	3,555	3,776	3,997	7.0%	6.3%
Broadcast Radio Receivers, Transmitter	1,900	1,900	1,900	1,900	1,900	1,900	0	0
Amateur Radio	10	10	10	10	10	10	0	0
Citizen's Band; Mobile & Base	10	10	10	10	10	10	0	0
Portable Radio Receivers, Transmitters	1,200	1,300	1,400	1,500	1,600	1,700	8.3%	7.2%
Radio Checkout Monitor, Evaluation, etc.	350	375	400	425	450	475	7.1%	6.3%
Comm. Antenna <890 MHz	0	0	0	0	0	0	N/M	N/M
Microwave Antenna >890 MHz	0	0	0	0	0	0	N/M	N/M
Mobile Communication Equipment	6,418	6,748	7,083	7,400	7,746	8,092	5.1%	4.7%

N/M = Not Meaningful

Source: Dataquest March 1990

Table 3g

North American Electronic Equipment Production
Communications History
(Millions of Dollars)

Equipment Type	1983	1984	1985	1986	1987	1988	1989
Audio Equipment	187	219	210	209	267	305	325
Video Equipment	461	496	509	527	641	710	800
Transmitters, RF Power Amps	111	107	135	122	124	125	125
Studio Transmitter Links	42	8	19	17	17	15	15
Cable TV Equipment	452	410	375	383	468	530	580
CCTV	99	109	125	141	165	180	200
Broadcast Transmitter Antenna	0	0	0	0	0	0	0
Other (Studio, Theater)	63	87	94	93	98	100	100
Broadcast & Studio	1,415	1,436	1,467	1,492	1,780	1,965	2,145
Intercomm. Equip Elec. Ampl.	176	213	172	195	221	230	250
Fiber Optic	275	254	529	568	701	755	800
Other (Laser, Infrared)	137	461	485	309	290	275	260
Light Communication System	412	715	1,014	877	991	1,030	1,060
Telemetering Systems	304	246	358	370	329	340	350
Other Telecom	892	1,174	1,544	1,442	1,541	1,600	1,660
Communications	16,449	19,481	21,919	22,914	24,989	27,483	29,915

Source: Dataquest
March 1990

Table 3h

North American Electronic Equipment Production Communications Forecast (Millions of Dollars)

Equipment Type	Actual 1989	1990	1991	Estimated 1992	1993	1994	CAGR 1989-1990	CAGR 1989-1994
Audio Equipment	325	350	375	400	425	450	7.7%	6.7%
Video Equipment	800	850	900	950	1,000	1,050	6.3%	5.6%
Transmitters, RF Power Amps	125	125	125	125	125	125	0	0
Studio Transmitter Links	15	15	15	15	15	15	0	0
Cable TV Equipment	580	650	700	750	800	850	12.1%	7.9%
CCTV	200	225	250	275	300	325	12.5%	10.2%
Broadcast Transmitter Antenna	0	0	0	0	0	0	N/M	N/M
Other (Studio, Theater)	100	100	100	100	100	100	0	0
Broadcast & Studio	2,145	2,315	2,465	2,615	2,765	2,915	7.9%	6.3%
Intercomm. Equip Elec. Ampl.	250	270	290	310	330	350	8.0%	7.0%
Fiber Optic	800	850	900	950	1,000	1,050	6.3%	5.6%
Other (Laser, Infrared)	260	250	250	250	250	250	(3.8%)	(0.8%)
Light Communication System	1,060	1,100	1,150	1,200	1,250	1,300	3.8%	4.2%
Telemetering Systems	350	350	350	350	350	350	0	0
Other Telecom	1,660	1,720	1,790	1,860	1,930	2,000	3.6%	3.8%
Communications	29,915	32,239	34,459	36,861	39,244	42,865	7.8%	7.5%

N/M = Not Meaningful

Source: Dataquest March 1990

Table 4a

North American Electronic Equipment Production
Industrial History
(Millions of Dollars)

Equipment Type	1983	1984	1985	1986	1987	1988	1989
Intrusion Detection	516	568	590	679	781	878	930
Fire Detection	364	477	431	427	436	473	509
Alarm Systems	880	1,045	1,021	1,106	1,217	1,351	1,439
Discrete Devices	537	548	565	582	599	622	636
MPU Load Programmers	26	19	20	23	26	29	32
Computerized Engy. Ctl. Sys.	554	348	361	358	369	391	399
Security/Energy Management	1,997	1,960	1,967	2,069	2,211	2,393	2,506
Semiconductor Production	945	1,795	1,598	1,199	1,258	1,914	2,157
ATE	1,188	1,300	1,422	1,609	1,694	1,974	2,047
General	3,654	4,445	4,548	4,503	4,818	5,203	5,431
Test Equipment	4,842	5,745	5,970	6,112	6,512	7,177	7,478
Process Control Systems	1,803	1,969	2,129	2,279	2,413	2,648	2,875
Programmable Machine Tools	677	740	921	767	754	815	892
Mech. Assembly Equipment	243	397	391	360	361	376	401
Plastic Process Machinery	567	779	604	588	621	645	699
Assembly	36	67	95	66	52	67	73
Material Handling/Loading	51	79	112	81	81	88	95
Painting	32	54	60	52	37	39	29
Spot Welding	33	61	106	85	61	55	48
Arc Welding	31	57	63	58	59	60	60
Machining, Other	49	62	56	37	28	29	44
Robot Systems	232	380	492	379	318	338	349
Guided Vehicles	40	130	160	117	117	130	142
Programmable Conveyors	323	378	450	409	436	474	511
Storage/Retrieval Systems	166	182	208	255	265	309	355
Programmable Monorails	20	36	65	138	137	160	185
Warehousing	160	170	181	173	183	209	236
Other	9	11	13	5	5	5	6
Automated Material Handling	718	907	1,077	1,097	1,143	1,287	1,435
Manufacturing Systems	10,027	12,712	13,182	12,781	13,380	15,200	16,286

Source: Dataquest
March 1990

Table 4b

North American Electronic Equipment Production
Industrial Forecast
(Millions of Dollars)

Equipment Type	Actual 1989	1990	1991	Estimated 1992	1993	1994	CAGR 1989-1990	CAGR 1989-1994
Intrusion Detection	930	999	1,069	1,140	1,223	1,312	7.4%	7.1%
Fire Detection	509	544	585	617	649	683	6.9%	6.0%
Alarm Systems	1,439	1,543	1,654	1,757	1,872	1,995	7.2%	6.7%
Discrete Devices	636	655	675	715	749	785	3.0%	4.3%
MPU Load Programmers	32	36	43	46	50	54	12.5%	11.2%
Computerized Engy. Ctl. Sys.	399	405	450	502	532	564	1.5%	7.2%
Security/Energy Management	2,506	2,639	2,822	3,020	3,203	3,397	5.3%	6.3%
Semiconductor Production	2,157	2,083	2,649	3,264	3,631	4,039	(3.4%)	13.4%
ATE	2,047	2,106	2,243	2,373	2,499	2,632	2.9%	5.2%
General	5,431	5,644	5,977	6,270	6,527	6,795	3.9%	4.6%
Test Equipment	7,478	7,750	8,220	8,643	9,026	9,426	3.6%	4.7%
Process Control Systems	2,875	3,090	3,345	3,612	3,952	4,324	7.5%	8.5%
Programmable Machine Tools	892	942	999	1,048	1,079	1,111	5.6%	4.5%
Mechanical Assembly Equipment	401	411	425	430	440	450	2.5%	2.3%
Plastic Process Machinery	699	744	785	831	882	936	6.4%	6.0%
Assembly	73	80	87	85	90	95	9.6%	5.5%
Material Handling/ Loading	95	102	108	114	120	126	7.4%	5.9%
Painting	29	31	32	34	35	36	6.9%	4.4%
Spot Welding	48	44	40	37	34	31	(8.3%)	(8.2%)
Arc Welding	60	61	62	63	64	65	1.7%	1.6%
Machining, Other	44	46	47	49	51	53	4.5%	3.8%
Robot Systems	349	364	376	382	394	407	4.3%	3.1%
Guided Vehicles	142	154	166	176	188	201	8.5%	7.2%
Programmable Conveyors	511	544	591	644	699	759	6.5%	8.2%
Storage/Retrieval Systems	355	403	450	494	549	610	13.5%	11.4%
Programmable Monorails	185	210	236	260	285	312	13.5%	11.0%
Warehousing	236	263	289	314	350	390	11.4%	10.6%
Other	6	7	7	8	9	10	16.7%	11.0%
Automated Material Handling	1,435	1,581	1,739	1,896	2,080	2,282	10.2%	9.7%
Manufacturing Systems	16,286	16,965	18,538	20,106	21,484	22,976	4.2%	7.1%

Source: Dataquest
March 1990

Table 4c

North American Electronic Equipment Production
Industrial History
(Millions of Dollars)

Equipment Type	1983	1984	1985	1986	1987	1988	1989
Integrating and Totalizing Meters for Gas & Liquids	449	493	547	557	601	651	649
Counting Devices	173	209	198	202	198	211	220
Digital Panel Meters	27	36	34	33	34	41	41
Analog Panel Meters	10	5	6	6	6	5	6
Panel Type	116	128	119	124	141	162	163
Elapsed-Time Meters	27	16	12	11	13	16	12
Portable Elec. Measuring Instr.	22	23	18	18	23	25	20
Electronic Recording Instr.	323	418	438	469	517	568	559
Physical Property Test, Inpection & Measure	564	652	678	690	750	820	870
Comm. Meteorological & Gen. Purpose Instruments	294	381	334	300	350	378	447
Nuclear Radiation Detection & Monitoring Instruments	503	495	514	543	526	558	580
Surveying & Drafting Instr.	246	327	368	390	461	487	511
Ultrasonic Cleaners, Drills	107	127	112	108	124	139	148
Metorological	79	86	112	140	167	181	197
Geophysical	228	316	313	266	285	306	328
Analytical & Scientific Intr.	2,439	2,749	2,768	2,713	2,984	3,226	3,371
Instrumentation	5,607	6,461	6,571	6,570	7,180	7,774	8,122
Automatic Blood Analyzer	744	724	715	787	865	952	1,047
CAT Scanner	510	666	513	457	416	407	387
Digital Radiography	55	60	57	63	68	81	87
Electrocardiographs	72	118	96	98	106	114	122
Electrencephalographs	15	20	13	15	16	18	20
Nuclear Magnetic Resonanc	69	81	155	264	385	500	590
Respiratory Analysis	16	17	15	15	16	16	16
Ultrasonic Scanners	376	294	187	168	182	208	218
X-Ray	711	656	685	719	751	788	805
Other Diagnostic	291	254	263	276	280	292	303
Diagnostic	2,859	2,890	2,699	2,862	3,085	3,376	3,595
Patient Monitoring	659	577	640	666	699	741	771
Hearing Aids	340	363	395	419	444	477	500
Prosthetic	340	363	395	419	444	477	500
Surgical Support	104	130	181	217	239	250	256
Defibrillators	86	91	104	111	117	126	130
Dialysis, Diatheray	73	65	71	74	78	85	87
Electrosurgical	64	81	80	79	83	89	95
Pacemakers	263	371	304	312	320	318	336
Ultrasonic Generators	18	32	27	25	27	30	34
Other Therapeutic	274	280	258	237	253	293	313
Therapeutic	778	920	844	838	878	941	995
Medical Equipment	4,740	4,880	4,759	5,002	5,345	5,785	6,117

Source: Dataquest
March 1990

Table 4d

North American Electronic Equipment Production
Industrial Forecast
(Millions of Dollars)

Equipment Type	Actual 1989	1990	1991	Estimated 1992	1993	1994	CAGR 1989-1990	CAGR 1989-1994
Integrating and Totalizing Meters for Gas & Liquids	649	634	685	720	748	777	(2.3%)	3.7%
Counting Devices	220	223	258	281	305	331	1.4%	8.5%
Digital Panel Meters	41	44	50	57	63	70	7.3%	11.2%
Analog Panel Meters	6	6	5	4	4	4	0	(7.8%)
Panel Type	163	196	214	222	235	249	20.2%	8.8%
Elapsed-Time Meters	12	13	15	18	20	22	8.3%	13.1%
Portable Elec. Measuring Instr.	20	21	22	27	30	33	5.0%	10.8%
Electronic Recording Instruments	559	584	656	689	723	759	4.5%	6.3%
Physical Property Test, Inpection & Measure	870	921	1,000	1,065	1,125	1,188	5.9%	6.4%
Comm. Meteorological & Gen. Purpose Instruments	447	470	506	530	565	602	5.1%	6.1%
Nuclear Radiation Detection & Monitoring Instruments	580	559	601	643	665	688	(3.6%)	3.5%
Surveying & Drafting Instruments	511	538	581	619	655	693	5.3%	6.3%
Ultrasonic Cleaners, Drills	148	159	172	187	202	218	7.4%	8.1%
Metorological	197	209	234	252	273	296	6.1%	8.5%
Geophysical	328	347	377	407	439	474	5.8%	7.6%
Analytical & Scientific Intruments	3,371	3,512	3,766	3,962	4,084	4,210	4.2%	4.5%
Instrumentation	8,122	8,436	9,142	9,683	10,136	10,614	3.9%	5.5%
Automaic Blood Analyzer	1,047	1,152	1,267	1,361	1,475	1,599	10.0%	8.8%
CAT Scanner	387	360	331	315	297	280	(7.0%)	(6.3%)
Digital Radiography	87	97	110	119	130	142	11.5%	10.3%
Electrocardiographs	122	129	135	143	151	159	5.7%	5.5%
Electrencephalographs	20	23	26	28	31	34	15.0%	11.4%
Nuclear Magnetic Resonanc	590	649	714	771	846	928	10.0%	9.5%
Respiratory Analysis	16	17	18	19	20	21	6.3%	5.6%
Ultrasonic Scanners	218	243	257	269	284	300	11.5%	6.6%
X-Ray	805	841	877	896	921	947	4.5%	3.3%
Other Diagnostic	303	312	324	333	343	353	3.0%	3.1%
Diagnostic	3,595	3,823	4,059	4,254	4,498	4,764	6.3%	5.8%
Patient Monitoring	771	817	882	882	902	922	6.0%	3.7%
Hearing Aids	500	534	570	589	615	642	6.8%	5.1%
Prosthetic	500	534	570	589	615	642	6.8%	5.1%
Surgical Support	256	270	287	298	310	322	5.5%	4.7%
Defibrillators	130	135	142	149	156	163	3.8%	4.7%
Dialysis, Diatheray	87	89	92	99	105	111	2.3%	5.1%
Electrosurgical	95	98	105	113	121	130	3.2%	6.4%
Pacemakers	336	345	357	373	389	406	2.7%	3.8%
Ultrasonic Generators	34	36	37	40	44	48	5.9%	7.3%
Other Therapeutic	313	338	365	374	390	407	8.0%	5.4%
Therapeutic	995	1,041	1,098	1,148	1,205	1,265	4.6%	4.9%
Medical Equipment	6,117	6,485	6,896	7,171	7,530	7,916	6.0%	5.3%

Source: Dataquest
March 1990

Table 4e

North American Electronic Equipment Production
Industrial History
(Millions of Dollars)

Equipment Type	1983	1984	1985	1986	1987	1988	1989
Radar	0	0	0	1,493	1,590	1,825	2,080
Space	0	0	0	2,911	2,693	2,470	2,818
Navigation/Communication	0	0	0	625	663	713	808
Aircraft Flight Systems	0	0	0	1,692	1,783	1,892	2,198
Simulation & Training	0	0	0	185	201	216	245
Civil Aerospace	1,764	5,763	6,454	6,906	6,930	7,116	8,149
Vending Machines	334	394	429	408	386	398	415
Laser Systems (Exc. Communications)	545	623	621	625	679	760	821
Power Supplies	815	964	1,131	1,338	1,580	1,881	2,052
Traffic Control	481	474	453	462	485	509	537
Particle Accelerator Elec.	34	29	19	17	20	23	25
Industrial & Scientific X-Ray	21	53	61	67	75	83	90
Laboratory & Scientific Apparatus	976	1,101	1,136	1,194	1,290	1,397	1,451
Teaching Machines and Aids	65	64	67	70	77	84	90
Scientific Not Elsewhere Classified	185	187	185	183	185	221	238
Other Industrial	3,456	3,889	4,102	4,364	4,777	5,356	5,719
Industrial	27,591	35,665	37,035	37,692	39,823	43,624	46,899

Source: Dataquest
March 1990

Table 4f

North American Electronic Equipment Production
Industrial Forecast
(Millions of Dollars)

Equipment Type	Actual 1989	1990	1991	Estimated 1992	1993	1994	CAGR 1989-1990	CAGR 1989-1994
Radar	2,080	2,355	2,645	2,949	3,228	3,533	13.2%	11.2%
Space	2,818	3,330	3,865	4,456	5,145	5,941	18.2%	16.1%
Navigation/ Communication	808	910	1,074	1,185	1,298	1,422	12.6%	12.0%
Aircraft Flight Systems	2,198	2,536	2,892	3,245	3,559	3,903	15.4%	12.2%
Simulation & Training	245	280	331	393	464	548	14.3%	17.5%
Civil Aerospace	8,149	9,411	10,807	12,228	13,694	15,347	15.5%	13.5%
Vending Machines	415	421	427	459	459	459	1.4%	2.0%
Laser Systems (Exc. Communications)	821	893	984	1,087	1,188	1,298	8.8%	9.6%
Power Supplies	2,052	2,205	2,432	2,613	2,843	3,093	7.5%	8.6%
Traffic Control	537	562	587	619	651	685	4.7%	5.0%
Particle Accelerator Electronic	25	24	25	26	27	28	(4.0%)	2.3%
Industrial & Scientific X-Ray	90	95	102	109	116	123	5.6%	6.5%
Laboratory & Scientific Apparatus	1,451	1,495	1,589	1,670	1,751	1,836	3.0%	4.8%
Teaching Machines and Aids	90	97	105	111	118	125	7.8%	6.9%
Scientific Not Elsewhere Classified	238	261	286	297	314	332	9.7%	6.9%
Other Industrial	5,719	6,053	6,537	6,991	7,467	7,980	5.8%	6.9%
Industrial	46,899	49,989	54,742	59,199	63,514	68,230	6.6%	7.8%

Source: Dataquest March 1990

Table 5a

North American Electronic Equipment Production
Consumer History
(Millions of Dollars)

Equipment Type	1983	1984	1985	1986	1987	1988	1989
Audio Amplifiers	23	16	17	16	14	11	12
Compact Disc Players	0	0	0	0	0	0	0
Radio	19	23	18	19	25	30	33
Stereo (Hi-Fi) Components	202	186	193	205	200	207	210
Stereo Headphone	0	0	0	0	0	0	0
Musical Instruments	11	10	13	15	17	18	19
Tape Recorders	15	11	11	14	13	13	11
Audio	270	246	252	269	269	279	285
Videocameras	303	354	225	60	35	20	10
VTRs (VCRs)	20	58	78	105	157	184	205
Videodisc Players	0	3	5	6	8	9	9
Color Televisions	4,473	4,834	4,936	5,028	5,298	5,395	5,510
Black & White Televisions	173	59	40	33	24	20	15
Video	4,969	5,308	5,284	5,232	5,522	5,628	5,749
Games	959	383	236	137	141	132	130
Cameras	13	15	18	17	20	23	25
Watches	68	62	64	67	72	69	65
Clocks	8	13	13	14	16	17	19
Personal Electronics	1,048	473	331	235	249	241	239
Air Conditioners	873	991	1,286	1,140	1,140	1,200	1,250
Microwave Ovens	1,044	1,252	1,300	1,300	1,350	1,400	1,450
Washers & Dryers	1,876	2,079	2,168	2,700	3,400	3,350	3,350
Refrigerators	2,249	2,573	2,718	2,894	3,082	3,080	3,247
Dishwashers, Disposals	1,600	1,800	1,900	2,050	2,100	2,150	2,150
Ranges & Ovens	1,300	1,477	1,517	1,589	1,600	1,650	1,700
Appliances	8,942	10,172	10,889	11,673	12,672	12,830	13,147
Automatic Garage Door Openers	187	198	184	208	222	232	240
Consumer Elec. Equip. Not Elsewhere Class	322	449	626	689	723	760	797
Other Consumer	509	647	810	897	945	992	1,037
Consumer	15,738	16,846	17,566	18,306	19,657	19,970	20,457

Source: Dataquest March 1990

Table 5b

North American Electronic Equipment Production
Consumer Forecast
(Millions of Dollars)

Equipment Type	Actual 1989	1990	1991	Estimated 1992	1993	1994	CAGR 1989-1990	CAGR 1989-1994
Audio Amplifiers	12	12	11	10	10	10	0	(3.6%)
Compact Disc Players	0	0	0	0	0	0	N/M	N/M
Radio	33	36	38	43	45	48	9.1%	7.8%
Stereo (Hi-Fi) Components	210	214	220	223	225	228	1.9%	1.7%
Stereo Headphone	0	0	0	0	0	0	N/M	N/M
Musical Instruments	19	20	21	22	23	24	5.3%	4.8%
Tape Recorders	11	10	9	8	8	8	(9.1%)	(6.2%)
Audio	285	292	299	306	311	318	2.5%	2.2%
Videocameras	10	0	0	0	0	0	(100.0%)	(100.0%)
VTRs (VCRs)	205	200	200	200	200	200	(2.4%)	(0.5%)
Videodisc Players	9	8	7	8	8	8	(11.1%)	(2.3%)
Color Televisions	5,510	5,646	5,807	5,998	6,224	6,500	2.5%	3.4%
Black & White Televisions	15	10	0	0	0	0	(33.3%)	(100.0%)
Video	5,749	5,864	6,014	6,206	6,432	6,708	2.0%	3.1%
Games	130	130	130	130	130	130	0	0
Cameras	25	26	26	24	24	24	4.0%	(0.8%)
Watches	65	61	59	57	57	57	(6.2%)	(2.6%)
Clocks	19	23	26	28	28	28	21.1%	8.1%
Personal Electronics	239	240	241	239	239	239	0.4%	0
Air Conditioners	1,250	1,300	1,350	1,400	1,450	1,500	4.0%	3.7%
Microwave Ovens	1,450	1,500	1,550	1,600	1,650	1,700	3.4%	3.2%
Washers & Dryers	3,350	3,400	3,450	3,500	3,550	3,600	1.5%	1.4%
Refrigerators	3,247	3,312	3,468	3,617	3,700	3,750	2.0%	2.9%
Dishwashers, Disposals	2,150	2,250	2,300	2,350	2,400	2,450	4.7%	2.6%
Ranges & Ovens	1,700	1,750	1,800	1,850	1,900	1,950	2.9%	2.8%
Appliances	13,147	13,512	13,918	14,317	14,650	14,950	2.8%	2.6%
Automatic Garage Door Openers	240	246	257	272	257	257	2.5%	1.4%
Consumer Elec. Equip. Not Elsewhere Class	797	832	869	899	900	900	4.4%	2.5%
Other Consumer	1,037	1,078	1,126	1,171	1,157	1,157	4.0%	2.2%
Consumer	20,457	20,986	21,598	22,239	22,789	23,372	2.6%	2.7%

Source: Dataquest March 1990

Table 6a

North American Electronic Equipment Production
Military History
(Millions of Dollars)

Equipment Type	1983	1984	1985	1986	1987	1988	1989
Radar	N/A	N/A	N/A	6,911	6,945	6,521	6,456
Sonar	N/A	N/A	N/A	2,754	2,875	2,984	2,870
Missile-Weapon	N/A	N/A	N/A	5,937	6,228	6,385	6,461
Space	N/A	N/A	N/A	5,025	5,281	5,148	5,552
Navigation	N/A	N/A	N/A	1,465	1,537	1,606	1,602
Communications	N/A	N/A	N/A	4,388	4,616	4,791	4,944
Electronic Warfare	N/A	N/A	N/A	3,250	3,029	3,044	3,021
Reconnaissance	N/A	N/A	N/A	2,314	2,422	2,495	2,550
Aircraft Systems	N/A	N/A	N/A	4,330	4,555	4,327	4,312
Computer Systems	N/A	N/A	N/A	1,983	2,112	2,207	2,308
Simulation & Training	N/A	N/A	N/A	632	671	744	845
Misc. Equipment	N/A	N/A	N/A	10,381	10,661	10,811	10,806
Military	N/A	N/A	47,300	49,370	50,932	51,063	51,727

N/A = Not Available

Source: Dataquest March 1990

Table 6b

North American Electronic Equipment Production
Military Forecast
(Millions of Dollars)

Equipment Type	Actual 1989	1990	1991	Estimated 1992	1993	1994	CAGR 1989-1990	CAGR 1989-1994
Radar	6,456	6,552	6,650	6,783	7,089	7,435	1.5%	2.9%
Sonar	2,870	3,050	3,172	3,270	3,405	3,558	6.3%	4.4%
Missile-Weapon	6,461	6,450	6,665	6,895	7,120	7,298	(0.2%)	2.5%
Space	5,552	5,898	6,329	6,760	7,220	7,718	6.2%	6.8%
Navigation	1,602	1,635	1,686	1,740	1,794	1,849	2.1%	2.9%
Communications	4,944	5,118	5,245	5,409	5,580	5,750	3.5%	3.1%
Electronic Warfare	3,021	3,112	3,235	3,335	3,458	3,565	3.0%	3.4%
Reconnaissance	2,550	2,615	2,696	2,796	2,893	2,962	2.5%	3.0%
Aircraft Systems	4,312	4,337	4,411	4,624	4,929	5,302	0.6%	4.2%
Computer Systems	2,308	2,421	2,545	2,708	2,892	3,088	4.9%	6.0%
Simulation & Training	845	946	1,054	1,170	1,328	1,495	12.0%	12.1%
Misc. Equipment	10,806	10,784	10,575	10,355	10,158	9,978	(0.2%)	(1.6%)
Military	51,727	52,918	54,263	55,845	57,866	59,998	2.3%	3.0%

Source: Dataquest March 1990

Table 7a

North American Electronic Equipment Production
Transportation History
(Millions of Dollars)

Equipment Type	1983	1984	1985	1986	1987	1988	1989
Entertainment	1,549	2,142	2,380	2,647	2,780	2,876	2,968
Body Controls	777	1,060	1,261	1,513	1,640	1,772	1,912
Driver Information	798	1,060	1,237	1,458	1,583	1,708	1,839
Powertrain	1,933	2,473	2,782	3,007	3,155	3,259	3,351
Safety & Convenience	490	706	820	955	1,041	1,129	1,222
Transportation	5,547	7,441	8,480	9,580	10,199	10,744	11,292

Source: Dataquest
March 1990

Table 7b

North American Electronic Equipment Production
Transportation Forecast
(Millions of Dollars)

Equipment Type	Actual 1989	1990	1991	Estimated 1992	1993	1994	CAGR 1989-1990	CAGR 1989-1994
Entertainment	2,968	3,028	3,192	3,338	3,468	3,548	2.0%	3.6%
Body Controls	1,912	2,075	2,415	2,704	2,903	3,052	8.5%	9.8%
Driver Information	1,839	1,959	2,170	2,381	2,545	2,658	6.5%	7.6%
Powertrain	3,351	3,441	3,595	3,724	3,839	3,933	2.7%	3.3%
Safety & Convenience	1,222	1,325	1,525	1,805	2,081	2,258	8.4%	13.1%
Transportation	11,292	11,828	12,897	13,952	14,836	15,449	4.7%	6.5%

Source: Dataquest
March 1990

Semiconductor Consumption Analysis

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

- ➡ Semiconductor Revenue By Application Market
- Semiconductor Shipments

NOTE: The arrow symbol indicates the latest document(s) correct location behind this subject tab.

Semiconductor Revenue by Application Market

In the Semiconductor Application Markets (SAM) database, input/output (I/O) ratios are estimated for the broad semiconductor product families (e.g., MOS memory) by electronic system group (e.g., computers). Detailed semiconductor product analysis of key (specific) electronic equipment types provides the basis for these aggregate estimates.

Tables 1 through 6 present forecast North American merchant semiconductor revenue (i.e., the dollar value of chip expenditure by indigenous North American systems manufacturers) and related information for the total market.

Tables 7 through 48 present similar information for the six major North American application markets: data processing, communications, industrial, consumer, military, and transportation.

These tables include the value of electronic equipment production and associated semiconductor revenue; I/O ratios; annual growth rates; and percentage share of semiconductor revenue by semiconductor product family and by application market.

Semiconductor product revenue and related information also are broken out by electronic system group and may be found directly behind the appropriate application market tabs in the remaining sections of the service notebook.

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Table 1

Forecast North American Electronic Equipment Production
Total Market
(Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR (%) 1989-1990	CAGR (%) 1989-1994
Factory Revenue	253,879	269,231	284,957	303,057	322,968	344,161	367,463	5.8	6.4

Source: Dataquest (July 1990)

Table 2

Forecast North American Merchant Semiconductor Revenue
Total Market
(Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR (%) 1989-1990	CAGR (%) 1989-1994
Total Semiconductor	15,844	17,707	17,165	19,951	24,045	30,539	33,519	(3.1)	13.6
Total IC	13,815	15,694	15,090	17,736	21,567	27,861	30,705	(3.8)	14.4
Bipolar Digital	2,012	1,709	1,571	1,655	1,734	1,816	1,633	(8.1)	(0.9)
Bipolar Memory	235	239	207	187	165	153	136	(13.4)	(10.7)
Bipolar Logic	1,777	1,470	1,364	1,468	1,569	1,663	1,497	(7.2)	0.4
MOS	9,606	11,602	11,030	13,166	16,594	22,277	24,753	(4.9)	16.4
MOS Memory	4,298	6,056	5,171	6,376	8,375	11,661	13,230	(14.6)	16.9
MOS Micro	2,707	2,739	2,905	3,335	3,969	5,303	5,870	6.1	16.5
MOS Logic	2,601	2,807	2,954	3,455	4,250	5,313	5,653	5.2	15.0
Analog	2,197	2,383	2,489	2,915	3,239	3,768	4,319	4.4	12.6
Discrete	1,676	1,660	1,722	1,833	2,073	2,239	2,337	3.7	7.1
Opto	353	353	353	382	405	439	477	0	6.2

Source: Dataquest (July 1990)

Table 3

Forecast North American Merchant Semiconductor Revenue
Total Market
(Input/Output Ratios, Percentage)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	6.2	6.6	6.0	6.6	7.4	8.9	9.1
Total IC	5.4	5.8	5.3	5.9	6.7	8.1	8.4
Bipolar Digital	0.8	0.6	0.6	0.5	0.5	0.5	0.4
Bipolar Memory	0.1	0.1	0.1	0.1	0.1	0	0
Bipolar Logic	0.7	0.5	0.5	0.5	0.5	0.5	0.4
MOS	3.8	4.3	3.9	4.3	5.1	6.5	6.7
MOS Memory	1.7	2.2	1.8	2.1	2.6	3.4	3.6
MOS Micro	1.1	1.0	1.0	1.1	1.2	1.5	1.6
MOS Logic	1.0	1.0	1.0	1.1	1.3	1.5	1.5
Analog	0.9	0.9	0.9	1.0	1.0	1.1	1.2
Discrete	0.7	0.6	0.6	0.6	0.6	0.7	0.6
Opto	0.1	0.1	0.1	0.1	0.1	0.1	0.1

Source: Dataquest (July 1990)

Table 4

Forecast North American Electronic Equipment Production
Total Market
(Annual Percentage Growth)

	1989	1990	1991	1992	1993	1994
Factory Revenue	6.0	5.8	6.4	6.6	6.6	6.8

Source: Dataquest (July 1990)

Table 5

Forecast North American Merchant Semiconductor Revenue
Total Market
(Annual Percentage Growth)

	1989	1990	1991	1992	1993	1994
Total Semiconductor	11.8	(3.1)	16.2	20.5	27.0	9.8
Total IC	13.6	(3.8)	17.5	21.6	29.2	10.2
Bipolar Digital	(15.1)	(8.1)	5.3	4.8	4.7	(10.1)
Bipolar Memory	1.7	(13.4)	(9.7)	(11.8)	(7.3)	(11.1)
Bipolar Logic	(17.3)	(7.2)	7.6	6.9	6.0	(10.0)
MOS	20.8	(4.9)	19.4	26.0	34.2	11.1
MOS Memory	40.9	(14.6)	23.3	31.4	39.2	13.5
MOS Micro	1.2	6.1	14.8	19.0	33.6	10.7
MOS Logic	7.9	5.2	17.0	23.0	25.0	6.4
Analog	8.5	4.4	17.1	11.1	16.3	14.6
Discrete	(1.0)	3.7	6.4	13.1	8.0	4.4
Opto	0	0	8.2	6.0	8.4	8.7

Source: Dataquest (July 1990)

Table 6

Forecast North American Merchant Semiconductor Revenue
Total Market
(Product Family Percentage Share of Total Semiconductor)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total IC	87.2	88.6	87.9	88.9	89.7	91.2	91.6
Bipolar Digital	12.7	9.7	9.2	8.3	7.2	5.9	4.9
Bipolar Memory	1.5	1.3	1.2	0.9	0.7	0.5	0.4
Bipolar Logic	11.2	8.3	7.9	7.4	6.5	5.4	4.5
MOS	60.6	65.5	64.3	66.0	69.0	72.9	73.8
MOS Memory	27.1	34.2	30.1	32.0	34.8	38.2	39.5
MOS Micro	17.1	15.5	16.9	16.7	16.5	17.4	17.5
MOS Logic	16.4	15.9	17.2	17.3	17.7	17.4	16.9
Analog	13.9	13.5	14.5	14.6	13.5	12.3	12.9
Discrete	10.6	9.4	10.0	9.2	8.6	7.3	7.0
Opto	2.2	2.0	2.1	1.9	1.7	1.4	1.4

Source: Dataquest (July 1990)

Table 7

Forecast North American Electronic Equipment Production
Data Processing
(Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR (%) 1989-1990	CAGR (%) 1989-1994
Factory Revenue	100,995	108,941	116,997	125,098	134,872	145,912	157,549	7.4	7.7

Source: Dataquest (July 1990)

Table 8

Forecast North American Merchant Semiconductor Revenue
Data Processing
(Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR (%) 1989-1990	CAGR (%) 1989-1994
Total Semiconductor	7,702	9,097	8,664	10,488	13,282	17,890	19,908	(4.8)	17.0
Total IC	7,492	8,881	8,436	10,233	12,987	17,560	19,548	(5.0)	17.1
Bipolar Digital	1,246	1,064	1,006	1,137	1,262	1,385	1,261	(5.4)	3.5
Bipolar Memory	115	131	117	110	101	97	88	(10.7)	(7.7)
Bipolar Logic	1,131	933	889	1,026	1,161	1,288	1,174	(4.7)	4.7
MOS	5,903	7,423	7,004	8,571	11,123	15,446	17,424	(5.6)	18.6
MOS Memory	2,874	4,272	3,677	4,693	6,390	9,207	10,655	(13.9)	20.1
MOS Micro	1,684	1,711	1,831	2,134	2,588	3,561	3,973	7.0	18.4
MOS Logic	1,345	1,441	1,496	1,744	2,145	2,678	2,796	3.8	14.2
Analog	343	394	425	525	603	729	863	8.0	17.0
Discrete	133	136	146	161	192	216	231	7.6	11.2
Opto	77	80	83	93	102	114	129	3.4	10.0

Source: Dataquest (July 1990)

Table 9

Forecast North American Merchant Semiconductor Revenue
Data Processing
(Input/Output Ratios, Percentage)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	7.6	8.4	7.4	8.4	9.8	12.3	12.6
Total IC	7.4	8.2	7.2	8.2	9.6	12.0	12.4
Bipolar Digital	1.2	1.0	0.9	0.9	0.9	0.9	0.8
Bipolar Memory	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Bipolar Logic	1.1	0.9	0.8	0.8	0.9	0.9	0.7
MOS	5.8	6.8	6.0	6.9	8.2	10.6	11.1
MOS Memory	2.8	3.9	3.1	3.8	4.7	6.3	6.8
MOS Micro	1.7	1.6	1.6	1.7	1.9	2.4	2.5
MOS Logic	1.3	1.3	1.3	1.4	1.6	1.8	1.8
Analog	0.3	0.4	0.4	0.4	0.4	0.5	0.5
Discrete	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Opto	0.1	0.1	0.1	0.1	0.1	0.1	0.1

Source: Dataquest (July 1990)

Table 10

Forecast North American Electronic Equipment Production
Data Processing
(Annual Percentage Growth)

	1989	1990	1991	1992	1993	1994
Factory Revenue	7.9	7.4	6.9	7.8	8.2	8.0

Source: Dataquest (July 1990)

Table 11

Forecast North American Merchant Semiconductor Revenue
Data Processing
(Annual Percentage Growth)

	1989	1990	1991	1992	1993	1994
Total Semiconductor	18.1	(4.8)	21.0	26.6	34.7	11.3
Total IC	18.5	(5.0)	21.3	26.9	35.2	11.3
Bipolar Digital	(14.7)	(5.4)	13.0	11.0	9.8	(9.0)
Bipolar Memory	14.0	(10.7)	(5.6)	(8.7)	(3.6)	(9.8)
Bipolar Logic	(17.6)	(4.7)	15.4	13.1	11.0	(8.9)
MOS	25.8	(5.6)	22.4	29.8	38.9	12.8
MOS Memory	48.6	(13.9)	27.6	36.2	44.1	15.7
MOS Micro	1.6	7.0	16.6	21.3	37.6	11.6
MOS Logic	7.2	3.8	16.6	23.0	24.8	4.4
Analog	14.9	8.0	23.5	14.7	20.9	18.5
Discrete	2.3	7.6	10.2	19.3	12.0	7.1
Opto	4.1	3.4	13.1	9.3	12.2	12.5

Source: Dataquest (July 1990)

Table 12

Forecast North American Merchant Semiconductor Revenue
Data Processing
(Percentage of Product Family Market)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	48.6	51.4	50.5	52.6	55.2	58.6	59.4
Total IC	54.2	56.6	55.9	57.7	60.2	63.0	63.7
Bipolar Digital	61.9	62.2	64.0	68.7	72.8	76.3	77.2
Bipolar Memory	48.9	54.8	56.5	59.0	61.1	63.5	64.4
Bipolar Logic	63.7	63.4	65.2	69.9	74.0	77.5	78.4
MOS	61.4	64.0	63.5	65.1	67.0	69.3	70.4
MOS Memory	66.9	70.5	71.1	73.6	76.3	79.0	80.5
MOS Micro	62.2	62.5	63.0	64.0	65.2	67.2	67.7
MOS Logic	51.7	51.3	50.6	50.5	50.5	50.4	49.5
Analog	15.6	16.5	17.1	18.0	18.6	19.3	20.0
Discrete	7.9	8.2	8.5	8.8	9.3	9.6	9.9
Opto	21.7	22.6	23.4	24.4	25.2	26.1	27.0

Source: Dataquest (July 1990)

Table 13

Forecast North American Merchant Semiconductor Revenue
Data Processing
(Product Family Percentage Share of Total Semiconductor)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total IC	97.3	97.6	97.4	97.6	97.8	98.2	98.2
Bipolar Digital	16.2	11.7	11.6	10.8	9.5	7.7	6.3
Bipolar Memory	1.5	1.4	1.3	1.1	0.8	0.5	0.4
Bipolar Logic	14.7	10.3	10.3	9.8	8.7	7.2	5.9
MOS	76.6	81.6	80.8	81.7	83.7	86.3	87.5
MOS Memory	37.3	47.0	42.4	44.8	48.1	51.5	53.5
MOS Micro	21.9	18.8	21.1	20.3	19.5	19.9	20.0
MOS Logic	17.5	15.8	17.3	16.6	16.1	15.0	14.0
Analog	4.5	4.3	4.9	5.0	4.5	4.1	4.3
Discrete	1.7	1.5	1.7	1.5	1.4	1.2	1.2
Opto	1.0	0.9	1.0	0.9	0.8	0.6	0.6

Source: Dataquest (July 1990)

Table 14

Forecast North American Electronic Equipment Production
Communications
(Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR (%) 1989-1990	CAGR (%) 1989-1994
Factory Revenue	27,483	29,915	32,239	34,459	36,861	39,244	42,865	7.8	7.5

Source: Dataquest (July 1990)

Table 15

Forecast North American Merchant Semiconductor Revenue Communications (Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR (%) 1989-1990	CAGR (%) 1989-1994
Total Semiconductor	2,251	2,476	2,335	2,654	3,100	3,780	4,010	(5.7)	10.1
Total IC	1,956	2,173	2,011	2,296	2,679	3,308	3,499	(7.4)	10.0
Bipolar Digital	97	66	50	45	39	34	25	(24.6)	(18.0)
Bipolar Memory	10	11	8	7	6	5	4	(20.3)	(17.7)
Bipolar Logic	86	56	41	37	33	29	20	(25.4)	(18.1)
MOS	1,436	1,631	1,459	1,645	1,960	2,470	2,544	(10.5)	9.3
MOS Memory	587	771	586	661	795	1,012	1,035	(23.9)	6.1
MOS Micro	352	335	335	366	416	536	560	0.2	10.9
MOS Logic	498	526	538	618	749	921	948	2.3	12.5
Analog	423	475	502	606	680	804	931	5.6	14.4
Discrete	233	240	259	287	345	388	418	8.1	11.7
Opto	62	63	64	71	76	84	92	1.3	7.8

Source: Dataquest (July 1990)

Table 16

Forecast North American Merchant Semiconductor Revenue Communications (Input/Output Ratios, Percentage)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	8.2	8.3	7.2	7.7	8.4	9.6	9.4
Total IC	7.1	7.3	6.2	6.7	7.3	8.4	8.2
Bipolar Digital	0.4	0.2	0.2	0.1	0.1	0.1	0.1
Bipolar Memory	0	0	0	0	0	0	0
Bipolar Logic	0.3	0.2	0.1	0.1	0.1	0.1	0
MOS	5.2	5.5	4.5	4.8	5.3	6.3	5.9
MOS Memory	2.1	2.6	1.8	1.9	2.2	2.6	2.4
MOS Micro	1.3	1.1	1.0	1.1	1.1	1.4	1.3
MOS Logic	1.8	1.8	1.7	1.8	2.0	2.3	2.2
Analog	1.5	1.6	1.6	1.8	1.8	2.0	2.2
Discrete	0.8	0.8	0.8	0.8	0.9	1.0	1.0
Opto	0.2	0.2	0.2	0.2	0.2	0.2	0.2

Source: Dataquest (July 1990)

Table 17

Forecast North American Electronic Equipment Production
Communications
(Annual Percentage Growth)

	1989	1990	1991	1992	1993	1994
Factory Revenue	8.8	7.8	6.9	7.0	6.5	9.2

Source: Dataquest (July 1990)

Table 18

Forecast North American Merchant Semiconductor Revenue
Communications
(Annual Percentage Growth)

	1989	1990	1991	1992	1993	1994
Total Semiconductor	10.0	(5.7)	13.7	16.8	21.9	6.1
Total IC	11.1	(7.4)	14.2	16.7	23.5	5.8
Bipolar Digital	(31.5)	(24.6)	(10.7)	(12.7)	(13.3)	(27.4)
Bipolar Memory	1.7	(20.3)	(15.8)	(18.6)	(14.0)	(19.5)
Bipolar Logic	(35.5)	(25.4)	(9.7)	(11.5)	(13.2)	(28.7)
MOS	13.6	(10.5)	12.7	19.2	26.0	3.0
MOS Memory	31.3	(23.9)	12.8	20.3	27.3	2.3
MOS Micro	(4.9)	0.2	9.2	13.6	28.9	4.5
MOS Logic	5.6	2.3	14.9	21.2	23.0	2.9
Analog	12.4	5.6	20.8	12.2	18.2	15.8
Discrete	2.8	8.1	10.8	20.0	12.6	7.7
Opto	2.0	1.3	10.8	7.0	9.9	10.2

Source: Dataquest (July 1990)

Table 19

Forecast North American Merchant Semiconductor Revenue
Communications
(Percentage of Product Family Market)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	14.2	14.0	13.6	13.3	12.9	12.4	12.0
Total IC	14.2	13.8	13.3	12.9	12.4	11.9	11.4
Bipolar Digital	4.8	3.9	3.2	2.7	2.2	1.9	1.5
Bipolar Memory	4.5	4.5	4.1	3.8	3.5	3.3	3.0
Bipolar Logic	4.9	3.8	3.0	2.6	2.1	1.7	1.4
MOS	15.0	14.1	13.2	12.5	11.8	11.1	10.3
MOS Memory	13.7	12.7	11.3	10.4	9.5	8.7	7.8
MOS Micro	13.0	12.2	11.5	11.0	10.5	10.1	9.5
MOS Logic	19.1	18.7	18.2	17.9	17.6	17.3	16.8
Analog	19.3	19.9	20.2	20.8	21.0	21.3	21.6
Discrete	13.9	14.4	15.1	15.7	16.6	17.3	17.9
Opto	17.6	18.0	18.2	18.6	18.8	19.1	19.4

Source: Dataquest (July 1990)

Table 20

Forecast North American Merchant Semiconductor Revenue
Communications
(Product Family Percentage Share of Total Semiconductor)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total IC	86.9	87.8	86.1	86.5	86.4	87.5	87.3
Bipolar Digital	4.3	2.7	2.1	1.7	1.3	0.9	0.6
Bipolar Memory	0.5	0.4	0.4	0.3	0.2	0.1	0.1
Bipolar Logic	3.8	2.2	1.8	1.4	1.1	0.8	0.5
MOS	63.8	65.9	62.5	62.0	63.2	65.4	63.4
MOS Memory	26.1	31.1	25.1	24.9	25.7	26.8	25.8
MOS Micro	15.6	13.5	14.4	13.8	13.4	14.2	14.0
MOS Logic	22.1	21.2	23.0	23.3	24.2	24.4	23.6
Analog	18.8	19.2	21.5	22.8	21.9	21.3	23.2
Discrete	10.4	9.7	11.1	10.8	11.1	10.3	10.4
Opto	2.8	2.6	2.8	2.7	2.5	2.2	2.3

Source: Dataquest (July 1990)

Table 21

Forecast North American Electronic Equipment Production
Consumer
(Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR (%) 1989-1990	CAGR (%) 1989-1994
Factory Revenue	19,970	20,457	20,986	21,598	22,239	22,789	23,372	2.6	2.7

Source: Dataquest (July 1990)

Table 22

Forecast North American Merchant Semiconductor Revenue
Consumer
(Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR (%) 1989-1990	CAGR (%) 1989-1994
Total Semiconductor	1,160	1,211	1,137	1,254	1,387	1,586	1,657	(6.0)	6.5
Total IC	911	963	881	980	1,073	1,246	1,304	(8.5)	6.2
Bipolar Digital	72	48	37	34	31	27	20	(23.6)	(16.4)
Bipolar Memory	4	4	3	2	2	1	1	(23.6)	(21.1)
Bipolar Logic	68	45	34	32	29	26	19	(23.6)	(16.1)
MOS	416	458	381	409	463	561	552	(16.9)	3.8
MOS Memory	206	259	188	203	234	286	280	(27.2)	1.6
MOS Micro	122	111	106	110	119	147	146	(4.4)	5.7
MOS Logic	89	89	87	95	110	129	126	(2.5)	7.2
Analog	423	457	463	537	579	658	732	1.4	9.9
Discrete	232	229	239	255	295	320	332	4.2	7.7
Opto	18	18	17	19	19	20	22	(2.0)	4.3

Source: Dataquest (July 1990)

Table 23

Forecast North American Merchant Semiconductor Revenue
Consumer
(Input/Output Ratios, Percentage)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	5.8	5.9	5.4	5.8	6.2	7.0	7.1
Total IC	4.6	4.7	4.2	4.5	4.8	5.5	5.6
Bipolar Digital	0.4	0.2	0.2	0.2	0.1	0.1	0.1
Bipolar Memory	0	0	0	0	0	0	0
Bipolar Logic	0.3	0.2	0.2	0.1	0.1	0.1	0.1
MOS	2.1	2.2	1.8	1.9	2.1	2.5	2.4
MOS Memory	1.0	1.3	0.9	0.9	1.1	1.3	1.2
MOS Micro	0.6	0.5	0.5	0.5	0.5	0.6	0.6
MOS Logic	0.4	0.4	0.4	0.4	0.5	0.6	0.5
Analog	2.1	2.2	2.2	2.5	2.6	2.9	3.1
Discrete	1.2	1.1	1.1	1.2	1.3	1.4	1.4
Opto	0.1	0.1	0.1	0.1	0.1	0.1	0.1

Source: Dataquest (July 1990)

Table 24

Forecast North American Electronic Equipment Production
Consumer
(Annual Percentage Growth)

	1989	1990	1991	1992	1993	1994
Factory Revenue	2.4	2.6	2.9	3.0	2.5	2.6

Source: Dataquest (July 1990)

Table 25

Forecast North American Merchant Semiconductor Revenue
Consumer
(Annual Percentage Growth)

	1989	1990	1991	1992	1993	1994
Total Semiconductor	4.3	(6.0)	10.2	10.7	14.3	4.5
Total IC	5.8	(8.5)	11.2	9.5	16.1	4.7
Bipolar Digital	(32.3)	(23.6)	(8.3)	(10.1)	(11.4)	(26.7)
Bipolar Memory	(2.5)	(23.6)	(19.3)	(21.9)	(17.5)	(22.8)
Bipolar Logic	(33.9)	(23.6)	(7.5)	(9.3)	(11.0)	(27.0)
MOS	10.2	(16.9)	7.3	13.4	21.1	(1.6)
MOS Memory	25.8	(27.2)	8.0	15.2	21.9	(2.1)
MOS Micro	(9.2)	(4.4)	4.1	8.4	23.0	(0.3)
MOS Logic	0.6	(2.5)	9.4	15.5	17.2	(2.0)
Analog	7.9	1.4	16.0	7.8	13.5	11.3
Discrete	(0.9)	4.2	6.7	15.6	8.5	3.8
Opto	(1.3)	(2.0)	7.2	3.5	6.3	6.6

Source: Dataquest (July 1990)

Table 26

Forecast North American Merchant Semiconductor Revenue
Consumer
(Percentage of Product Family Market)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	7.3	6.8	6.6	6.3	5.8	5.2	4.9
Total IC	6.6	6.1	5.8	5.5	5.0	4.5	4.2
Bipolar Digital	3.6	2.8	2.4	2.1	1.8	1.5	1.2
Bipolar Memory	1.5	1.5	1.3	1.2	1.0	0.9	0.8
Bipolar Logic	3.8	3.1	2.5	2.2	1.8	1.5	1.3
MOS	4.3	4.0	3.5	3.1	2.8	2.5	2.2
MOS Memory	4.8	4.3	3.6	3.2	2.8	2.5	2.1
MOS Micro	4.5	4.0	3.6	3.3	3.0	2.8	2.5
MOS Logic	3.4	3.2	2.9	2.7	2.6	2.4	2.2
Analog	19.3	19.2	18.6	18.4	17.9	17.5	16.9
Discrete	13.8	13.8	13.9	13.9	14.2	14.3	14.2
Opto	5.1	5.0	4.9	4.9	4.7	4.7	4.6

Source: Dataquest (July 1990)

Table 27

Forecast North American Merchant Semiconductor Revenue
Consumer
(Product Family Percentage Share of Total Semiconductor)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total IC	78.5	79.6	77.5	78.2	77.4	78.5	78.7
Bipolar Digital	6.2	4.0	3.3	2.7	2.2	1.7	1.2
Bipolar Memory	0.3	0.3	0.2	0.2	0.1	0.1	0.1
Bipolar Logic	5.9	3.7	3.0	2.5	2.1	1.6	1.1
MOS	35.9	37.9	33.5	32.6	33.4	35.4	33.3
MOS Memory	17.7	21.4	16.6	16.2	16.9	18.0	16.9
MOS Micro	10.5	9.1	9.3	8.8	8.6	9.3	8.8
MOS Logic	7.6	7.4	7.6	7.6	7.9	8.1	7.6
Analog	36.5	37.7	40.7	42.9	41.7	41.5	44.1
Discrete	20.0	19.0	21.0	20.4	21.3	20.2	20.0
Opto	1.5	1.5	1.5	1.5	1.4	1.3	1.3

Source: Dataquest (July 1990)

Table 28

Forecast North American Electronic Equipment Production
Industrial
(Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR (%) 1989-1990	CAGR (%) 1989-1994
Factory Revenue	43,624	46,899	49,989	54,742	59,199	63,514	68,230	6.6	7.8

Source: Dataquest (July 1990)

Table 29
Forecast North American Merchant Semiconductor Revenue
Industrial
(Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR (%) 1989-1990	CAGR (%) 1989-1994
Total Semiconductor	2,115	2,288	2,341	2,744	3,319	4,153	4,636	2.3	15.2
Total IC	1,403	1,587	1,623	1,982	2,457	3,227	3,677	2.2	18.3
Bipolar Digital	178	130	104	98	91	84	65	(20.2)	(13.0)
Bipolar Memory	20	20	16	13	11	9	7	(21.8)	(19.2)
Bipolar Logic	158	109	88	85	81	75	58	(19.9)	(12.0)
MOS	822	991	1,012	1,254	1,639	2,259	2,559	2.2	20.9
MOS Memory	236	330	267	322	412	560	610	(18.9)	13.1
MOS Micro	216	230	258	314	399	576	673	12.1	24.0
MOS Logic	370	431	487	618	827	1,124	1,276	13.0	24.2
Analog	403	466	507	630	727	884	1,053	8.6	17.7
Discrete	601	591	611	648	743	801	825	3.4	6.9
Opto	111	109	107	114	118	126	134	(2.2)	4.1

Source: Dataquest (July 1990)

Table 30
Forecast North American Merchant Semiconductor Revenue
Industrial
(Input/Output Ratios, Percentage)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	4.8	4.9	4.7	5.0	5.6	6.5	6.8
Total IC	3.2	3.4	3.2	3.6	4.2	5.1	5.4
Bipolar Digital	0.4	0.3	0.2	0.2	0.2	0.1	0.1
Bipolar Memory	0	0	0	0	0	0	0
Bipolar Logic	0.4	0.2	0.2	0.2	0.1	0.1	0.1
MOS	1.9	2.1	2.0	2.3	2.8	3.6	3.8
MOS Memory	0.5	0.7	0.5	0.6	0.7	0.9	0.9
MOS Micro	0.5	0.5	0.5	0.6	0.7	0.9	1.0
MOS Logic	0.8	0.9	1.0	1.1	1.4	1.8	1.9
Analog	0.9	1.0	1.0	1.2	1.2	1.4	1.5
Discrete	1.4	1.3	1.2	1.2	1.3	1.3	1.2
Opto	0.3	0.2	0.2	0.2	0.2	0.2	0.2

Source: Dataquest (July 1990)

Table 31

Forecast North American Electronic Equipment Production
Industrial
(Annual Percentage Growth)

	1989	1990	1991	1992	1993	1994
Factory Revenue	7.5	6.6	9.5	8.1	7.3	7.4

Source: Dataquest (July 1990)

Table 32

Forecast North American Merchant Semiconductor Revenue
Industrial
(Annual Percentage Growth)

	1989	1990	1991	1992	1993	1994
Total Semiconductor	8.1	2.3	17.2	20.9	25.1	11.6
Total IC	13.1	2.2	22.1	24.0	31.3	13.9
Bipolar Digital	(27.2)	(20.2)	(5.2)	(7.0)	(7.8)	(23.2)
Bipolar Memory	(0.2)	(21.8)	(17.4)	(20.1)	(15.6)	(21.0)
Bipolar Logic	(30.7)	(19.9)	(3.0)	(5.0)	(6.8)	(23.5)
MOS	20.6	2.2	23.9	30.7	37.8	13.3
MOS Memory	40.0	(18.9)	20.2	28.3	35.7	9.0
MOS Micro	6.4	12.1	22.1	27.0	44.1	16.8
MOS Logic	16.6	13.0	26.8	33.9	35.8	13.6
Analog	15.6	8.6	24.3	15.4	21.6	19.2
Discrete	(1.6)	3.4	6.0	14.7	7.7	3.0
Opto	(1.5)	(2.2)	7.0	3.3	6.1	6.4

Source: Dataquest (July 1990)

Table 33

Forecast North American Merchant Semiconductor Revenue Industrial (Percentage of Product Family Market)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	13.4	12.9	13.6	13.8	13.8	13.6	13.8
Total IC	10.2	10.1	10.8	11.2	11.4	11.6	12.0
Bipolar Digital	8.9	7.6	6.6	5.9	5.3	4.6	4.0
Bipolar Memory	8.7	8.5	7.7	7.1	6.4	5.8	5.2
Bipolar Logic	8.9	7.4	6.4	5.8	5.1	4.5	3.8
MOS	8.6	8.5	9.2	9.5	9.9	10.1	10.3
MOS Memory	5.5	5.4	5.2	5.0	4.9	4.8	4.6
MOS Micro	8.0	8.4	8.9	9.4	10.1	10.9	11.5
MOS Logic	14.2	15.4	16.5	17.9	19.5	21.1	22.6
Analog	18.4	19.6	20.4	21.6	22.4	23.5	24.4
Discrete	35.9	35.6	35.5	35.3	35.9	35.8	35.3
Opto	31.5	31.0	30.3	30.0	29.2	28.6	28.0

Source: Dataquest (July 1990)

Table 34

Forecast North American Merchant Semiconductor Revenue Industrial (Product Family Percentage Share of Total Semiconductor)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total IC	66.3	69.4	69.3	72.2	74.0	77.7	79.3
Bipolar Digital	8.4	5.7	4.4	3.6	2.8	2.0	1.4
Bipolar Memory	1.0	0.9	0.7	0.5	0.3	0.2	0.2
Bipolar Logic	7.5	4.8	3.7	3.1	2.4	1.8	1.2
MOS	38.8	43.3	43.2	45.7	49.4	54.4	55.2
MOS Memory	11.1	14.4	11.4	11.7	12.4	13.5	13.2
MOS Micro	10.2	10.0	11.0	11.5	12.0	13.9	14.5
MOS Logic	17.5	18.9	20.8	22.5	24.9	27.1	27.5
Analog	19.1	20.4	21.6	22.9	21.9	21.3	22.7
Discrete	28.4	25.8	26.1	23.6	22.4	19.3	17.8
Opto	5.3	4.8	4.6	4.2	3.6	3.0	2.9

Source: Dataquest (July 1990)

Table 35

Forecast North American Electronic Equipment Production Military (Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR (%) 1989-1990	CAGR (%) 1989-1994
Factory Revenue	51,063	51,727	52,918	54,263	55,845	57,866	59,998	2.3	3.0

Source: Dataquest (July 1990)

Table 36

Forecast North American Merchant Semiconductor Revenue Military (Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR (%) 1989-1990	CAGR (%) 1989-1994
Total Semiconductor	1,669	1,679	1,716	1,766	1,843	1,946	2,069	2.2	4.3
Total IC	1,313	1,338	1,375	1,417	1,484	1,575	1,684	2.7	4.7
Bipolar Digital	368	356	336	309	284	263	243	(5.6)	(7.4)
Bipolar Memory	66	58	51	44	39	35	32	(12.8)	(11.1)
Bipolar Logic	302	298	286	265	246	228	211	(4.2)	(6.7)
MOS	619	671	727	791	868	955	1,054	8.4	9.5
MOS Memory	241	268	291	315	345	382	423	8.5	9.6
MOS Micro	141	150	162	176	195	215	238	8.0	9.7
MOS Logic	237	253	274	299	328	359	393	8.5	9.2
Analog	326	312	312	318	332	357	387	0	4.5
Discrete	293	281	283	288	295	303	311	0.5	2.0
Opto	63	60	59	61	64	69	74	(1.5)	4.3

Source: Dataquest (July 1990)

Table 37

Forecast North American Merchant Semiconductor Revenue
Military
(Input/Output Ratios, Percentage)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	3.3	3.2	3.2	3.3	3.3	3.4	3.4
Total IC	2.6	2.6	2.6	2.6	2.7	2.7	2.8
Bipolar Digital	0.7	0.7	0.6	0.6	0.5	0.5	0.4
Bipolar Memory	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Bipolar Logic	0.6	0.6	0.5	0.5	0.4	0.4	0.4
MOS	1.2	1.3	1.4	1.5	1.6	1.7	1.8
MOS Memory	0.5	0.5	0.5	0.6	0.6	0.7	0.7
MOS Micro	0.3	0.3	0.3	0.3	0.3	0.4	0.4
MOS Logic	0.5	0.5	0.5	0.6	0.6	0.6	0.7
Analog	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Discrete	0.6	0.5	0.5	0.5	0.5	0.5	0.5
Opto	0.1	0.1	0.1	0.1	0.1	0.1	0.1

Source: Dataquest (July 1990)

Table 38

Forecast North American Electronic Equipment Production
Military
(Annual Percentage Growth)

	1989	1990	1991	1992	1993	1994
Factory Revenue	1.3	2.3	2.5	2.9	3.6	3.7

Source: Dataquest (July 1990)

Table 39

Forecast North American Merchant Semiconductor Revenue
Military
(Annual Percentage Growth)

	1989	1990	1991	1992	1993	1994
Total Semiconductor	0.6	2.2	2.9	4.4	5.6	6.3
Total IC	1.9	2.7	3.1	4.7	6.1	7.0
Bipolar Digital	(3.3)	(5.6)	(8.1)	(8.0)	(7.6)	(7.4)
Bipolar Memory	(12.0)	(12.8)	(12.5)	(12.2)	(9.8)	(8.3)
Bipolar Logic	(1.4)	(4.2)	(7.3)	(7.3)	(7.3)	(7.3)
MOS	8.3	8.4	8.8	9.7	10.1	10.3
MOS Memory	11.1	8.5	8.5	9.5	10.5	11.0
MOS Micro	6.3	8.0	9.0	10.6	10.5	10.5
MOS Logic	6.8	8.5	9.0	9.5	9.5	9.5
Analog	(4.5)	0	2.0	4.5	7.5	8.5
Discrete	(3.8)	0.5	1.8	2.3	2.7	2.7
Opto	(5.1)	(1.5)	2.5	6.4	7.0	7.5

Source: Dataquest (July 1990)

Table 40

Forecast North American Merchant Semiconductor Revenue
Military
(Percentage of Product Family Market)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	10.5	9.5	10.0	8.9	7.7	6.4	6.2
Total IC	9.5	8.5	9.1	8.0	6.9	5.7	5.5
Bipolar Digital	18.3	20.8	21.4	18.7	16.4	14.5	14.9
Bipolar Memory	28.0	24.2	24.4	23.6	23.5	22.9	23.6
Bipolar Logic	17.0	20.3	20.9	18.0	15.6	13.7	14.1
MOS	6.4	5.8	6.6	6.0	5.2	4.3	4.3
MOS Memory	5.6	4.4	5.6	4.9	4.1	3.3	3.2
MOS Micro	5.2	5.5	5.6	5.3	4.9	4.1	4.1
MOS Logic	9.1	9.0	9.3	8.7	7.7	6.7	6.9
Analog	14.9	13.1	12.5	10.9	10.3	9.5	9.0
Discrete	17.5	17.0	16.4	15.7	14.2	13.5	13.3
Opto	17.9	17.0	16.7	15.8	15.9	15.7	15.5

Source: Dataquest (July 1990)

Table 41

Forecast North American Merchant Semiconductor Revenue
Military
(Product Family Percentage Share of Total Semiconductor)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total IC	78.7	79.7	80.1	80.3	80.5	80.9	81.4
Bipolar Digital	22.1	21.2	19.6	17.5	15.4	13.5	11.7
Bipolar Memory	3.9	3.4	2.9	2.5	2.1	1.8	1.6
Bipolar Logic	18.1	17.8	16.6	15.0	13.3	11.7	10.2
MOS	37.1	39.9	42.3	44.8	47.1	49.1	50.9
MOS Memory	14.4	15.9	16.9	17.9	18.7	19.6	20.5
MOS Micro	8.4	8.9	9.4	10.0	10.6	11.1	11.5
MOS Logic	14.2	15.1	16.0	16.9	17.8	18.4	19.0
Analog	19.6	18.5	18.1	18.0	18.0	18.3	18.7
Discrete	17.5	16.8	16.5	16.3	16.0	15.5	15.0
Opto	3.8	3.6	3.4	3.4	3.5	3.5	3.6

Source: Dataquest (July 1990)

Table 42

Forecast North American Electronic Equipment Production
Transportation
(Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR (%) 1989-1990	CAGR (%) 1989-1994
Factory Revenue	10,744	11,292	11,828	12,897	13,952	14,836	15,449	4.7	6.5

Source: Dataquest (July 1990)

Table 43

Forecast North American Merchant Semiconductor Revenue Transportation (Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR (%) 1989-1990	CAGR (%) 1989-1994
Total Semiconductor	946	957	971	1,045	1,114	1,184	1,239	1.5	5.3
Total IC	740	752	765	828	886	945	992	1.8	5.7
Bipolar Digital	51	45	38	33	27	23	20	(14.8)	(15.2)
Bipolar Memory	20	16	12	10	7	6	4	(20.0)	(23.0)
Bipolar Logic	31	29	26	23	20	18	15	(12.0)	(12.0)
MOS	410	428	446	497	541	585	620	4.3	7.7
MOS Memory	155	157	161	181	198	214	226	2.5	7.5
MOS Micro	192	203	214	234	251	268	280	5.0	6.6
MOS Logic	63	67	72	82	92	103	114	6.5	11.1
Analog	278	279	281	299	318	337	353	0.5	4.8
Discrete	185	182	183	194	203	212	221	0.5	3.9
Opto	22	23	23	24	25	26	27	0.9	3.1

Source: Dataquest (July 1990)

Table 44

Forecast North American Merchant Semiconductor Revenue Transportation (Input/Output Ratios, Percentage)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	8.8	8.5	8.2	8.1	8.0	8.0	8.0
Total IC	6.9	6.7	6.5	6.4	6.4	6.4	6.4
Bipolar Digital	0.5	0.4	0.3	0.3	0.2	0.2	0.1
Bipolar Memory	0.2	0.1	0.1	0.1	0.1	0	0
Bipolar Logic	0.3	0.3	0.2	0.2	0.1	0.1	0.1
MOS	3.8	3.8	3.8	3.8	3.9	3.9	4.0
MOS Memory	1.4	1.4	1.4	1.4	1.4	1.4	1.5
MOS Micro	1.8	1.8	1.8	1.8	1.8	1.8	1.8
MOS Logic	0.6	0.6	0.6	0.6	0.7	0.7	0.7
Analog	2.6	2.5	2.4	2.3	2.3	2.3	2.3
Discrete	1.7	1.6	1.5	1.5	1.5	1.4	1.4
Opto	0.2	0.2	0.2	0.2	0.2	0.2	0.2

Source: Dataquest (July 1990)

Table 45

Forecast North American Electronic Equipment Production
Transportation
(Annual Percentage Growth)

	1989	1990	1991	1992	1993	1994
Factory Revenue	5.1	4.7	9.0	8.2	6.3	4.1

Source: Dataquest (July 1990)

Table 46

Forecast North American Merchant Semiconductor Revenue
Transportation
(Annual Percentage Growth)

	1989	1990	1991	1992	1993	1994
Total Semiconductor	1.1	1.5	7.6	6.6	6.2	4.7
Total IC	1.6	1.8	8.2	7.1	6.7	4.9
Bipolar Digital	(12.2)	(14.8)	(14.7)	(16.0)	(15.4)	(15.2)
Bipolar Memory	(21.3)	(20.0)	(20.2)	(25.3)	(24.3)	(25.0)
Bipolar Logic	(6.4)	(12.0)	(12.1)	(11.9)	(12.1)	(12.0)
MOS	4.3	4.3	11.2	8.9	8.2	6.0
MOS Memory	1.6	2.5	12.5	9.0	8.5	5.5
MOS Micro	5.7	5.0	9.5	7.5	6.5	4.5
MOS Logic	6.3	6.5	13.5	12.5	12.0	10.9
Analog	0.3	0.5	6.5	6.5	6.0	4.5
Discrete	(1.3)	0.5	5.6	5.0	4.5	4.0
Opto	3.2	0.9	4.4	4.2	4.0	2.3

Source: Dataquest (July 1990)

Table 47

Forecast North American Merchant Semiconductor Revenue
Transportation
(Percentage of Product Family Market)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	6.0	5.4	5.7	5.2	4.6	3.9	3.7
Total IC	5.4	4.8	5.1	4.7	4.1	3.4	3.2
Bipolar Digital	2.5	2.6	2.4	2.0	1.6	1.3	1.2
Bipolar Memory	8.4	6.5	6.0	5.3	4.5	3.7	3.1
Bipolar Logic	1.8	2.0	1.9	1.5	1.3	1.1	1.0
MOS	4.3	3.7	4.0	3.8	3.3	2.6	2.5
MOS Memory	3.6	2.6	3.1	2.8	2.4	1.8	1.7
MOS Micro	7.1	7.4	7.3	7.0	6.3	5.0	4.8
MOS Logic	2.4	2.4	2.4	2.4	2.2	1.9	2.0
Analog	12.7	11.7	11.3	10.3	9.8	9.0	8.2
Discrete	11.0	11.0	10.6	10.6	9.8	9.5	9.5
Opto	6.2	6.4	6.5	6.3	6.1	5.9	5.6

Source: Dataquest (July 1990)

Table 48

Forecast North American Merchant Semiconductor Revenue
Transportation
(Product Family Percentage Share of Total Semiconductor)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total IC	78.1	78.6	78.8	79.2	79.5	79.9	80.0
Bipolar Digital	5.4	4.7	3.9	3.1	2.4	2.0	1.6
Bipolar Memory	2.1	1.6	1.3	0.9	0.7	0.5	0.3
Bipolar Logic	3.3	3.1	2.6	2.2	1.8	1.5	1.2
MOS	43.4	44.7	46.0	47.5	48.5	49.4	50.0
MOS Memory	16.3	16.4	16.6	17.3	17.7	18.1	18.3
MOS Micro	20.3	21.2	22.0	22.4	22.6	22.6	22.6
MOS Logic	6.7	7.0	7.4	7.8	8.2	8.7	9.2
Analog	29.4	29.2	28.9	28.6	28.6	28.5	28.4
Discrete	19.5	19.1	18.9	18.5	18.2	17.9	17.8
Opto	2.3	2.4	2.4	2.3	2.2	2.2	2.1

Source: Dataquest (July 1990)

Semiconductor Shipments

INTRODUCTION

Semiconductor shipment data comprise a set of detailed tables that estimate the size of the semiconductor total available market (TAM) worldwide and for four major geographical regions for the years 1979 through 1994 and 1999. Semiconductor shipment tables contain both historical data and forecasts. Historical data begin with 1979 and end with 1988, while forecast data provide annual market size estimates for 1989 through 1994, with additional estimates for 1999. Below is a list of tables detailing the type of data, region, time period, and units of measure.

LIST OF TABLES

(Continued)

LIST OF TABLES (Continued)

Each table gives estimates of semiconductor shipments listed by the major semiconductor device product categories. In these tables, semiconductor components are divided into three major product groups: integrated circuits, discrete devices, and optoelectronic devices. These groups are divided into a number of subgroups, some of which are segmented further.

DEFINITIONS AND CONVENTIONS

Dataquest uses a common manufacturer base for all data tables. This base includes all suppliers to the merchant semiconductor market. It includes aggregate revenue estimates for North American companies that manufacture devices solely for the benefit of the parent company, such as Burroughs, Delco, and IBM. Also included are companies that actively market semiconductor devices to the merchant market as well as to other divisions of their own companies. For such companies, both external and internal shipments are included. Devices that are used internally are valued at current market prices.

Shipment—Dataquest defines shipment as the purchase of a semiconductor device or devices. This definition must be differentiated from actual use of the device in a final product. A regional market size includes all devices sold to or shipped to that region, i.e., the total available market (TAM) in that region.

Hybrids—In earlier consumption data, hybrid devices were included as a separate segment of integrated circuits. Hybrid devices manufactured by semiconductor companies are now included in the most appropriate product segment, usually the analog segment.

The manufacturer base, product group definitions, and guidelines for including value of output that we have used in our tables may differ from those used in other studies of this type. Our base is nearly the same as that used by the World Semiconductor Trade Statistics program (WSTS), with the following exceptions:

- Dataquest includes all of AT&T's semiconductor revenue, both merchant and captive.
- Dataquest includes—and has included all along—nonrecurring engineering (NRE) charges associated with application-specific integrated circuit (ASIC) revenue. (This applies to both the bipolar digital and MOS digital logic categories.)
- Dataquest includes the revenue generated by sales of standalone circuit design software, sold by certain U.S. manufacturers of ASIC logic devices.
- Dataquest includes Signetics revenue with that of its parent company, Netherlands-based N.V. Philips.
- Dataquest includes revenue for Taiwanese semiconductor manufacturers.

- Dataquest includes revenue for three Japanese companies not estimated by WSTS: NBM Semiconductor, Seiko-Epson, and Yamaha.
- As noted herein, Dataquest includes hybrid revenue in the analog category.

Further information on the above points is available through Dataquest's Client Inquiry Center at (408) 437-8099.

Regions—North America is defined as including both the United States and Canada. Latin America, including Mexico, is considered part of the Rest of World (ROW) category. The ROW region also includes Asia/Pacific (including South Korea, Taiwan, Hong Kong, Singapore, and China). Western Europe includes Austria, Belgium, the Federal Republic of Germany, France, Italy, Luxembourg, the Scandinavian countries (Denmark, Finland, Norway, Sweden), Spain, and the United Kingdom and the rest of Europe. Japan, the fourth region, is the only single-country region.

DATA SOURCES

The information presented in the consumption data has been consolidated from a variety of sources, each of which focuses on a specific part of the market. These sources include the following:

- World Semiconductor Trade Statistics (WSTS) data, and Dataquest's estimates of regional company sales are used to determine shipments to North America.
- Japanese trade statistics compiled and published by the Ministry of Finance (MOF) and the Ministry of International Trade and Industry (MITI), WSTS data, and Dataquest's estimates of regional company sales are used to determine shipments to Japan.
- For Western European markets, marketing statistics from WSTS data and Dataquest's estimates of regional company sales are used to determine market size.
- In ROW, the major published sources used to estimate market size are WSTS data and Dataquest's estimates of company shipments into the region.

Dataquest believes that the estimates presented here are the most accurate and meaningful generally available today. The sources of the data and the guidelines for the forecasts presented in the tables are as follows:

- Unit sales or revenue (or both) published by major industry participants, both in the United States and abroad
- Estimates presented by knowledgeable and reliable industry spokesmen
- Government data or trade association data such as those from the Electronics Industry Association (EIA), MITI, WSTS, and the U.S. Department of Commerce
- Published product literature and price lists
- Interviews with knowledgeable manufacturers, distributors, and users
- Relevant projected world economic data

ACCURACY

The tables presented here represent Dataquest estimates that we believe are reasonably accurate. Where we have no reasonable estimate, none is given. A zero in a table represents an estimate.

VALUATION OF SHIPMENTS

Regional market size is expressed in U.S. dollars (with the Japanese market also expressed in yen). To make the tables in this study useful in comparing different regions, it is necessary to express all values in a common currency, and we chose the U.S. dollar for convenience. However, the choice of the U.S. dollar (or any single currency, for that matter) as the currency basis for the tables brings with it some problems that require the readers' careful consideration in interpreting the data.

Inflation

All countries that participate significantly in international semiconductor markets suffered from an overall price inflation in the 1970s, continuing into the 1980s.

As a consequence, the dollar in a given year is not truly comparable with the dollar in any preceding year. Consumer and wholesale price indices and GNP deflators all measure price changes in various composite "market baskets" of goods. However, there is no price index that measures price changes of material, equipment, and labor inputs to the semiconductor industry. Indeed, the "mix" is changing so rapidly that what is used this year was sometimes unavailable last year, at any price. Nor is there a composite price index that measures price changes in aggregate semiconductor product. In an industry noted for its deflationary trends, this latter effect would tend to make the component purchaser's dollar worth more as time passed, in terms of purchasing ability.

We have made no adjustments in the historical data to account for these inflationary and deflationary effects. The data are expressed in current dollars (dollars that include the inflation rate and exchange rates of the given year) for all historical data; comparisons between different years must be interpreted accordingly.

Average Selling Prices

When considering the worldwide average selling prices (ASPs) for semiconductor components, one must look at the price per function of a circuit, the complexity of the circuit, and the product mix according to this increasing complexity. It is true that one characteristic of the semiconductor industry is that the price per function for integrated circuits has been dropping an average of 30 percent per year for the last 15 years. At the same time, circuits have become denser, resulting in an overall increase in the price of a device with a decreasing cost per function. Thus, Tables 3a through 3g show the worldwide ASPs increasing after many years of decreasing, due to the move toward higher-complexity devices. There are also regional differences in ASPs due to regional competition differences and the varying regional product consumption mix. The worldwide ASP is truly an aggregate measure and may differ significantly from ASPs in any specific market at any point in time.

Exchange Rates

Construction of the West European tables involves combining data from many countries, each of which has different and changing exchange rates. Dataquest uses Annual Foreign Exchange Rates for each year as published by The International Monetary Fund. As far as possible, we prepare our estimates in terms of local currencies before conversion to U.S. dollars. The exchange rates for major currencies can be found in Table 0 at the end of this introduction.

FORECAST

As mentioned previously, historical data are expressed in current dollars or dollars that include the given year's inflation rate and exchange rates. However, the shipment forecasts use constant dollars and exchange rates, with no allowance for inflation or variations in the rates of exchange between countries. All estimates for 1989 and beyond are made as if 1989 monetary conditions will continue through 1999 and, therefore, show the absolute year-to-year growth during this period.

Table 0

Foreign Exchange Rates (In U.S. Dollars)

Year	Yrly/ Qtrly	Japan (Yen per US$)	France (US$ per Franc)	West Germany (US$ per Deutsche Mark)	United Kingdom (US$ per Pound Sterling)	European Basket ECU (1980 = 100)
1970	YR	358	0.18	0.27	2.38	
1971	YR	343	0.18	0.29	2.44	
1972	YR	302	0.20	0.31	2.50	
1973	YR	269	0.22	0.37	2.44	
1974	YR	292	0.21	0.39	2.33	
1975	YR	297	0.23	0.41	2.22	
1976	YR	296	0.21	0.40	1.82	
1977	YR	269	0.20	0.43	1.75	
1978	YR	210	0.22	0.50	1.92	
1979	YR	219	0.24	0.55	2.13	
1980	YR	227	0.24	0.55	2.33	100
1981	YR	221	0.18	0.44	2.04	124
1982	YR	248	0.15	0.41	1.75	141
1983	YR	235	0.13	0.39	1.52	158
1984	YR	237	0.11	0.35	1.33	178
1985	YR	238	0.11	0.34	1.30	185
1986	YR	167	0.14	0.46	1.47	146
1987	YR	144	0.17	0.56	1.64	126
1988	YR	130	0.17	0.57	1.79	121

Source: The International Monetary Fund
Financial Times
Dataquest
February 1990

Table 1a

Worldwide Semiconductor Market
(Millions of Dollars)

	1979	1980	1981	1982	1983
Total Including Captives	11,114	14,118	14,828	15,261	21,552
North American Captives	N/A	N/A	N/A	N/A	2,015
Total Semiconductor	11,114	14,118	14,828	15,261	19,537
Total IC	7,028	9,546	10,046	10,894	14,700
Bipolar Digital	1,674	2,374	2,337	2,412	3,015
Memory	324	572	558	511	603
Logic	1,350	1,802	1,779	1,901	2,412
MOS Digital	3,346	4,715	4,822	5,642	7,951
Memory	1,676	2,230	2,075	2,701	3,719
Micro	541	862	1,085	1,318	1,979
Logic	1,129	1,623	1,662	1,623	2,253
Analog	2,008	2,457	2,887	2,840	3,734
Total Discrete	3,522	3,883	3,985	3,547	3,865
Total Optoelectronic	564	689	797	820	972

N/A = Not Available

Source: Dataquest
February 1990

Table 1b

Worldwide Semiconductor Market
(Millions of Dollars)

	1984	1985	1986	1987	1988	1989
Total Including Captives	31,403	27,130	33,729	41,478	54,521	60,504
North American Captives	2,500	2,773	2,895	3,227	3,662	4,065
Total Semiconductor	28,903	24,357	30,834	38,251	50,859	56,439
Total IC	22,686	18,555	23,618	29,887	41,068	46,761
Bipolar Digital	4,771	3,672	4,325	4,760	5,200	4,409
Memory	774	589	606	621	689	543
Logic	3,997	3,083	3,719	4,139	4,511	3,866
MOS Digital	12,970	10,122	12,815	17,473	26,988	33,554
Memory	6,229	3,821	4,511	6,056	11,692	16,884
Micro	3,234	2,748	3,489	5,108	7,144	7,431
Logic	3,507	3,553	4,815	6,309	8,152	9,239
Analog	4,945	4,761	6,478	7,654	8,880	8,798
Total Discrete	4,987	4,576	5,730	6,655	7,612	7,622
Total Optoelectronic	1,230	1,226	1,486	1,709	2,179	2,056

Source: Dataquest
February 1990

Table 1c

Worldwide Semiconductor Market (Millions of Dollars)

	1990	1991	1992	1993	1994	1999
Total Including Captives	61,460	70,678	85,130	111,830	121,386	254,535
North American Captives	4,165	4,767	5,723	7,518	8,107	20,740
Total Semiconductor	57,295	65,911	79,407	104,312	113,279	233,795
Total IC	47,537	55,111	67,301	90,264	97,765	210,688
Bipolar Digital	4,089	4,255	4,497	4,832	4,577	4,185
Memory	497	492	457	442	421	239
Logic	3,592	3,763	4,040	4,390	4,156	3,946
MOS Digital	34,474	40,385	50,312	69,981	75,630	174,069
Memory	17,078	19,415	24,143	35,417	38,300	91,985
Micro	7,781	9,412	11,666	15,914	17,486	39,410
Logic	9,615	11,558	14,503	18,650	19,844	42,674
Analog	8,974	10,471	12,492	15,451	17,558	32,434
Total Discrete	7,649	8,424	9,380	10,835	11,873	17,264
Total Optoelectronic	2,109	2,376	2,726	3,213	3,641	5,843

Source: Dataquest
February 1990

Table 1d

Worldwide Semiconductor Market (Percent Change)

	1979	1980	1981	1982	1983
Total Including Captives	N/A	N/A	N/A	N/A	N/A
North American Captives	N/A	N/A	N/A	N/A	N/A
Total Semiconductor	24.1%	27.0%	5.0%	2.9%	28.0%
Total IC	34.4%	35.8%	5.2%	8.4%	34.9%
Bipolar Digital	32.8%	41.8%	(1.6%)	3.2%	25.0%
Memory	N/A	76.5%	(2.4%)	(8.4%)	18.0%
Logic	N/A	33.5%	(1.3%)	6.9%	26.9%
MOS Digital	43.5%	40.9%	2.3%	17.0%	40.9%
Memory	N/A	33.1%	(7.0%)	30.2%	37.7%
Micro	N/A	59.3%	25.9%	21.5%	50.2%
Logic	N/A	43.8%	2.4%	(2.3%)	38.8%
Analog	22.7%	22.4%	17.5%	(1.6%	31.5%
Total Discrete	6.7%	10.2%	2.6%	(11.0%)	9.0%
Total Optoelectronic	33.6%	22.2%	15.7%	2.9%	18.5%

N/A = Not Available

Source: Dataquest
February 1990

Table 1e

Worldwide Semiconductor Market (Percent Change)

	1984	1985	1986	1987	1988	1989
Total Including Captives	45.7%	(13.6%)	24.3%	23.0%	31.4%	11.0%
North American Captives	24.1%	10.9%	4.4%	11.5%	13.5%	11.0%
Total Semiconductor	47.9%	(15.7%)	26.6%	24.1%	33.0%	11.0%
Total IC	54.3%	(18.2%)	27.3%	26.5%	37.4%	13.9%
Bipolar Digital	58.2%	(23.0%)	17.8%	10.1%	9.2%	(15.2%)
Memory	28.4%	(23.9%)	2.9%	2.5%	11.0%	(21.2%)
Logic	65.7%	(22.9%)	20.6%	11.3%	9.0%	(14.3%)
MOS Digital	63.1%	(22.0%)	26.6%	36.3%	54.5%	24.3%
Memory	67.5%	(38.7%)	18.1%	34.2%	93.1%	44.4%
Micro	63.4%	(15.0%)	27.0%	46.4%	39.9%	4.0%
Logic	55.7%	1.3%	35.5%	31.0%	29.2%	13.3%
Analog	32.4%	(3.7%)	36.1%	18.2%	16.0%	(0.9%)
Total Discrete	29.0%	(8.2%)	25.2%	16.1%	14.4%	0.1%
Total Optoelectronic	26.5%	(0.3%)	21.2%	15.0%	27.5%	(5.6%)

Source: Dataquest
February 1990

Table 1f

Worldwide Semiconductor Market (Percent Change)

	1990	1991	1992	1993	1994
Total Including Captives	1.6%	15.0%	20.4%	31.4%	8.5%
North American Captives	2.5%	14.5%	20.1%	31.4%	7.8%
Total Semiconductor	1.5%	15.0%	20.5%	31.4%	8.6%
Total IC	1.7%	15.9%	22.1%	34.1%	8.3%
Bipolar Digital	(7.3%)	4.1%	5.7%	7.4%	(5.3%)
Memory	(8.5%)	(1.0%)	(7.1%)	(3.3%)	(4.8%)
Logic	(7.1%)	4.8%	7.4%	8.7%	(5.3%)
MOS Digital	2.7%	17.1%	24.6%	39.1%	8.1%
Memory	1.1%	13.7%	24.4%	46.7%	8.1%
Micro	4.7%	21.0%	23.9%	36.4%	9.9%
Logic	4.1%	20.2%	25.5%	28.6%	6.4%
Analog	2.0%	16.7%	19.3%	23.7%	13.6%
Total Discrete	0.4%	10.1%	11.3%	15.5%	9.6%
Total Optoelectronic	2.6%	12.7%	14.7%	17.9%	13.3%

Source: Dataquest
February 1990

Table 1g

Worldwide Semiconductor Market (Compound Annual Growth Rates)

	CAGR (79-84)	CAGR (84-89)	CAGR (89-94)	CAGR (94-99)	CAGR (79-89)	CAGR (89-99)
Total Including Captives	N/A	14.0%	14.9%	16.0%	N/A	15.5%
North American Captives	N/A	10.2%	14.8%	20.7%	N/A	17.7%
Total Semiconductor	21.1%	14.3%	15.0%	15.6%	17.6%	15.3%
Total IC	26.4%	15.6%	15.9%	16.6%	20.9%	16.2%
Bipolar Digital	23.3%	(1.6%)	0.8%	(1.8%)	10.2%	(0.5%)
Memory	19.0%	(6.8%)	(5.0%)	(10.7%)	5.3%	(7.9%)
Logic	24.2%	(0.7%)	1.5%	(1.0%)	11.1%	0.2%
MOS Digital	31.1%	20.9%	17.6%	18.1%	25.9%	17.9%
Memory	30.0%	22.1%	17.8%	19.2%	26.0%	18.5%
Micro	43.0%	18.1%	18.7%	17.6%	30.0%	18.2%
Logic	25.4%	21.4%	16.5%	16.5%	23.4%	16.5%
Analog	19.8%	12.2%	14.8%	13.1%	15.9%	13.9%
Total Discrete	7.2%	8.9%	9.3%	7.8%	8.0%	8.5%
Total Optoelectronic	16.9%	10.8%	12.1%	9.9%	13.8%	11.0%

N/A = Not Available

Source: Dataquest February 1990

Table 2a

North American Semiconductor Market
(Millions of Dollars)

	1979	1980	1981	1982	1983
Total Including Captives	4,538	6,053	6,529	6,970	10,625
North American Captives	N/A	N/A	N/A	N/A	1,623
Total Semiconductor	4,538	6,053	6,529	6,970	9,002
Total IC	3,179	4,562	4,867	5,466	7,301
Bipolar Digital	901	1,411	1,339	1,367	1,664
Memory	185	396	375	320	373
Logic	716	1,015	964	1,047	1,291
MOS Digital	1,703	2,442	2,595	3,183	4,326
Memory	1,028	1,230	1,107	1,592	2,051
Micro	186	377	489	641	1,034
Logic	489	835	999	950	1,241
Analog	575	709	933	916	1,311
Total Discrete	1,161	1,269	1,378	1,201	1,353
Total Optoelectronic	198	222	284	303	348

N/A = Not Available

Source: Dataquest
February 1990

Table 2b

North American Semiconductor Market
(Millions of Dollars)

	1984	1985	1986	1987	1988	1989
Total Including Captives	15,033	11,663	13,171	15,454	18,789	21,395
North American Captives	2,027	2,243	2,327	2,596	2,945	3,271
Total Semiconductor	13,006	9,420	10,844	12,858	15,844	18,124
Total IC	11,089	7,757	8,986	10,886	13,815	16,073
Bipolar Digital	2,818	1,926	2,030	2,099	2,012	1,732
Memory	441	288	267	271	235	215
Logic	2,377	1,638	1,763	1,828	1,777	1,517
MOS Digital	6,503	4,322	4,912	6,738	9,606	12,218
Memory	3,426	1,753	1,775	2,497	4,298	6,447
Micro	1,634	1,258	1,362	2,012	2,707	2,745
Logic	1,443	1,311	1,775	2,229	2,601	3,026
Analog	1,768	1,509	2,044	2,049	2,197	2,123
Total Discrete	1,503	1,295	1,542	1,642	1,676	1,691
Total Optoelectronic	414	368	316	330	353	360

Source: Dataquest
February 1990

Table 2c

North American Semiconductor Market (Millions of Dollars)

	1990	1991	1992	1993	1994	1999
Total Including Captives	21,537	24,604	29,539	38,923	41,371	83,725
North American Captives	3,350	3,834	4,603	6,047	6,521	15,140
Total Semiconductor	18,187	20,770	24,936	32,876	34,850	68,585
Total IC	16,071	18,494	22,480	30,173	31,943	64,564
Bipolar Digital	1,548	1,614	1,662	1,747	1,580	923
Memory	184	183	166	161	153	80
Logic	1,364	1,431	1,496	1,586	1,427	843
MOS Digital	12,367	14,438	17,995	25,039	26,669	56,805
Memory	6,328	7,251	9,086	13,602	14,432	31,430
Micro	2,905	3,448	4,310	5,689	6,201	12,968
Logic	3,134	3,739	4,599	5,748	6,036	12,407
Analog	2,156	2,442	2,823	3,387	3,694	6,836
Total Discrete	1,742	1,863	2,001	2,179	2,325	3,126
Total Optoelectronic	374	413	455	524	582	895

Source: Dataquest
February 1990

Table 2d

North American Semiconductor Market (Percent Change)

	1979	1980	1981	1982	1983
Total Including Captives	N/A	N/A	N/A	N/A	N/A
North American Captives	N/A	N/A	N/A	N/A	N/A
Total Semiconductor	29.4%	33.4%	7.9%	6.8%	29.2%
Total IC	36.1%	43.5%	6.7%	12.3%	33.6%
Bipolar Digital	35.3%	56.6%	(5.1%)	2.1%	21.7%
Memory	N/A	114.1%	(5.3%)	(14.7%)	16.6%
Logic	N/A	41.8%	(5.0%)	8.6%	23.3%
MOS Digital	55.0%	43.4%	6.3%	22.7%	35.9%
Memory	N/A	19.6%	(10.0%)	43.8%	28.8%
Micro	N/A	102.7%	29.7%	31.1%	61.3%
Logic	N/A	70.8%	19.6%	(4.9%)	30.6%
Analog	0.9%	23.3%	31.6%	(1.8%)	43.1%
Total Discrete	15.5%	9.3%	8.6%	(12.8%)	12.7%
Total Optoelectronic	19.3%	12.1%	27.9%	6.7%	14.9%

N/A = Not Available

Source: Dataquest
February 1990

Table 2e

North American Semiconductor Market (Percent Change)

	1984	1985	1986	1987	1988	1989
Total Including Captives	41.5%	(22.4%)	12.9%	17.3%	21.6%	13.9%
North American Captives	24.9%	10.7%	3.7%	11.6%	13.4%	11.1%
Total Semiconductor	44.5%	(27.6%)	15.1%	18.6%	23.2%	14.4%
Total IC	51.9%	(30.0%)	15.8%	21.1%	26.9%	16.3%
Bipolar Digital	69.4%	(31.7%)	5.4%	3.4%	(4.1%)	(13.9%)
Memory	18.2%	(34.7%)	(7.3%)	1.5%	(13.3%)	(8.5%)
Logic	84.1%	(31.1%)	7.6%	3.7%	(2.8%)	(14.6%)
MOS Digital	50.3%	(33.5%)	13.7%	37.2%	42.6%	27.2%
Memory	67.0%	(48.8%)	1.3%	40.7%	72.1%	50.0%
Micro	58.0%	(23.0%)	8.3%	47.7%	34.5%	1.4%
Logic	16.3%	(9.1%)	35.4%	25.6%	16.7%	16.3%
Analog	34.9%	(14.6%)	35.5%	0.2%	7.2%	(3.4%)
Total Discrete	11.1%	(13.8%)	19.1%	6.5%	2.1%	0.9%
Total Optoelectronic	19.0%	(11.1%)	(14.1%)	4.4%	7.0%	2.0%

Source: Dataquest
February 1990

Table 2f

North American Semiconductor Market (Percent Change)

	1990	1991	1992	1993	1994
Total Including Captives	0.7%	14.2%	20.1%	31.8%	6.3%
North American Captives	2.4%	14.4%	20.1%	31.4%	7.8%
Total Semiconductor	0.3%	14.2%	20.1%	31.8%	6.0%
Total IC	0	15.1%	21.6%	34.2%	5.9%
Bipolar Digital	(10.6%)	4.3%	3.0%	5.1%	(9.6%)
Memory	(14.4%)	(0.5%)	(9.3%)	(3.0%)	(5.0%)
Logic	(10.1%)	4.9%	4.5%	6.0%	(10.0%)
MOS Digital	1.2%	16.7%	24.6%	39.1%	6.5%
Memory	(1.8%)	14.6%	25.3%	49.7%	6.1%
Micro	5.8%	18.7%	25.0%	32.0%	9.0%
Logic	3.6%	19.3%	23.0%	25.0%	5.0%
Analog	1.6%	13.3%	15.6%	20.0%	9.1%
Total Discrete	3.0%	6.9%	7.4%	8.9%	6.7%
Total Optoelectronic	3.9%	10.4%	10.2%	15.2%	11.1%

Source: Dataquest
February 1990

Table 2g

North American Semiconductor Market (Compound Annual Growth Rates)

	CAGR (79-84)	CAGR (84-89)	CAGR (89-94)	CAGR (94-99)	CAGR (79-89)	CAGR (89-99)
Total Including Captives	N/A	7.3%	14.1%	15.1%	N/A	14.6%
North American Captives	N/A	10.0%	14.8%	18.3%	N/A	16.6%
Total Semiconductor	23.4%	6.9%	14.0%	14.5%	14.9%	14.2%
Total IC	28.4%	7.7%	14.7%	15.1%	17.6%	14.9%
Bipolar Digital	25.6%	(9.3%)	(1.8%)	(10.2%)	6.8%	(6.1%)
Memory	19.0%	(13.4%)	(6.6%)	(12.2%)	1.5%	(9.4%)
Logic	27.1%	(8.6%)	(1.2%)	(10.0%)	7.8%	(5.7%)
MOS Digital	30.7%	13.4%	16.9%	16.3%	21.8%	16.6%
Memory	27.2%	13.5%	17.5%	16.8%	20.2%	17.2%
Micro	54.4%	10.9%	17.7%	15.9%	30.9%	16.8%
Logic	24.2%	16.0%	14.8%	15.5%	20.0%	15.2%
Analog	25.2%	3.7%	11.7%	13.1%	14.0%	12.4%
Total Discrete	5.3%	2.4%	6.6%	6.1%	3.8%	6.3%
Total Optoelectronic	15.9%	(2.8%)	10.1%	9.0%	6.2%	9.5%

N/A = Not Available

Source: Dataquest
February 1990

Table 3a

Worldwide Average Selling Prices
(Dollars)

	1979	1980	1981	1982	1983
Total Semiconductor	0.29	0.33	0.31	0.33	0.32
Total IC	0.97	1.07	1.02	0.99	1.03
Bipolar Digital	0.57	0.70	0.70	0.62	0.65
Memory	N/A	N/A	N/A	N/A	N/A
Logic	N/A	N/A	N/A	N/A	N/A
MOS Digital	1.93	1.81	1.66	1.63	1.66
Memory	5.15	4.90	3.17	2.62	2.79
Micro	3.96	3.61	3.40	3.26	3.35
Logic	0.89	0.85	0.86	0.80	0.79
Analog	0.78	0.83	0.81	0.79	0.76
Total Discrete	0.12	0.12	0.11	0.11	0.09
Total Optoelectronic	0.51	0.44	0.39	0.29	0.28

N/A = Not Available

Source: Dataquest
February 1990

Table 3b

Worldwide Average Selling Prices
(Dollars)

	1984	1985	1986	1987	1988	1989
Total Semiconductor	0.36	0.30	0.34	0.33	0.42	0.42
Total IC	1.10	1.05	1.09	1.18	1.40	1.45
Bipolar Digital	0.65	0.71	0.71	0.69	0.70	0.69
Memory	N/A	N/A	N/A	N/A	N/A	N/A
Logic	N/A	N/A	N/A	N/A	N/A	N/A
MOS Digital	1.95	1.64	1.63	1.94	2.36	2.35
Memory	3.90	2.59	2.41	3.09	4.70	6.62
Micro	3.53	3.14	3.13	3.56	4.15	3.67
Logic	0.85	0.93	0.99	1.12	1.13	0.95
Analog	0.75	0.76	0.84	0.82	0.84	0.76
Total Discrete	0.09	0.08	0.09	0.08	0.09	0.08
Total Optoelectronic	0.28	0.22	0.25	0.28	0.34	0.31

N/A = Not Available

Source: Dataquest
February 1990

Table 3c

Worldwide Average Selling Prices (Dollars)

	1990	1991	1992	1993	1994	1999
Total Semiconductor	0.42	0.48	0.52	0.58	0.52	0.75
Total IC	1.44	1.53	1.61	1.84	1.68	2.06
Bipolar Digital	0.68	0.69	0.70	0.71	0.69	0.69
Memory	N/A	N/A	N/A	N/A	N/A	N/A
Logic	N/A	N/A	N/A	N/A	N/A	N/A
MOS Digital	2.25	2.45	2.51	2.97	2.55	2.92
Memory	6.80	6.65	7.06	8.73	8.53	9.75
Micro	3.65	3.68	4.12	4.18	4.05	4.15
Logic	0.90	1.05	1.05	1.19	0.95	1.05
Analog	0.77	0.79	0.81	0.82	0.80	0.88
Total Discrete	0.08	0.09	0.09	0.09	0.08	0.09
Total Optoelectronic	0.31	0.34	0.35	0.36	0.35	0.38

N/A = Not Available

Source: Dataquest
February 1990

Table 3d

Worldwide Average Selling Prices (Percent Change in Dollars)

	1979	1980	1981	1982	1983
Total Semiconductor	3.6%	11.7%	(6.4%)	7.5%	(3.0%)
Total IC	(4.0%)	9.8%	(3.9%)	(2.8%)	3.1%
Bipolar Digital	(9.5%)	22.8%	0	(11.4%)	4.8%
Memory	N/A	N/A	N/A	N/A	N/A
Logic	N/A	N/A	N/A	N/A	N/A
MOS Digital	1.2%	(6.3%)	(8.4%)	(1.8%)	2.2%
Memory	N/A	(4.9%)	(35.3%)	(17.4%)	6.5%
Micro	N/A	(8.8%)	(5.8%)	(4.1%)	2.8%
Logic	N/A	(4.5%)	1.2%	(7.0%)	(1.3%)
Analog	(7.1%)	6.4%	(2.4%)	(2.5%)	(3.8%)
Total Discrete	(7.7%)	0	(8.3%)	0	(18.2%)
Total Optoelectronic	8.0%	(12.8%)	(11.9%)	(25.6%)	(3.4%)

N/A = Not Available

Source: Dataquest
February 1990

Table 3e

Worldwide Average Selling Prices (Percent Change in Dollars)

	1984	1985	1986	1987	1988	1989
Total Semiconductor	11.8%	(15.7%)	13.2%	(2.7%)	26.5%	(0.4%)
Total IC	7.5%	(4.4%)	3.5%	8.5%	18.0%	3.8%
Bipolar Digital	0	9.2%	0	(2.8%)	1.4%	(1.4%)
Memory	N/A	N/A	N/A	N/A	N/A	N/A
Logic	N/A	N/A	N/A	N/A	N/A	N/A
MOS Digital	17.3%	(16.0%)	(0.5%)	18.6%	22.1%	(0.7%)
Memory	39.8%	(33.6%)	(6.9%)	28.2%	52.1%	40.9%
Micro	5.4%	(11.0%)	(0.3%)	13.7%	16.6%	(11.6%)
Logic	7.6%	9.4%	6.5%	13.1%	0.9%	(15.9%)
Analog	(1.3%)	1.3%	10.5%	(2.4%)	2.4%	(9.5%)
Total Discrete	0	(11.1%)	15.0%	(13.0%)	12.5%	(11.1%)
Total Optoelectronic	0	(21.4%)	13.6%	12.0%	21.4%	(8.8%)

N/A = Not Available

Source: Dataquest February 1990

Table 3f

Worldwide Average Selling Prices (Percent Change in Dollars)

	1990	1991	1992	1993	1994
Total Semiconductor	0.6%	14.1%	6.8%	13.3%	(10.7%)
Total IC	(0.6%)	6.5%	4.6%	14.3%	(8.6%)
Bipolar Digital	(1.4%)	1.5%	1.4%	1.4%	(2.8%)
Memory	N/A	N/A	N/A	N/A	N/A
Logic	N/A	N/A	N/A	N/A	N/A
MOS Digital	(4.1%)	8.9%	2.4%	18.6%	(14.3%)
Memory	2.7%	(2.2%)	6.2%	23.7%	(2.3%)
Micro	(0.5%)	0.8%	12.0%	1.5%	(3.1%)
Logic	(5.3%)	16.7%	0	13.3%	(20.2%)
Analog	1.3%	2.6%	2.5%	1.2%	(2.4%)
Total Discrete	0	12.5%	0	0	(11.1%)
Total Optoelectronic	0	9.7%	2.9%	2.9%	(2.8%)

N/A = Not Available

Source: Dataquest February 1990

Table 3g

Worldwide Average Selling Prices (Compound Annual Growth Rates in U.S. Dollars)

	CAGR (79-84)	CAGR (84-89)	CAGR (89-94)	CAGR (94-99)	CAGR (79-89)	CAGR (89-99)
Total Semiconductor	4.1%	3.2%	4.4%	7.7%	3.6%	6.0%
Total IC	2.6%	5.6%	3.0%	4.1%	4.1%	3.6%
Bipolar Digital	2.7%	1.2%	0	0	1.9%	0
Memory	N/A	N/A	N/A	N/A	N/A	N/A
Logic	N/A	N/A	N/A	N/A	N/A	N/A
MOS Digital	0.2%	3.7%	1.7%	2.8%	2.0%	2.2%
Memory	(5.4%)	11.2%	5.2%	2.7%	2.5%	3.9%
Micro	(2.3%)	0.8%	2.0%	0.5%	(0.8%)	1.2%
Logic	(0.9%)	2.2%	0	2.0%	0.7%	1.0%
Analog	(0.8%)	0.3%	1.0%	1.9%	(0.3%)	1.5%
Total Discrete	(5.6%)	(2.3%)	0	2.4%	(4.0%)	1.2%
Total Optoelectronic	(11.2%)	2.1%	2.5%	1.7%	(4.8%)	2.1%

N/A = Not Available

Source: Dataquest
February 1990

Table 4a

Worldwide Semiconductor Market (Millions of Units)

	1979	1980	1981	1982	1983
Total Semiconductor	37,703	42,870	48,081	46,022	60,743
Total IC	7,242	8,955	9,809	10,949	14,327
Bipolar Digital	2,937	3,391	3,339	3,890	4,638
Memory	N/A	N/A	N/A	N/A	N/A
Logic	N/A	N/A	N/A	N/A	N/A
MOS Digital	1,731	2,603	2,906	3,464	4,776
Memory	325	455	655	1,031	1,333
Micro	137	239	319	404	591
Logic	1,269	1,909	1,933	2,029	2,852
Analog	2,574	2,960	3,564	3,595	4,913
Total Discrete	29,350	32,358	36,227	32,245	42,944
Total Optoelectronic	1,111	1,557	2,045	2,828	3,471

N/A = Not Available

Source: Dataquest
February 1990

Table 4b

Worldwide Semiconductor Market (Millions of Units)

	1984	1985	1986	1987	1988	1989
Total Semiconductor	80,377	80,380	89,881	114,551	120,410	134,174
Total IC	20,573	17,607	21,654	25,260	29,423	32,267
Bipolar Digital	7,340	5,172	6,092	6,899	7,429	6,390
Memory	N/A	N/A	N/A	N/A	N/A	N/A
Logic	N/A	N/A	N/A	N/A	N/A	N/A
MOS Digital	6,639	6,171	7,850	9,028	11,423	14,301
Memory	1,597	1,475	1,872	1,960	2,488	2,550
Micro	916	875	1,115	1,435	1,721	2,025
Logic	4,126	3,820	4,864	5,633	7,214	9,725
Analog	6,593	6,264	7,712	9,334	10,571	11,576
Total Discrete	55,411	57,200	62,283	83,188	84,578	95,275
Total Optoelectronic	4,393	5,573	5,944	6,104	6,409	6,632

N/A = Not Available

Source: Dataquest
February 1990

Table 4c

Worldwide Semiconductor Market
(Millions of Units)

	1990	1991	1992	1993	1994	1999
Total Semiconductor	135,410	136,494	153,921	178,499	217,092	309,694
Total IC	32,994	35,906	41,910	49,185	58,277	102,495
Bipolar Digital	6,013	6,167	6,424	6,806	6,633	6,065
Memory	N/A	N/A	N/A	N/A	N/A	N/A
Logic	N/A	N/A	N/A	N/A	N/A	N/A
MOS Digital	15,327	16,485	20,064	23,536	29,696	59,573
Memory	2,511	2,920	3,420	4,057	4,490	9,434
Micro	2,132	2,558	2,832	3,807	4,318	9,496
Logic	10,683	11,008	13,812	15,672	20,888	40,642
Analog	11,655	13,254	15,422	18,843	21,948	36,857
Total Discrete	95,613	93,600	104,222	120,389	148,413	191,822
Total Optoelectronic	6,803	6,988	7,789	8,925	10,403	15,376

N/A = Not Available

Source: Dataquest
February 1990

Table 4d

Worldwide Semiconductor Market
(Percent Change in Units)

	1979	1980	1981	1982	1983
Total Semiconductor	20%	14%	12%	(4%)	32%
Total IC	40%	24%	10%	12%	31%
Bipolar Digital	47%	15%	(2%)	17%	19%
Memory	N/A	N/A	N/A	N/A	N/A
Logic	N/A	N/A	N/A	N/A	N/A
MOS Digital	42%	50%	12%	19%	38%
Memory	N/A	40%	44%	57%	29%
Micro	N/A	75%	34%	27%	46%
Logic	N/A	51%	1%	5%	41%
Analog	32%	15%	20%	1%	37%
Total Discrete	16%	10%	12%	(11%)	33%
Total Optoelectronic	24%	40%	31%	38%	23%

N/A = Not Available

Source: Dataquest
February 1990

Table 4e

Worldwide Semiconductor Market (Percent Change in Units)

	1984	1985	1986	1987	1988	1989
Total Semiconductor	32%	0	12%	27%	5%	11%
Total IC	44%	(14%)	23%	17%	16%	10%
Bipolar Digital	58%	(30%)	18%	13%	8%	(14%)
Memory	N/A	N/A	N/A	N/A	N/A	N/A
Logic	N/A	N/A	N/A	N/A	N/A	N/A
MOS Digital	39%	(7%)	27%	15%	27%	25%
Memory	20%	(8%)	27%	5%	27%	3%
Micro	55%	(4%)	27%	29%	20%	18%
Logic	45%	(7%)	27%	16%	28%	35%
Analog	34%	(5%)	23%	21%	13%	10%
Total Discrete	29%	3%	9%	34%	2%	13%
Total Optoelectronic	27%	27%	7%	3%	5%	3%

N/A = Not Available

Source: Dataquest
February 1990

Table 4f

Worldwide Semiconductor Market (Percent Change in Units)

	1990	1991	1992	1993	1994
Total Semiconductor	1%	1%	13%	16%	22%
Total IC	2%	9%	17%	17%	18%
Bipolar Digital	(6%)	3%	4%	6%	(3%)
Memory	N/A	N/A	N/A	N/A	N/A
Logic	N/A	N/A	N/A	N/A	N/A
MOS Digital	7%	8%	22%	17%	26%
Memory	(2%)	16%	17%	19%	11%
Micro	5%	20%	11%	34%	13%
Logic	10%	3%	25%	13%	33%
Analog	1%	14%	16%	22%	16%
Total Discrete	0%	(2%)	11%	16%	23%
Total Optoelectronic	3%	3%	11%	15%	17%

N/A = Not Available

Source: Dataquest
February 1990

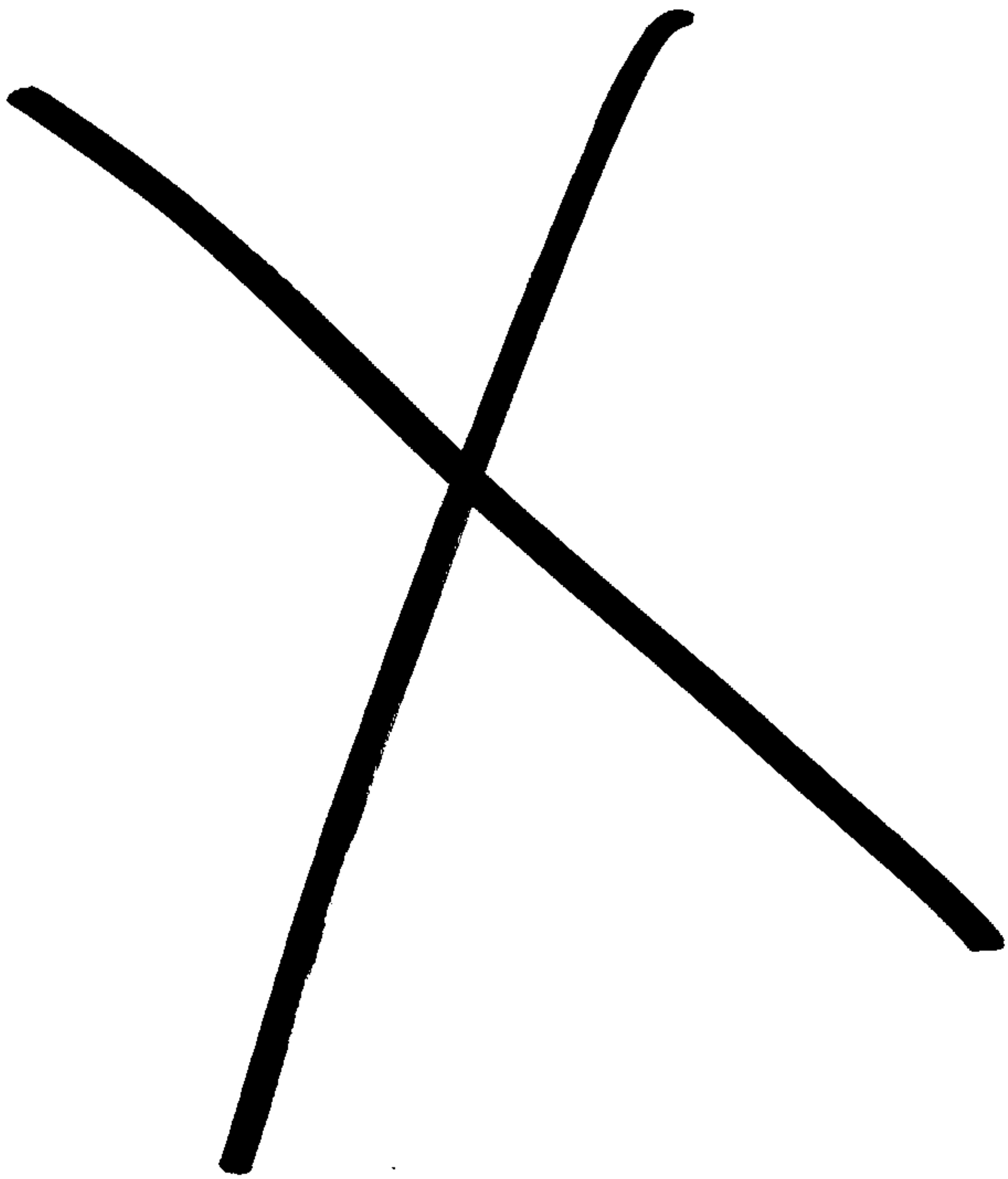
Table 4g

Worldwide Semiconductor Market
(Compound Annual Growth Rates in Millions of Units)

	CAGR (79-84)	CAGR (84-89)	CAGR (89-94)	CAGR (94-99)	CAGR (79-89)	CAGR (89-99)
Total Semiconductor	16.3%	10.8%	10.1%	7.4%	13.5%	8.7%
Total IC	23.2%	9.4%	12.6%	12.0%	16.1%	12.3%
Bipolar Digital	20.1%	(2.7%)	0.8%	(1.8%)	8.1%	(0.5%)
Memory	N/A	N/A	N/A	N/A	N/A	N/A
Logic	N/A	N/A	N/A	N/A	N/A	N/A
MOS Digital	30.9%	16.6%	15.7%	14.9%	23.5%	15.3%
Memory	37.5%	9.8%	12.0%	16.0%	22.9%	14.0%
Micro	46.3%	17.2%	16.4%	17.1%	30.9%	16.7%
Logic	26.6%	18.7%	16.5%	14.2%	22.6%	15.4%
Analog	20.7%	11.9%	13.6%	10.9%	16.2%	12.3%
Total Discrete	13.6%	11.4%	9.3%	5.3%	12.5%	7.2%
Total Optoelectronic	31.6%	8.6%	9.4%	8.1%	19.6%	8.8%

N/A = Not Available

Source: Dataquest
February 1990



Data Processing

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

- Semiconductor Consumption Data Processing
- Trends in Personal Computers
- Trends in Workstations
- ➡ Trends in Electronic Printers
- Trends in Disk Drives

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Semiconductor Consumption—Data Processing

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Table 1

Forecast North American Electronic Equipment Production Data Processing (Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR (%) 1989-1990	CAGR (%) 1989-1994
Factory Revenue (Net)	100,995	108,941	116,997	125,098	134,872	145,912	157,549	7.4	7.7

Source: Dataquest (July 1990)

Table 2

Forecast North American Merchant Semiconductor Revenue Data Processing (Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR (%) 1989-1990	CAGR (%) 1989-1994
Total Semiconductor	7,702	9,097	8,664	10,488	13,282	17,890	19,908	(4.8)	17.0
Total IC	7,492	8,881	8,436	10,233	12,987	17,560	19,548	(5.0)	17.1
Bipolar Digital	1,246	1,064	1,006	1,137	1,262	1,385	1,261	(5.5)	3.5
Bipolar Memory	115	131	117	110	101	97	88	(10.7)	(7.7)
Bipolar Logic	1,131	933	889	1,026	1,161	1,288	1,174	(4.7)	4.7
MOS	5,903	7,423	7,004	8,571	11,123	15,446	17,424	(5.6)	18.6
MOS Memory	2,874	4,272	3,677	4,693	6,390	9,207	10,655	(13.9)	20.1
MOS Micro	1,684	1,711	1,831	2,134	2,588	3,561	3,973	7.0	18.4
MOS Logic	1,345	1,441	1,496	1,744	2,145	2,678	2,796	3.8	14.2
Analog	343	394	425	525	603	729	863	8.0	17.0
Discrete	133	136	146	161	192	216	231	7.0	11.2
Opto	77	80	83	93	102	114	129	3.1	10.0

Source: Dataquest (July 1990)

Table 3

Forecast North American Merchant Semiconductor Revenue
Data Processing
(Input/Output Ratios, Percentage)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	7.6	8.4	7.4	8.4	9.8	12.3	12.6
Total IC	7.4	8.2	7.2	8.2	9.6	12.0	12.4
Bipolar Digital	1.2	1.0	0.9	0.9	0.9	0.9	0.8
Bipolar Memory	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Bipolar Logic	1.1	0.9	0.8	0.8	0.9	0.9	0.7
MOS	5.8	6.8	6.0	6.9	8.2	10.6	11.1
MOS Memory	2.8	3.9	3.1	3.8	4.7	6.3	6.8
MOS Micro	1.7	1.6	1.6	1.7	1.9	2.4	2.5
MOS Logic	1.3	1.3	1.3	1.4	1.6	1.8	1.8
Analog	0.3	0.4	0.4	0.4	0.4	0.5	0.5
Discrete	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Opto	0.1	0.1	0.1	0.1	0.1	0.1	0.1

Source: Dataquest (July 1990)

Table 4

Forecast North American Electronic Equipment Production
Data Processing
(Annual Percentage Growth)

	1989	1990	1991	1992	1993	1994
Factory Revenue (Net)	7.9	7.4	6.9	7.8	8.2	8.0

Source: Dataquest (July 1990)

Table 5

Forecast North American Merchant Semiconductor Revenue
Data Processing
(Annual Percentage Growth)

	1989	1990	1991	1992	1993	1994
Total Semiconductor	18.1	(4.8)	21.1	26.6	34.7	11.3
Total IC	18.5	(5.0)	21.3	26.9	35.2	11.3
Bipolar Digital	(14.6)	(5.5)	13.0	11.0	9.8	(8.9)
Bipolar Memory	13.9	(10.7)	(5.6)	(8.6)	(3.9)	(9.6)
Bipolar Logic	(17.5)	(4.7)	15.5	13.1	10.9	(8.9)
MOS	25.8	(5.6)	22.4	29.8	38.9	12.8
MOS Memory	48.6	(13.9)	27.6	36.2	44.1	15.7
MOS Micro	1.6	7.0	16.5	21.3	37.6	11.6
MOS Logic	7.1	3.8	16.6	23.0	24.9	4.4
Analog	14.9	8.0	23.5	14.8	20.9	18.4
Discrete	2.3	7.0	10.8	19.2	12.4	6.9
Opto	3.9	3.1	13.0	9.4	11.8	13.2

Source: Dataquest (July 1990)

Table 6

Forecast North American Merchant Semiconductor Revenue
Data Processing
(Percentage of Total Data Processing)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total IC	97.3	97.6	97.4	97.6	97.8	98.2	98.2
Bipolar Digital	16.2	11.7	11.6	10.8	9.5	7.7	6.3
Bipolar Memory	1.5	1.4	1.4	1.1	0.8	0.5	0.4
Bipolar Logic	14.7	10.3	10.3	9.8	8.7	7.2	5.9
MOS	76.6	81.6	80.8	81.7	83.7	86.3	87.5
MOS Memory	37.3	47.0	42.4	44.7	48.1	51.5	53.5
MOS Micro	21.9	18.8	21.1	20.3	19.5	19.9	20.0
MOS Logic	17.3	15.8	17.3	16.6	16.1	15.0	14.0
Analog	4.5	4.3	4.9	5.0	4.5	4.1	4.3
Discrete	1.7	1.5	1.7	1.5	1.4	1.2	1.2
Opto	1.0	0.9	1.0	0.9	0.8	0.6	0.6

Source: Dataquest (July 1990)

Table 7

Forecast North American Electronic Equipment Production
Computers
(Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR (%) 1989-1990	CAGR (%) 1989-1994
Factory Revenue	68,769	74,757	80,892	88,073	96,980	105,998	115,910	8.2	9.2

Source: Dataquest (July 1990)

Table 8

Forecast North American Merchant Semiconductor Revenue
Computers
(Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR (%) 1989-1990	CAGR (%) 1989-1994
Total Semiconductor	5,532	6,505	6,189	7,459	9,413	12,600	13,831	(4.9)	16.3
Total IC	5,398	6,365	6,040	7,292	9,219	12,382	13,592	(5.1)	16.4
Bipolar Digital	1,019	874	828	938	1,043	1,146	1,045	(5.2)	3.6
Bipolar Memory	94	108	97	91	84	81	73	(10.3)	(7.4)
Bipolar Logic	925	766	732	847	959	1,065	971	(4.5)	4.9
MOS	4,321	5,428	5,147	6,278	8,095	11,144	12,446	(5.2)	18.1
MOS Memory	2,048	3,033	2,592	3,274	4,400	6,243	7,101	(14.5)	18.5
MOS Micro	1,264	1,300	1,404	1,649	2,012	2,782	3,115	8.0	19.1
MOS Logic	1,009	1,095	1,150	1,355	1,683	2,119	2,230	5.1	15.3
Analog	58	64	65	76	82	92	101	2.4	9.7
Discrete	81	84	91	102	122	139	150	8.4	12.4
Opto	53	56	58	65	71	79	89	3.5	9.9

Source: Dataquest (July 1990)

Table 9

Forecast North American Merchant Semiconductor Revenue
Computers
(Input/Output Ratios, Percentage)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	8.0	8.7	7.7	8.5	9.7	11.9	11.9
Total IC	7.8	8.5	7.5	8.3	9.5	11.7	11.7
Bipolar Digital	1.5	1.2	1.0	1.1	1.1	1.1	0.9
Bipolar Memory	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Bipolar Logic	1.3	1.0	0.9	1.0	1.0	1.0	0.8
MOS	6.3	7.3	6.4	7.1	8.3	10.5	10.7
MOS Memory	3.0	4.1	3.2	3.7	4.5	5.9	6.1
MOS Micro	1.8	1.7	1.7	1.9	2.1	2.6	2.7
MOS Logic	1.5	1.5	1.4	1.5	1.7	2.0	1.9
Analog	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Discrete	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Opto	0.1	0.1	0.1	0.1	0.1	0.1	0.1

Source: Dataquest (July 1990)

Table 10

Forecast North American Electronic Equipment Production
Computers
(Annual Percentage Growth)

	1989	1990	1991	1992	1993	1994
Factory Revenue	8.7	8.2	8.9	10.1	9.3	9.4

Source: Dataquest (July 1990)

Table 11

Forecast North American Merchant Semiconductor Revenue
Computers
(Annual Percentage Growth)

	1989	1990	1991	1992	1993	1994
Total Semiconductor	17.6	(4.9)	20.5	26.2	33.9	9.8
Total IC	17.9	(5.1)	20.7	26.4	34.3	9.8
Bipolar Digital	(14.3)	(5.2)	13.2	11.2	9.9	(8.8)
Bipolar Memory	14.4	(10.3)	(5.3)	(8.3)	(3.6)	(9.4)
Bipolar Logic	(17.2)	(4.5)	15.7	13.3	11.1	(8.8)
MOS	25.6	(5.2)	22.0	28.9	37.7	11.7
MOS Memory	48.1	(14.5)	26.3	34.4	41.9	13.7
MOS Micro	2.8	8.0	17.4	22.0	38.3	12.0
MOS Logic	8.6	5.1	17.8	24.2	25.9	5.2
Analog	9.8	2.4	16.3	7.5	12.7	10.0
Discrete	3.8	8.4	12.1	20.4	13.5	7.8
Opto	5.0	3.5	13.0	9.2	11.4	12.6

Source: Dataquest (July 1990)

Table 12

Forecast North American Merchant Semiconductor Revenue
Computers
(Percentage of Data Processing)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	71.8	71.5	71.4	71.1	70.9	70.4	69.5
Total IC	72.1	71.7	71.6	71.3	71.0	70.5	69.5
Bipolar Digital	81.8	82.1	82.3	82.5	82.6	82.7	82.8
Bipolar Memory	81.8	82.2	82.5	82.8	83.1	83.3	83.5
Bipolar Logic	81.8	82.1	82.3	82.5	82.6	82.7	82.8
MOS	73.2	73.1	73.5	73.3	72.8	72.1	71.4
MOS Memory	71.2	71.0	70.5	69.8	68.9	67.8	66.6
MOS Micro	75.1	76.0	76.7	77.3	77.8	78.1	78.4
MOS Logic	75.0	76.0	76.9	77.7	78.5	79.1	79.8
Analog	16.9	16.2	15.3	14.4	13.5	12.6	11.7
Discrete	60.6	61.5	62.3	63.1	63.7	64.3	64.8
Opto	68.9	69.7	69.9	69.9	69.8	69.5	69.2

Source: Dataquest (July 1990)

Table 13

Forecast North American Merchant Semiconductor Revenue
Computers
(Percentage of Total Computer)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total IC	97.6	97.9	97.6	97.8	97.9	98.3	98.3
Bipolar Digital	18.4	13.4	13.4	12.6	11.1	9.1	7.6
Bipolar Memory	1.7	1.7	1.6	1.2	0.9	0.6	0.5
Bipolar Logic	16.7	11.8	11.8	11.3	10.2	8.5	7.0
MOS	78.1	83.4	83.2	84.2	86.0	88.4	90.0
MOS Memory	37.0	46.6	41.9	43.9	46.7	49.5	51.3
MOS Micro	22.9	20.0	22.7	22.1	21.4	22.1	22.5
MOS Logic	18.2	16.8	18.6	18.2	17.9	16.8	16.1
Analog	1.0	1.0	1.1	1.0	0.9	0.7	0.7
Discrete	1.5	1.3	1.5	1.4	1.3	1.1	1.1
Opto	1.0	0.9	0.9	0.9	0.8	0.6	0.6

Source: Dataquest (July 1990)

Table 14

Forecast North American Electronic Equipment Production
Data Storage/Subsystems
(Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR (%) 1989-1990	CAGR (%) 1989-1994
Factory Revenue (Gross)	16,120	17,998	19,736	20,254	21,262	23,077	24,144	9.7	6.1
Factory Revenue (Net)	13,200	14,940	16,410	16,545	16,913	17,979	18,273	9.8	4.1

Source: Dataquest (July 1990)

Table 15

Forecast North American Merchant Semiconductor Revenue
Data Storage/Subsystems
(Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR (%) 1989-1990	CAGR (%) 1989-1994
Total Semiconductor	1,135	1,441	1,439	1,828	2,391	3,329	3,910	(0.1)	22.1
Total IC	1,100	1,405	1,401	1,785	2,341	3,273	3,849	(0.3)	22.3
Bipolar Digital	100	86	81	91	101	110	100	(5.7)	3.1
Bipolar Memory	9	11	10	9	8	8	7	(10.4)	(7.5)
Bipolar Logic	91	75	71	82	92	102	92	(5.0)	4.3
MOS	777	1,049	1,014	1,302	1,775	2,583	3,046	(3.3)	23.8
MOS Memory	433	683	622	837	1,198	1,811	2,195	(9.0)	26.3
MOS Micro	177	187	208	251	314	445	512	10.9	22.3
MOS Logic	166	178	185	215	263	327	339	3.7	13.8
Analog	223	271	306	392	465	579	703	13.0	21.0
Discrete	24	24	26	29	35	40	43	7.9	11.9
Opto	11	11	12	13	15	17	19	4.2	10.6

Source: Dataquest (July 1990)

Table 16

Forecast North American Merchant Semiconductor Revenue
Data Storage/Subsystems
(Input/Output Ratios, Percentage)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	7.0	8.0	7.3	9.0	11.2	14.4	16.2
Total IC	6.8	7.8	7.1	8.8	11.0	14.2	15.9
Bipolar Digital	0.6	0.5	0.4	0.4	0.5	0.5	0.4
Bipolar Memory	0.1	0.1	0	0	0	0	0
Bipolar Logic	0.6	0.4	0.4	0.4	0.4	0.4	0.4
MOS	4.8	5.8	5.1	6.4	8.3	11.2	12.6
MOS Memory	2.7	3.8	3.2	4.1	5.6	7.8	9.1
MOS Micro	1.1	1.0	1.1	1.2	1.5	1.9	2.1
MOS Logic	1.0	1.0	0.9	1.1	1.2	1.4	1.4
Analog	1.4	1.5	1.5	1.9	2.2	2.5	2.9
Discrete	0.1	0.1	0.1	0.1	0.2	0.2	0.2
Opto	0.1	0.1	0.1	0.1	0.1	0.1	0.1

Source: Dataquest (July 1990)

Table 17

Forecast North American Electronic Equipment Production
Data Storage/Subsystems
(Annual Percentage Growth)

	1989	1990	1991	1992	1993	1994
Factory Revenue (Gross)	11.7	9.7	2.6	5.0	8.5	4.6
Factory Revenue (Net)	13.2	9.8	0.8	2.2	6.3	1.6

Source: Dataquest (July 1990)

Table 18

Forecast North American Merchant Semiconductor Revenue
Data Storage/Subsystems
(Annual Percentage Growth)

	1989	1990	1991	1992	1993	1994
Total Semiconductor	27.0	(0.1)	27.0	30.8	39.2	17.5
Total IC	27.7	(0.3)	27.5	31.1	39.8	17.6
Bipolar Digital	(14.7)	(5.7)	12.6	10.6	9.3	(9.3)
Bipolar Memory	14.3	(10.4)	(5.4)	(8.4)	(3.7)	(9.5)
Bipolar Logic	(17.7)	(5.0)	15.1	12.7	10.5	(9.3)
MOS	35.0	(3.3)	28.4	36.3	45.6	17.9
MOS Memory	57.8	(9.0)	34.6	43.2	51.2	21.2
MOS Micro	5.5	10.9	20.6	25.3	42.0	15.0
MOS Logic	7.1	3.7	16.3	22.5	24.3	3.8
Analog	21.2	13.0	28.4	18.6	24.4	21.4
Discrete	3.3	7.9	11.6	19.9	13.0	7.4
Opto	5.7	4.2	13.7	9.9	12.1	13.4

Source: Dataquest (July 1990)

Table 19

Forecast North American Merchant Semiconductor Revenue Data Storage/Subsystems (Percentage of Data Processing)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	14.7	15.8	16.6	17.4	18.0	18.6	19.6
Total IC	14.7	15.8	16.6	17.4	18.0	18.6	19.7
Bipolar Digital	8.1	8.0	8.0	8.0	8.0	7.9	7.9
Bipolar Memory	8.2	8.2	8.2	8.3	8.3	8.3	8.3
Bipolar Logic	8.0	8.0	8.0	8.0	7.9	7.9	7.9
MOS	13.2	14.1	14.5	15.2	16.0	16.7	17.5
MOS Memory	15.1	16.0	16.9	17.8	18.8	19.7	20.6
MOS Micro	10.5	10.9	11.3	11.7	12.1	12.5	12.9
MOS Logic	12.4	12.4	12.3	12.3	12.3	12.2	12.1
Analog	65.1	68.7	71.9	74.7	77.2	79.4	81.4
Discrete	17.8	18.0	18.1	18.3	18.4	18.5	18.5
Opto	14.0	14.2	14.4	14.5	14.5	14.6	14.6

Source: Dataquest (July 1990)

Table 20

Forecast North American Merchant Semiconductor Revenue Data Storage/Subsystems (Percentage of Total Data Storage/Subsystems)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total IC	97.0	97.5	97.3	97.7	97.9	98.3	98.4
Bipolar Digital	8.8	5.9	5.6	5.0	4.2	3.3	2.6
Bipolar Memory	0.8	0.7	0.7	0.5	0.3	0.2	0.2
Bipolar Logic	8.0	5.2	4.9	4.5	3.9	3.1	2.4
MOS	68.4	72.8	70.5	71.2	74.2	77.6	77.9
MOS Memory	38.2	47.4	43.2	45.8	50.1	54.4	56.1
MOS Micro	15.6	13.0	14.4	13.7	13.1	13.4	13.1
MOS Logic	14.6	12.4	12.8	11.7	11.0	9.8	8.7
Analog	19.7	18.8	21.2	21.5	19.5	17.4	18.0
Discrete	2.1	1.7	1.8	1.6	1.5	1.2	1.1
Opto	0.9	0.8	0.8	0.7	0.6	0.5	0.5

Source: Dataquest (July 1990)

Table 21

Forecast North American Electronic Equipment Production
Terminals
(Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR (%) 1989-1990	CAGR (%) 1989-1994
Factory Revenue	3,110	2,584	2,081	1,712	1,446	1,238	1,173	(19.5)	(14.6)

Source: Dataquest (July 1990)

Table 22

Forecast North American Merchant Semiconductor Revenue
Terminals
(Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR (%) 1989-1990	CAGR (%) 1989-1994
Total Semiconductor	187	164	117	104	95	92	75	(28.6)	(14.6)
Total IC	180	158	113	101	92	89	72	(28.9)	(14.5)
Bipolar Digital	22	15	12	11	10	8	6	(23.4)	(16.4)
Bipolar Memory	2	2	2	1	1	1	1	(25.7)	(23.3)
Bipolar Logic	20	13	10	10	9	8	6	(23.0)	(15.5)
MOS	128	118	81	72	67	67	54	(31.5)	(14.3)
MOS Memory	66	69	42	38	36	36	29	(39.2)	(15.7)
MOS Micro	39	30	24	21	19	20	17	(19.6)	(11.3)
MOS Logic	23	19	15	13	12	11	9	(22.2)	(14.6)
Analog	29	25	20	18	15	14	12	(19.8)	(14.1)
Discrete	5	4	4	3	3	3	2	(15.2)	(12.1)
Opto	2	1	1	1	0	0	0	(42.3)	(38.8)

Source: Dataquest (July 1990)

Table 23

Forecast North American Merchant Semiconductor Revenue
Terminals
(Input/Output Ratios, Percentage)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	6.0	6.4	5.6	6.1	6.6	7.4	6.4
Total IC	5.8	6.1	5.4	5.9	6.4	7.2	6.2
Bipolar Digital	0.7	0.6	0.6	0.6	0.7	0.7	0.5
Bipolar Memory	0.1	0.1	0.1	0.1	0.1	0.1	0
Bipolar Logic	0.6	0.5	0.5	0.6	0.6	0.6	0.5
MOS	4.1	4.6	3.9	4.2	4.6	5.4	4.6
MOS Memory	2.1	2.7	2.0	2.2	2.5	2.9	2.5
MOS Micro	1.3	1.2	1.2	1.2	1.3	1.6	1.4
MOS Logic	0.8	0.7	0.7	0.7	0.8	0.9	0.7
Analog	0.9	1.0	1.0	1.1	1.1	1.1	1.0
Discrete	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Opto	0.1	0.1	0	0	0	0	0

Source: Dataquest (July 1990)

Table 24

Forecast North American Electronic Equipment Production
Terminals
(Annual Percentage Growth)

	1989	1990	1991	1992	1993	1994
Factory Revenue	(16.9)	(19.5)	(17.7)	(15.5)	(14.4)	(5.3)

Source: Dataquest (July 1990)

Table 25

Forecast North American Merchant Semiconductor Revenue Terminals (Annual Percentage Growth)

	1989	1990	1991	1992	1993	1994
Total Semiconductor	(12.4)	(28.6)	(10.9)	(8.7)	(3.4)	(18.8)
Total IC	(11.8)	(28.9)	(10.7)	(8.6)	(3.1)	(18.8)
Bipolar Digital	(30.6)	(23.4)	(8.7)	(10.4)	(11.4)	(26.4)
Bipolar Memory	(5.2)	(25.7)	(21.6)	(24.1)	(20.2)	(24.9)
Bipolar Logic	(33.3)	(23.0)	(6.8)	(8.7)	(10.5)	(26.5)
MOS	(8.1)	(31.5)	(11.4)	(6.5)	0.1	(18.9)
MOS Memory	5.3	(39.2)	(10.2)	(4.5)	0.9	(19.1)
MOS Micro	(23.5)	(19.6)	(12.6)	(9.2)	2.9	(16.6)
MOS Logic	(19.6)	(22.2)	(12.8)	(8.1)	(6.8)	(22.1)
Analog	(14.0)	(19.8)	(8.9)	(15.8)	(11.7)	(13.9)
Discrete	(18.8)	(15.2)	(12.3)	(5.8)	(11.2)	(15.6)
Opto	(41.5)	(42.3)	(37.1)	(39.2)	(38.0)	(37.3)

Source: Dataquest (July 1990)

Table 26

Forecast North American Merchant Semiconductor Revenue Terminals (Percentage of Data Processing)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	2.4	1.8	1.4	1.0	0.7	0.5	0.4
Total IC	2.4	1.8	1.3	1.0	0.7	0.5	0.4
Bipolar Digital	1.8	1.4	1.2	0.9	0.8	0.6	0.5
Bipolar Memory	1.9	1.6	1.3	1.1	0.9	0.7	0.6
Bipolar Logic	1.8	1.4	1.1	0.9	0.7	0.6	0.5
MOS	2.2	1.6	1.2	0.8	0.6	0.4	0.3
MOS Memory	2.3	1.6	1.1	0.8	0.6	0.4	0.3
MOS Micro	2.3	1.8	1.3	1.0	0.7	0.6	0.4
MOS Logic	1.7	1.3	1.0	0.7	0.5	0.4	0.3
Analog	8.5	6.4	4.7	3.5	2.6	1.9	1.4
Discrete	4.1	3.2	2.6	2.0	1.6	1.3	1.0
Opto	3.2	1.8	1.0	0.6	0.3	0.2	0.1

Source: Dataquest (July 1990)

Table 27

Forecast North American Merchant Semiconductor Revenue Terminals (Percentage of Total Terminals)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total IC	95.8	96.4	96.1	96.4	96.4	96.8	96.7
Bipolar Digital	11.7	9.3	10.0	10.2	10.0	9.2	8.3
Bipolar Memory	1.1	1.2	1.3	1.1	0.9	0.8	0.7
Bipolar Logic	10.6	8.1	8.7	9.1	9.1	8.4	7.6
MOS	68.4	71.8	68.9	68.5	70.2	72.8	72.7
MOS Memory	35.0	42.0	35.8	36.0	37.7	39.4	39.2
MOS Micro	21.0	18.3	20.7	20.3	20.2	21.5	22.1
MOS Logic	12.5	11.4	12.5	12.2	12.3	11.9	11.4
Analog	15.6	15.3	17.2	17.6	16.2	14.8	15.7
Discrete	2.9	2.7	3.2	3.1	3.2	3.0	3.1
Opto	1.3	0.9	0.7	0.5	0.3	0.2	0.2

Source: Dataquest (July 1990)

Table 28

Forecast North American Electronic Equipment Production Input/Output (Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR (%) 1989-1990	CAGR (%) 1989-1994
Factory Revenue	10,541	11,336	12,281	13,287	14,339	15,560	17,034	8.3	8.5

Source: Dataquest (July 1990)

Table 29

Forecast North American Merchant Semiconductor Revenue
Input/Output
(Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR (%) 1989-1990	CAGR (%) 1989-1994
Total Semiconductor	584	708	684	847	1,106	1,545	1,780	(3.3)	20.3
Total IC	558	682	656	815	1,070	1,503	1,735	(3.7)	20.5
Bipolar Digital	74	65	62	72	82	92	85	(3.4)	5.8
Bipolar Memory	7	8	7	7	6	6	5	(11.1)	(8.2)
Bipolar Logic	67	57	55	65	76	86	80	(2.3)	7.2
MOS	459	589	566	712	955	1,375	1,610	(3.9)	22.3
MOS Memory	217	347	319	435	630	964	1,182	(7.9)	27.8
MOS Micro	134	132	137	153	179	237	254	3.4	13.9
MOS Logic	107	111	110	123	145	174	174	(0.2)	9.5
Analog	26	28	28	32	33	37	40	0.4	7.6
Discrete	17	18	19	20	24	27	28	5.9	9.7
Opto	8	9	9	11	13	15	17	7.9	14.6

Source: Dataquest (July 1990)

Table 30

Forecast North American Merchant Semiconductor Revenue
Input/Output
(Input/Output Ratios, Percentage)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	5.5	6.2	5.6	6.4	7.7	9.9	10.4
Total IC	5.3	6.0	5.3	6.1	7.5	9.7	10.2
Bipolar Digital	0.7	0.6	0.5	0.5	0.6	0.6	0.5
Bipolar Memory	0.1	0.1	0.1	0	0	0	0
Bipolar Logic	0.6	0.5	0.5	0.5	0.5	0.6	0.5
MOS	4.4	5.2	4.6	5.4	6.7	8.8	9.4
MOS Memory	2.1	3.1	2.6	3.3	4.4	6.2	6.9
MOS Micro	1.3	1.2	1.1	1.2	1.2	1.5	1.5
MOS Logic	1.0	1.0	0.9	0.9	1.0	1.1	1.0
Analog	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Discrete	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Opto	0.1	0.1	0.1	0.1	0.1	0.1	0.1

Source: Dataquest (July 1990)

Table 31

Forecast North American Electronic Equipment Production Input/Output (Annual Percentage Growth)

	1989	1990	1991	1992	1993	1994
Factory Revenue	7.5	8.3	8.2	7.9	8.5	9.5

Source: Dataquest (July 1990)

Table 32

Forecast North American Merchant Semiconductor Revenue Input/Output (Annual Percentage Growth)

	1989	1990	1991	1992	1993	1994
Total Semiconductor	21.3	(3.3)	23.7	30.6	39.6	15.2
Total IC	22.1	(3.7)	24.2	31.2	40.5	15.4
Bipolar Digital	(12.7)	(3.4)	15.5	13.5	12.3	(7.0)
Bipolar Memory	13.5	(11.1)	(6.1)	(9.1)	(4.4)	(10.1)
Bipolar Logic	(15.4)	(2.3)	18.3	15.8	13.6	(6.8)
MOS	28.5	(3.9)	25.7	34.1	44.0	17.1
MOS Memory	59.7	(7.9)	36.2	44.9	53.0	22.6
MOS Micro	(1.7)	3.4	12.3	16.7	32.3	7.1
MOS Logic	3.1	(0.2)	11.9	17.9	19.6	(0.1)
Analog	7.7	0.4	14.1	5.4	10.6	7.9
Discrete	1.4	5.9	9.5	17.6	10.8	5.3
Opto	9.5	7.9	17.8	13.9	16.1	17.5

Source: Dataquest (July 1990)

Table 33

Forecast North American Merchant Semiconductor Revenue Input/Output (Percentage of Data Processing)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	7.6	7.8	7.9	8.1	8.3	8.6	8.9
Total IC	7.5	7.7	7.8	8.0	8.2	8.6	8.9
Bipolar Digital	5.9	6.1	6.2	6.3	6.5	6.6	6.8
Bipolar Memory	6.0	6.0	6.0	6.0	5.9	5.9	5.9
Bipolar Logic	5.9	6.1	6.2	6.4	6.5	6.7	6.8
MOS	7.8	7.9	8.1	8.3	8.6	8.9	9.2
MOS Memory	7.6	8.1	8.7	9.3	9.9	10.5	11.1
MOS Micro	8.0	7.7	7.5	7.2	6.9	6.6	6.4
MOS Logic	8.0	7.7	7.4	7.1	6.8	6.5	6.2
Analog	7.5	7.0	6.5	6.0	5.5	5.1	4.6
Discrete	13.1	13.0	12.8	12.7	12.5	12.3	12.1
Opto	10.3	10.9	11.4	11.9	12.3	12.8	13.3

Source: Dataquest (July 1990)

Table 34

Forecast North American Merchant Semiconductor Revenue Input/Output (Percentage of Total Input/Output)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total IC	95.7	96.3	95.9	96.3	96.7	97.3	97.5
Bipolar Digital	12.7	9.1	9.1	8.5	7.4	5.9	4.8
Bipolar Memory	1.2	1.1	1.0	0.8	0.5	0.4	0.3
Bipolar Logic	11.5	8.0	8.1	7.7	6.8	5.6	4.5
MOS	78.6	83.3	82.7	84.0	86.3	89.0	90.4
MOS Memory	37.2	49.0	46.7	51.4	57.0	62.4	66.4
MOS Micro	23.0	18.7	20.0	18.1	16.2	15.3	14.3
MOS Logic	18.4	15.6	16.1	14.6	13.1	11.3	9.8
Analog	4.4	3.9	4.0	3.7	3.0	2.4	2.2
Discrete	3.0	2.5	2.7	2.4	2.2	1.7	1.6
Opto	1.4	1.2	1.4	1.3	1.1	0.9	1.0

Source: Dataquest (July 1990)

Table 35

Forecast North American Electronic Equipment Production
Dedicated Systems
(Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR (%) 1989-1990	CAGR (%) 1989-1994
Factory Revenue	5,375	5,324	5,333	5,481	5,194	5,137	5,159	0.2	(0.6)

Source: Dataquest (July 1990)

Table 36

Forecast North American Merchant Semiconductor Revenue
Dedicated Systems
(Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR (%) 1989-1990	CAGR (%) 1989-1994
Total Semiconductor	264	280	234	249	276	324	312	(16.4)	2.2
Total IC	256	271	225	239	266	313	300	(17.0)	2.1
Bipolar Digital	30	25	23	25	27	29	25	(8.4)	0.3
Bipolar Memory	2	3	2	2	2	2	1	(13.7)	(10.9)
Bipolar Logic	28	22	21	23	25	27	24	(7.7)	1.3
MOS	219	240	196	207	232	277	268	(18.2)	2.2
MOS Memory	111	140	102	110	126	152	148	(27.1)	1.1
MOS Micro	68	62	58	60	64	77	75	(5.5)	4.2
MOS Logic	40	38	36	38	42	47	44	(6.2)	2.9
Analog	7	7	6	7	7	7	8	(4.3)	2.6
Discrete	6	6	6	6	7	8	8	2.9	6.6
Opto	3	3	3	3	3	3	4	(0.4)	5.8

Source: Dataquest (July 1990)

Table 37

Forecast North American Merchant Semiconductor Revenue
Dedicated Systems
(Input/Output Ratios, Percentage)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	4.9	5.3	4.4	4.5	5.3	6.3	6.0
Total IC	4.8	5.1	4.2	4.4	5.1	6.1	5.8
Bipolar Digital	0.6	0.5	0.4	0.5	0.5	0.6	0.5
Bipolar Memory	0	0	0	0	0	0	0
Bipolar Logic	0.5	0.4	0.4	0.4	0.5	0.5	0.5
MOS	4.1	4.5	3.7	3.8	4.5	5.4	5.2
MOS Memory	2.1	2.6	1.9	2.0	2.4	3.0	2.9
MOS Micro	1.3	1.2	1.1	1.1	1.2	1.5	1.5
MOS Logic	0.7	0.7	0.7	0.7	0.8	0.9	0.9
Analog	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Discrete	0.1	0.1	0.1	0.1	0.1	0.2	0.2
Opto	0.1	0.1	0.1	0.1	0.1	0.1	0.1

Source: Dataquest (July 1990)

Table 38

Forecast North American Electronic Equipment Production
Dedicated Systems
(Annual Percentage Growth)

	1989	1990	1991	1992	1993	1994
Factory Revenue	(0.9)	0.2	2.8	(5.2)	(1.1)	0.4

Source: Dataquest (July 1990)

Table 39

Forecast North American Merchant Semiconductor Revenue
Dedicated Systems
(Annual Percentage Growth)

	1989	1990	1991	1992	1993	1994
Total Semiconductor	6.0	(16.4)	6.3	10.9	17.3	(3.6)
Total IC	6.2	(17.0)	6.3	10.9	17.7	(3.9)
Bipolar Digital	(17.7)	(8.4)	9.7	7.7	6.3	(12.0)
Bipolar Memory	10.1	(13.7)	(8.9)	(11.8)	(7.2)	(12.8)
Bipolar Logic	(20.1)	(7.7)	11.7	9.4	7.3	(11.9)
MOS	9.6	(18.2)	5.8	11.7	19.4	(3.3)
MOS Memory	26.3	(27.1)	7.7	14.6	21.0	(3.0)
MOS Micro	(10.1)	(5.5)	2.7	6.7	20.9	(2.1)
MOS Logic	(3.1)	(6.2)	5.1	10.8	12.4	(6.1)
Analog	2.7	(4.3)	8.8	0.5	5.4	2.8
Discrete	(1.5)	2.9	6.3	14.2	7.7	2.3
Opto	1.1	(0.4)	8.7	5.1	7.2	8.4

Source: Dataquest (July 1990)

Table 40

Forecast North American Merchant Semiconductor Revenue
Dedicated Systems
(Percentage of Data Processing)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	3.4	3.1	2.7	2.4	2.1	1.8	1.6
Total IC	3.4	3.1	2.7	2.3	2.0	1.8	1.5
Bipolar Digital	2.4	2.3	2.3	2.2	2.1	2.1	2.0
Bipolar Memory	2.1	2.0	1.9	1.9	1.8	1.7	1.7
Bipolar Logic	2.5	2.4	2.3	2.2	2.2	2.1	2.0
MOS	3.7	3.2	2.8	2.4	2.1	1.8	1.5
MOS Memory	3.8	3.3	2.8	2.3	2.0	1.7	1.4
MOS Micro	4.1	3.6	3.2	2.8	2.5	2.2	1.9
MOS Logic	2.9	2.7	2.4	2.2	2.0	1.8	1.6
Analog	1.9	1.7	1.5	1.3	1.2	1.0	0.9
Discrete	4.4	4.3	4.1	3.9	3.8	3.6	3.5
Opto	3.5	3.4	3.3	3.2	3.0	2.9	2.8

Source: Dataquest (July 1990)

Table 41

Forecast North American Merchant Semiconductor Revenue
Dedicated Systems
(Percentage of Total Dedicated Systems)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total IC	96.7	96.9	96.3	96.3	96.2	96.6	96.3
Bipolar Digital	11.5	8.9	9.8	10.1	9.8	8.9	8.1
Bipolar Memory	0.9	0.9	1.0	0.8	0.7	0.5	0.5
Bipolar Logic	10.6	8.0	8.8	9.3	9.1	8.3	7.6
MOS	82.8	85.6	83.8	83.3	83.9	85.4	85.7
MOS Memory	41.9	49.9	43.5	44.1	45.6	47.0	47.3
MOS Micro	25.9	22.0	24.8	24.0	23.1	23.8	24.2
MOS Logic	15.0	13.7	15.4	15.2	15.2	14.6	14.2
Analog	2.5	2.4	2.8	2.8	2.6	2.3	2.5
Discrete	2.2	2.1	2.6	2.6	2.6	2.4	2.6
Opto	1.0	1.0	1.2	1.2	1.1	1.0	1.2

Source: Dataquest (July 1990)

Trends in Personal Computers

INTRODUCTION

This section provides an overview of the personal computer (PC) market. The information in this section was provided by Dataquest's Personal Computer Industry Service (PCIS). This section presents market data for PCs by package type, bus type, microprocessor type, and average memory configuration.

DEFINITION OF A PERSONAL COMPUTER

The Dataquest definition of a PC is based on features and attributes that clearly distinguish PCs from other microprocessor-based products.

The key features that make up Dataquest's definition of a PC include the following:

- Human oriented—PCs are intended to meet individual business, professional, educational, and personal data processing needs and are not generally used as instrument controllers or automation devices.
- Single-user oriented—Although communications may be involved, systems are intended for the data processing needs of individuals and involve only one interactive device. PCs generally are purchased, operated, and used by an individual rather than an organization.
- Full alphanumeric keyboard—This feature distinguishes PCs from programmable calculators, video games, and dedicated special-function computers.
- Local programming capability using high-level programming languages—Most PCs support BASIC or a derivative of BASIC. Other languages such as Pascal, C, FORTRAN, and COBOL are available on personal computers.
- Resident operating system—PCs contain their own operating system, such as MS-DOS, PC-DOS, MAC-DOS, and OS/2, in either ROM or magnetic media. This factor distinguishes PCs from terminals.
- Ability to run general-purpose applications—This distinguishes a PC from systems dedicated through permanent hardware or firmware adaptation to functions such as word processing and financial analysis.

SUBCATEGORIES OF PERSONAL COMPUTERS

Desktop Computers

Desktop computers are defined as follows:

- Includes all personal computer systems that are not covered in the following definitions of transportable or true portable systems (Currently, "deskside" or "tower" systems also are included in the desktop systems definition.)
- System located on the user's desktop or working surface

Transportable Computers

Transportable computers include the following features:

- "Lunchbox" case style
- AC power supply
- Display type—Self-contained with at least 25 lines x 80 columns
- Storage—Self-contained flexible disk drive or compact hard disk drive
- Keyboard—Detachable, full-size, full-travel
- Interface/expansion—Capable of interfacing with typical PC peripherals via standard ports and expansion slots
- Entire system can be moved as one unit

Laptop-AC Computers

Laptop-AC computers have the following characteristics:

- "Clamshell" case style
- AC power supply
- Display type—Self-contained, with at least 25 lines x 80 columns
- Storage—Self-contained flexible disk drive or compact hard disk drive
- Keyboard—Full-size, full-travel, may be detachable
- Interface/expansion—Capable of interfacing with typical PC peripherals via standard ports and expansion slots
- Entire system can be moved as one unit

Laptop-DC Computers

Laptop-DC computers have the following features:

- "Clamshell" case style
- DC power supply—Self-contained or attachable battery pack
- Display type—Self-contained or attachable flat-panel display
- Display size—At least 4 lines x 40 columns
- Storage—Self-contained or external mass storage
- Keyboard—Full-size, full-travel, may be detachable
- Interface/expansion—Capable of interfacing with typical PC peripherals via standard ports and expansion slots
- Entire system can be moved as one unit

Notebook Computers

Notebook computers include the following characteristics:

- "Clamshell" case style
- DC power supply—Self-contained or attachable battery pack
- Display type—Self-contained or attachable flat-panel display
- Display size—At least 4 lines x 40 columns
- Storage—Self-contained or external mass storage
- Keyboard—Full-size, full-travel, may be detachable
- Total system weight—Not more than seven pounds
- Dimensions—Not larger than 8 x 11 x 1 inches
- Interface/expansion—Capable of interfacing with typical PC peripherals via standard ports and expansion slots
- Entire system can be moved as one unit

Hand-Held Computers

Hand-held computers include the following features:

- Case style designed to fit in the palm of one's hand
- DC power supply—Self-contained or attachable battery pack
- Display type—Self-contained or attachable flat-panel display
- Display size—At least 4 lines x 40 columns
- Storage capability—Self-contained
- Keyboard—Full-size, full-travel
- Total system weight—Not more than three pounds
- Interface/expansion—Capable of interfacing with typical PC peripherals via standard ports

MARKET ANALYSIS AND FORECAST

Table 1 shows worldwide PC historical shipment and forecast data by unit and revenue. Note that prior to 1988, average selling price (ASP) was defined as the end-user cost for a basic system. Since 1988, ASP is defined as the manufacturer's full list price for the average configuration of a given model.

Table 1

Worldwide Personal Computer Shipment History and Forecast

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Units (Millions)	14.7	15.1	16.8	19.2	22.2	24.9	28.2	31.4	35.3	40.0
Cumulative Units	49.0	64.0	80.0	100.0	122.0	147.0	175.0	206.0	242.0	282.0
ASP ($K)	2.07	2.04	1.96	2.70	3.06	3.34	3.49	3.55	3.35	3.08
ISV ($B)	30.4	30.7	33.0	51.7	67.9	83.1	98.5	111.5	118.3	123.1

Source: Dataquest (August 1990)

Dataquest foresees a period of relatively stable growth for PCs during the next five years following wild swings in growth rate during the mid-1980s. Worldwide market growth is expected to remain within the 11 to 13 percent range throughout the forecast period.

Several factors are expected to contribute to this continued growth. From a packaging perspective, we expect growth in the portable segments (laptop, notebook, and hand-held) to substantially outperform the traditional desktop market. On a regional basis, areas that have lagged in adopting PCs should continue to catch up with the leading PC-consuming regions.

Several leading PC manufacturers are once again targeting the home market, not only with low-cost hardware products but with consumer-oriented software as well. The justification for renewed optimism in this elusive market is based on the impressive communications and information management capabilities of programs such as Prodigy. If PC manufacturers can find a way to turn a profit at consumer price points, the home computer market may finally live up to its potential.

Finally, as the mainstream business market becomes increasingly reliant on replacement sales, the issue of installed-base obsolescence becomes an important one. Dataquest anticipates that the combination of multitasking operating environments and multimedia applications will dramatically increase system memory and compute power requirements, stimulating replacement sales.

Market Share

The PC market is both highly competitive and subject to rapid change. These competitive forces have shaped a very fragmented supplier base, with the top ten suppliers accounting for less than one-half of the market.

Table 2 lists the forecast top ten PC manufacturers' unit market shares for 1988, 1989, and 1990. Although there is some stability at the top, there also is substantial turnover among the top ten from year to year.

Table 3 lists the top ten PC manufacturers' market share in terms of revenue for 1988, 1989, and 1990.

Table 2

Estimated Worldwide Vendor Market Shares—Unit Shipments (Millions of Units)

Vendor	1988	Vendor	1989	Vendor	1990
IBM	11.3%	IBM	10.8%	IBM	10.8%
Apple	9.2	Apple	9.8	Commodore	7.2
Commodore	8.5	Commodore	8.1	Apple	6.8
NEC	4.8	NEC	4.8	NEC	5.6
Atari	4.5	Atari	4.3	Atari	4.9
Amstrad	3.9	Amstrad	3.8	Compaq	3.5
Tandy	3.2	Tandy	3.2	Toshiba	3.1
Zenith	2.9	Zenith	2.9	Olivetti	2.9
Compaq	2.7	Compaq	2.9	Tandy	2.6
Olivetti	2.3	Olivetti	2.7	Amstrad	2.6
Others	46.7	Others	46.7	Others	50.2
Total	100.0%	Total	100.0%	Total	100.0%

Source: Dataquest (August 1990)

Table 3

Estimated Worldwide Vendor Market Shares—If-Sold Value (Millions of Dollars)

Vendor	1988	Vendor	1989	Vendor	1990
IBM	15.5%	IBM	13.9%	IBM	15.3%
Apple	9.8	Apple	9.7	Apple	10.6
Compaq	5.9	Compaq	5.9	NEC	6.9
NEC	5.2	NEC	5.2	Compaq	6.6
Zenith	4.9	Zenith	4.9	Toshiba	3.0
Commodore	3.3	Olivetti	3.1	Zenith	2.9
Olivetti	2.4	Commodore	2.7	Commodore	2.6
Tandy	1.7	Toshiba	2.0	Olivetti	2.5
Epson	1.7	Tandy	1.9	Epson	2.2
Toshiba	1.5	Epson	1.4	Packard Bell	1.9
Others	48.1	Others	49.3	Others	45.4
Total	100.0%	Total	100.0%	Total	100.0%

Source: Dataquest (August 1990)

Shipment Breakouts

Shipments by Package Type

Although desktop systems continue to account for the vast majority of systems shipments, it is the emerging portable segments that are expected to provide most of the market growth. Table 4 shows Dataquest's forecast for PC shipments by package type.

The contrast between current market size and expected growth rates for the various package segments is shown in Figures 1 and 2.

Table 4

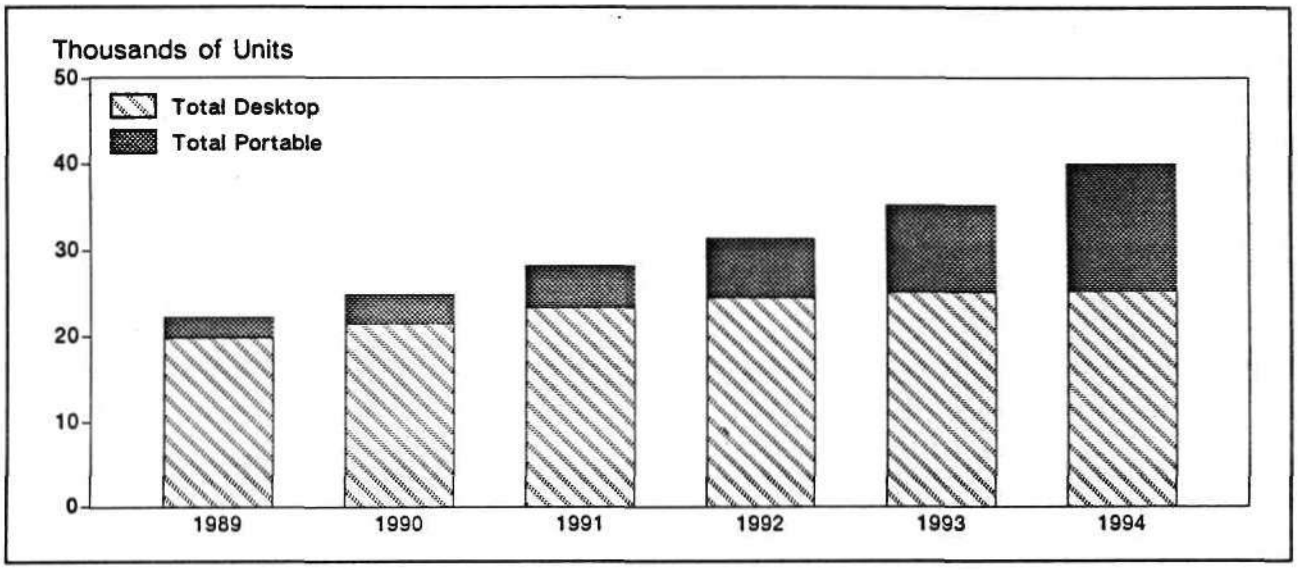
Worldwide PC Shipment Forecast by Package Type (Thousands of Units)

	1989	1990	1991	1992	1993	1994	CAGR 1990-1994
Portable							
Transportable	133	92	60	44	34	23	(29.3%)
Laptop AC	456	509	433	290	154	61	(41.2%)
Laptop DC	1,489	1,776	2,113	2,430	2,770	3,047	14.4%
Notebook	204	662	1,430	2,669	4,096	6,431	76.5%
Hand-Held	82	398	800	1,472	3,084	5,216	90.3%
Total Portable	2,364	3,437	4,836	6,905	10,138	14,778	44.0%
Desktop	19,843	21,480	23,355	24,482	25,164	25,229	4.1%
Total	22,207	24,917	28,191	31,387	35,302	40,007	12.6%

Source: Dataquest (August 1990)

Figure 1

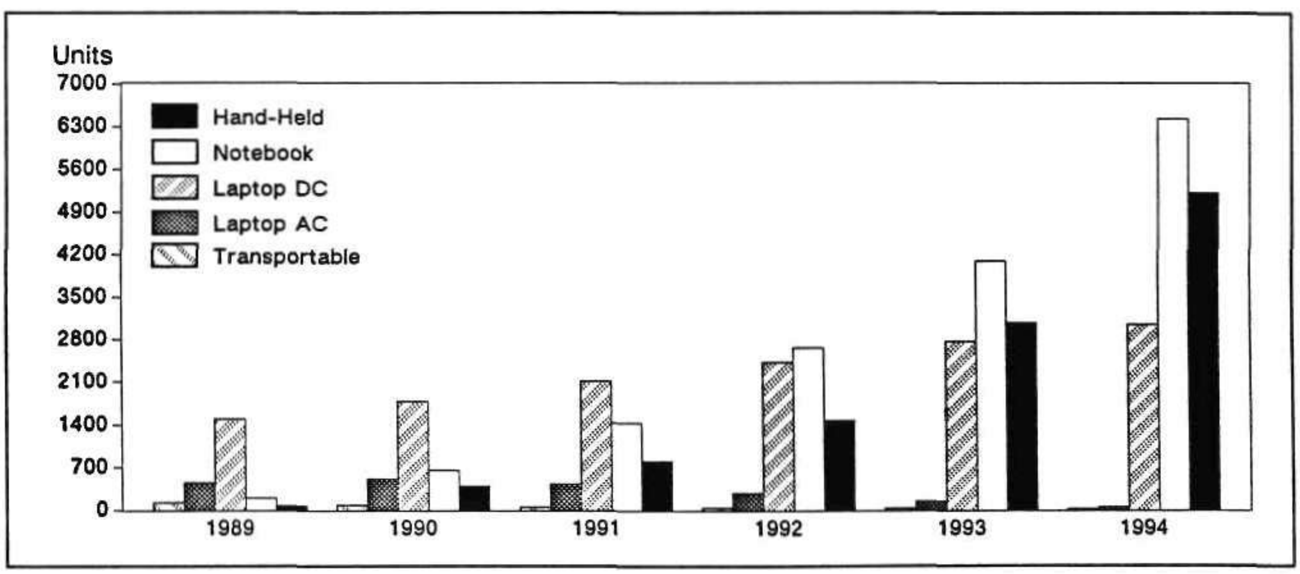
Worldwide PC Shipment Forecast: Desktop vs. Portable



Source: Dataquest (August 1990)

Figure 2

Portable PC Shipment Forecast



Source: Dataquest (August 1990)

PC Shipments by Bus Type

Table 5 and Figure 3 shows Dataquest's PC forecast by bus type. As with many other technology issues, the leading edge tends to receive a disproportionate share of attention, skewing the individual's view of the market as a whole. Dataquest expects the unit shipments of AT-bus systems to continue to grow throughout the forecast period, and the EISA and MCA bus systems to gain share at the high end.

Table 5

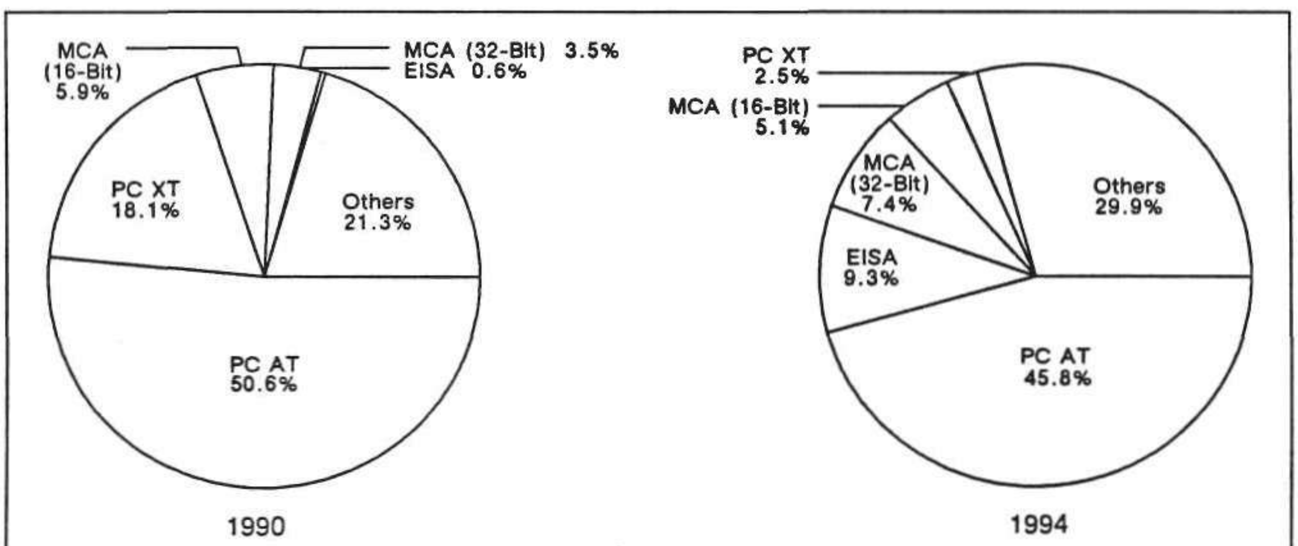
Worldwide PC Shipment Forecast by Bus Type (Thousands of Units)

Bus Type	1989	1990	1991	1992	1993	1994
PC/XT	4,598	4,498	3,558	2,423	1,686	996
AT	10,794	12,624	14,770	16,717	17,646	18,284
MCA (16-Bit)	1,221	1,463	1,689	1,852	1,976	2,059
MCA (32-Bit)	603	864	1,337	1,771	2,296	2,979
EISA	2	156	545	1,321	2,501	3,716
Other	4,988	5,312	6,292	7,302	9,196	11,972
Total	22,206	24,917	28,191	31,386	35,301	40,006

Source: Dataquest (August 1990)

Figure 3

Worldwide PC Shipment Forecast by Bus Type



Source: Dataquest (August 1990)

PC Shipments by Microprocessor Type

A similar situation can be seen in the forecast by microprocessor type. Although 80486- and 80586-based systems gain attention and market share with their high growth rates, the 80286- and 80386SX-based systems make up the bulk of the market throughout the forecast period. In fact, Dataquest expects 80386SX-based systems to continue growing through 1994.

Table 6 and Figure 4 show Dataquest's PC forecast by microprocessor type.

Table 6

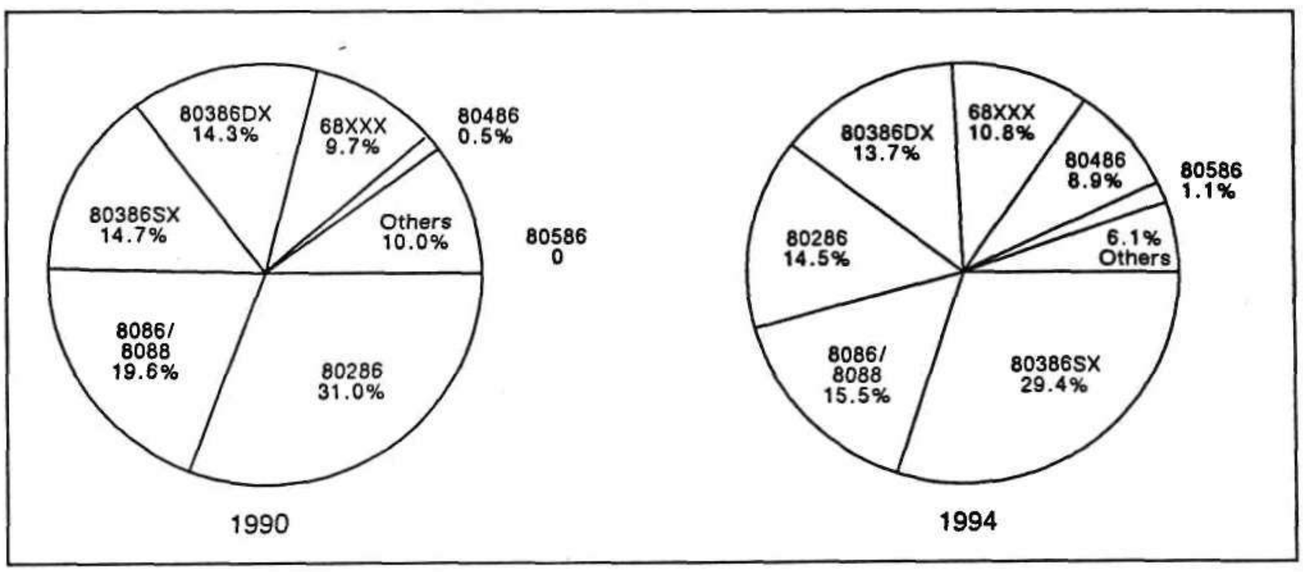
Worldwide PC Shipment Forecast by Microprocessor Type (Thousands of Units)

Processor	1989	1990	1991	1992	1993	1994
8086/8088	4,680	4,896	4,358	3,896	4,770	6,212
80286	7,928	7,734	7,579	7,312	6,654	5,789
80386SX	1,925	3,667	6,121	8,311	10,145	11,751
80386DX	2,767	3,570	4,096	4,648	4,978	5,489
80486	5	137	545	1,390	2,565	3,579
80586	NA	NA	NA	1	77	430
68XXX	2,068	2,423	2,881	3,333	3,803	4,305
Others	2,834	2,491	2,611	2,497	2,309	2,451
Total	22,207	24,918	28,191	31,388	35,301	40,006

NA = Not available
Source: Dataquest (August 1990)

Figure 4

Worldwide PC Shipment Forecast by Microprocessor Type



Source: Dataquest (August 1990)

PC Memory Demand

As compute requirements push the micro and logic elements of PC hardware to ever-higher levels of sophistication, system memory demands are likely to rise dramatically as well.

Table 7 shows Dataquest's estimated main memory configurations by microprocessor type for the forecast period.

Table 7

Estimated Memory Configuration by Microprocessor Type
(Megabytes per System)

Processor	1989	1990	1991	1992	1993	1994
8086/8088	0.60	1.00	1.20	1.50	2.00	3.00
80286	1.00	1.30	1.80	2.70	3.50	5.00
80386SX	1.00	1.40	2.50	4.00	6.00	8.00
80386DX	1.50	2.00	4.00	7.00	10.00	14.00
80486	NA	5.00	8.00	12.00	16.00	20.00
80586	NA	NA	NA	16.00	23.00	32.00
68XXX	1.60	1.80	2.80	3.60	6.00	8.00
Others	0.64	0.82	1.00	1.40	2.00	3.00

NA = Not available
Source: Dataquest (August 1990)

Trends in Personal Computers

INTRODUCTION

This section provides an overview of the personal computer (PC) market. The information in this section was provided by Dataquest's Personal Computer Industry Service (PCIS). The section presents market data for PCs by price segment, package type, bus type, microprocessor type, and average memory configuration.

DEFINITION OF A PERSONAL COMPUTER

The Dataquest personal computer definition is based on features and attributes that clearly distinguish personal computers from other microprocessor-based products. Price is also a component of the definition, but the price range covered, $0 to $10,000, is intended to include any systems that share these particular features and attributes.

Key Features of Personal Computers

The key features that make up Dataquest's definition of a personal computer include the following:

- Human Oriented—Personal computers are intended to meet individual business, professional, educational, and personal data processing needs, and do not generally act as instrument controllers or automation devices.

- Single-User Oriented—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.

- Full Alphanumeric Keyboard—This feature distinguishes personal computers from programmable calculators, video games, and dedicated special-function computers.

- Local Programming Capability Using High-Level Programming Languages—Most personal computers support BASIC, or a derivative of it. Other languages such as Pascal, FORTRAN, and COBOL are available on personal computers.

- Resident Operating System—Personal computers contain their own operating system in ROM, or magnetic media. This distinguishes PCs from terminals.

- Ability to Run General-Purpose Applications—This distinguishes a personal computer from systems dedicated through permanent hardware of firmware adaptation to such functions as word processing and financial analysis.

- Average System Price $0 to $10,000—Systems conforming to the foregoing elements of the personal computer definition may be found in a very wide price range, with very sophisticated high-performance systems at the high end and basic entry-level home systems at the low end. Some high-end systems in their more highly configured versions may have a list price greater than $10,000. However, the price criterion applies to the average actual selling price for all of a system's possible configurations.

Subcategories of Personal Computers

Personal computers are divided further into the following subcategories:

- Desktop Computers
  - Includes all personal computer systems that are not covered in the following definitions of transportable, true portable, and hand-held systems. (Currently, "deskside" or "tower" systems are also included with desktop systems.)
  - Systems located on the user's desktop or working surface

- Transportable Computers
  - AC power supply: May have optional battery capability
  - Display type: Self-contained 25 lines x 80 columns
  - Storage: Self-contained flexible disk drive; compact hard disk drives
  - Amount of memory: Minimum internal user memory of 64 Kbytes
  - Keyboard: Detachable, full-size, full-travel
  - Total system weight: 15 to 40 pounds
  - Interface/expansion: Capability to interface with typical PC peripherals via standard ports and expansion slots
  - Entire system can be moved as one unit

- True Portable Computers
  - DC power supply: Self-contained or attachable (i.e., not separate) battery pack
  - Display type: Self-contained or attachable flat-panel display, principally LDCs today
  - Display size: Minimum display size of 4 lines x 40 columns
  - Storage capability: Self-contained or external mass storage
  - Amount of memory: Minimum internal user memory of 32 Kbytes
  - Keyboard: Full-size, full-travel ("touch-typeable")
  - Total system weight: 5 to 10 pounds for systems unit; configured, not more than 15 pounds
  - Interface/expansion: Capability to interface with hard copy device, other computer devices via "standard" ports

The average PC configuration is shown in Table 1.

Table 1

Components of Typical System Configuration, Average System Price, and If-Sold Value

Includes	Does Not Include
CPU	Modems (unless integral)
Keyboard	Printers (unless integral)
Monitor*	Applications software
Disk drives and controller cards*	Service/maintenance contracts
Bundled application software	Leasing revenue
Manufacturer's optional add-in cards	Training/support
Auxiliary input device options	Add-in cards (third party)
Hard disk options	Books
Documentation	Third-party documentation
Standard-level video circuitry	

*System manufacturer (and/or third party)

Source: Dataquest
October 1988

MARKET ANALYSIS

All Personal Computers

Market Forecast

The PC market has experienced quite a resurgence in 1987 and 1988. Nonetheless, the industry has not seen the triple-digit growth rates of 1983, although still well ahead of the 0.5 percent revenue growth in 1986. In 1987, the worldwide PC market grew 7.7 percent. In 1988, we expect worldwide PC revenue to climb 17.0 percent above 1987. We forecast the PC market to grow healthily from 1987 through 1992 at a 10.6 percent unit shipment compound annual growth rate (CAGR) and a revenue CAGR of 11.4 percent. Table 2 and Figure 1 display Dataquest's worldwide PC forecast.

Table 2

Worldwide Personal Computer Forecast

	1983	1984	1985	1986	1987	CAGR 1983-1987
Less than $1,000						
Units (M)	7.18	7.63	6.29	5.53	5.21	(7.7%)
If-Sold Value ($B)	$ 2.82	$ 3.73	$ 3.67	$ 2.97	$ 2.74	(0.7%)
Greater than $1,000						
Units (M)	3.92	7.38	8.43	9.64	11.59	31.1%
If-Sold Value ($B)	$11.80	$20.72	$26.76	$27.62	$30.22	26.5%
Total						
Units (M)	11.10	15.01	14.72	15.17	16.80	10.9%
If-Sold Value ($B)	$14.62	$24.45	$30.43	$30.59	$32.96	22.5%

	1988	1989	1990	1991	1992	CAGR 1988-1992
Less than $1,000						
Units (M)	5.01	5.85	6.61	7.39	7.92	12.1%
If-Sold Value ($B)	$ 2.57	$ 3.54	$ 4.20	$ 4.58	$ 4.99	18.0%
Greater than $1,000						
Units (M)	14.00	15.33	16.71	18.03	19.86	9.1%
If-Sold Value ($B)	$36.07	$39.64	$44.24	$47.63	$51.68	9.4%
Total						
Units (M)	19.01	21.18	23.32	25.42	27.78	9.9%
If-Sold Value ($B)	$38.64	$43.18	$48.44	$52.21	$56.67	10.0%

Source: Dataquest
October 1988

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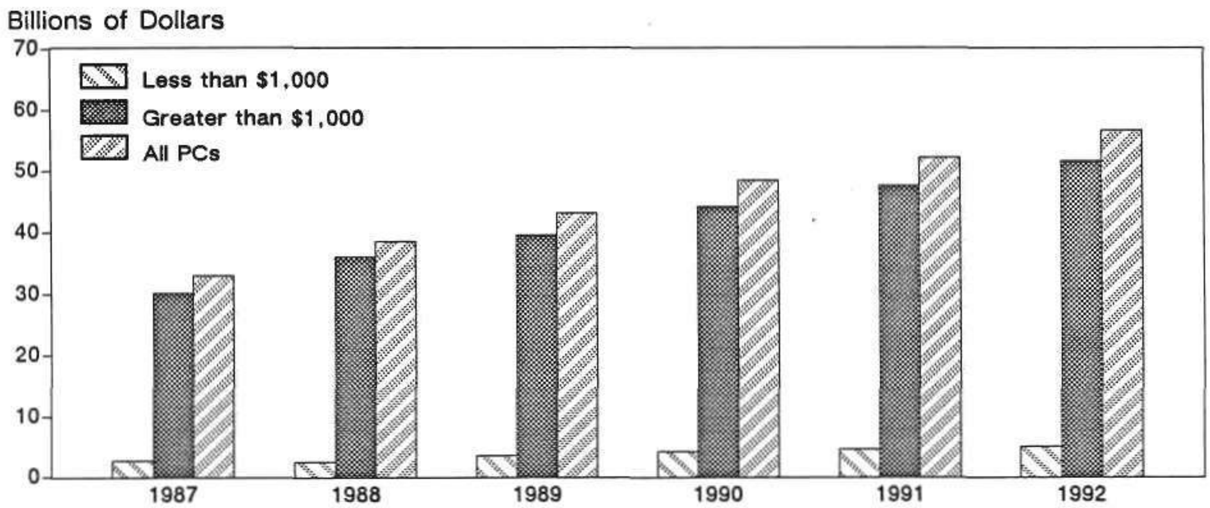
Figure 1

Worldwide Personal Computer Forecast



Source: Dataquest
October 1988

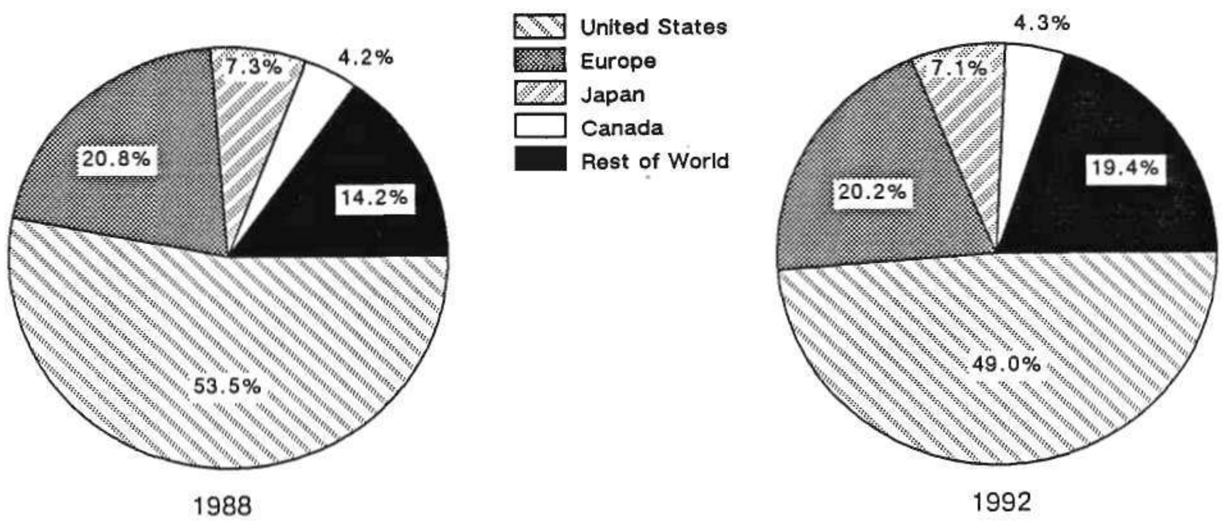
Several developments are expected to influence the growth of the market over the next five years. In general, the growth of the market is expected to be sustained by continued technological evolution, by increased reliance of major commercial and noncommercial institutions on personal computers as tools for white-collar workers, by the continued penetration of educational institutions with personal computers, and by the development of a new more powerful and useful generation of PCs for the home. In addition, areas of the world that have lagged in adopting the PC will continue to catch up with the leading PC-consuming regions.

The U.S market for personal computers is the largest of the five regions that Dataquest follows: United States, Canada, Europe, Japan, and Rest of World (ROW). We forecast the U.S. market to lose the largest market share over the forecast period, dropping from 58.2 percent in 1988 to 51.5 percent in 1992. Most of the U.S. market share loss will result from market share growth in ROW as PC use in the rest of the world becomes more common. Figures 2 and 3 show worldwide PC shipments by region.

Although the U.S. market will lose market share to other regions in the world, the U.S. PC market will continue to grow through 1992. Dataquest forecasts U.S. PC consumption to grow at a 7.4 percent CAGR from 1988 to 1992. Table 3 and Figure 4 show Dataquest's U.S. personal computer forecast.

Figure 2

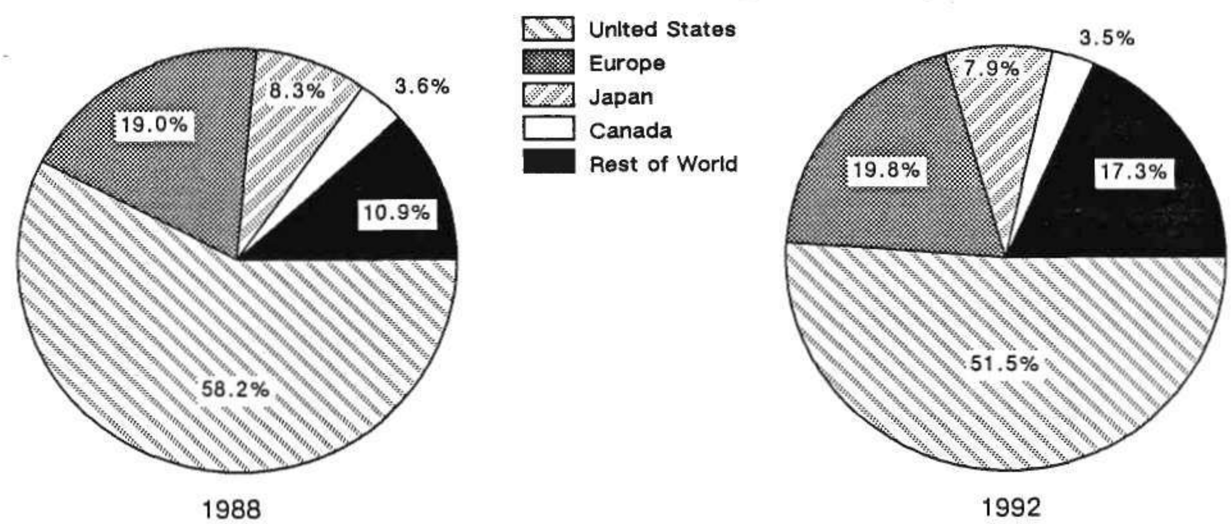
Worldwide PC Unit Shipments by Region (1988–1992)



Source: Dataquest
October 1988

Figure 3

Worldwide PC If-Sold Value by Region (1988–1992)



Source: Dataquest
October 1988

Table 3

United States Personal Computer Forecast
(Billions of Dollars and Millions of Units)

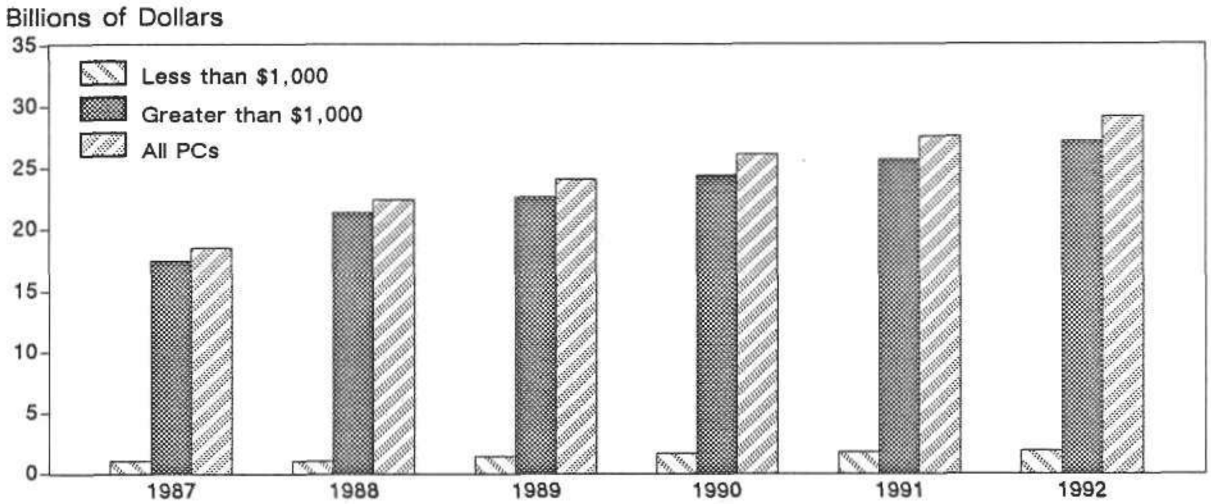
	1983	1984	1985	1986	1987	CAGR 1983-1987
Less than $1,000						
Units	3.97	3.21	1.61	1.64	1.93	(16.5%)
If-Sold Value	$ 1.53	$ 1.69	$ 0.89	$ 0.92	$ 1.06	(8.8%)
Greater than $1,000						
Units	2.22	4 .53	2.78	5.39	6.79	32.2%
If-Sold Value	$ 7.08	$12.57	$15.35	$15.37	$17.45	25.3%
Total						
Units	6.19	7.74	4.39	7.03	8.72	8.9%
If-Sold Value	$ 8.61	$14.26	$16.24	$16.29	$18.51	21.1%

	1988	1989	1990	1991	1992	CAGR 1988-1992
Less than $1,000						
Units	1.96	2.35	2.63	2.91	3.09	12.1%
If-Sold Value	$ 1.05	$ 1.45	$ 1.69	$ 1.80	$ 1.92	16.3%
Greater than $1,000						
Units	8.23	8.78	9.21	9.73	10.48	6.2%
If-Sold Value	$21.37	$22.63	$24.38	$25.75	$27.26	6.3%
Total						
Units	10.19	11.13	11.84	12.64	13.57	7.4%
If-Sold Value	$22.42	$24.08	$26.07	$27.55	$29.18	6.8%

Source: Dataquest
October 1988

Figure 4

United States Personal Computer Forecast



Source: Dataquest
October 1988

Market Share

Unit Share. In 1987, Commodore continued its market share decline by losing 1.7 percentage points or 15.0 percent of its share worldwide. We expect Commodore's decline in overall unit market share to continue into 1988 with another drop of 17.0 percent of the total market to 8.0 percent. IBM widened its margin in the number one position to a 4.2 percentage point gap to the closest competitor. IBM regained some market share lost in 1986 with demand for its new PS/2 line of computers. We expect IBM's share to remain constant in 1988 with help from continuous new additions to the IBM PS/2 family. Due to the strong performance of the Macintosh line of computers, Apple's market share increased in 1987 to 9.0 percent from 7.8 percent. Dataquest projects this momentum to continue into 1988. NEC's position in the top five is due to its dominance of the Japanese market and its success in foreign markets. Table 4 lists the top 10 PC manufacturers' unit market shares for 1986 through 1988. Figure 5 illustrates those manufacturers' unit market shares for 1988.

Table 4

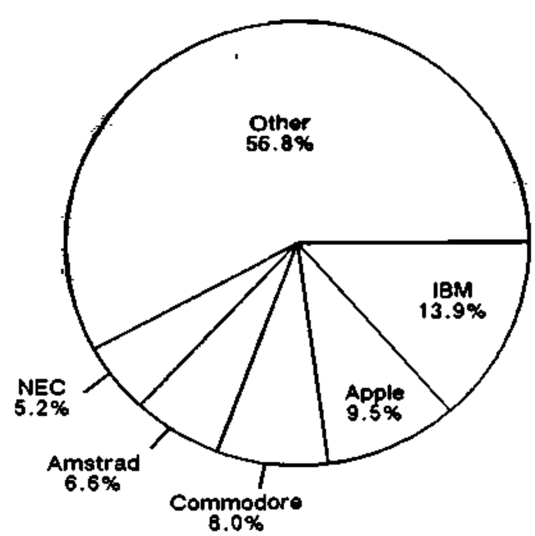
Estimated Worldwide Vendor Market Shares—Unit Basis
All Personal Computers
(1986–1988)

Vendor	1986	Vendor	1987	Vendor	1988
IBM	12.9%	IBM	13.9%	IBM	13.9%
Commodore	11.4	Commodore	9.7	Apple	9.5
Apple	7.8	Apple	9.0	Commodore	8.0
Amstrad	5.9	NEC	5.0	Amstrad	6.6
NEC	5.3	Amstrad	8.0	NEC	5.2
Tandy	3.9	Atari	5.1	Atari	4.5
Atari	3.7	Tandy	4.1	Tandy	4.5
Fujitsu	2.2	Compaq	2.4	Zenith	3.1
Sanyo	1.8	Olivetti	2.1	Compaq	2.8
Compaq	1.8	Zenith	2.7	Olivetti	2.2
Other	43.3	Other	38.0	Other	39.7
Total	100.0%		100.0%		100.0%

Source: Dataquest
October 1988

Figure 5

Estimated 1988 Worldwide Market Share—Unit Basis
All Personal Computers



Source: Dataquest
October 1988

Trends in Personal Computers

Dollar Share. In terms of dollars, IBM is the overwhelming market leader, due to its high unit share coupled with the higher average selling price (ASP) of a typical IBM system. Nonetheless, the gap between IBM and Apple has narrowed over the years as Apple's high-end systems move into the business market. Compaq has been narrowing the gap, with NEC aiming for the number three position. We expect Compaq to stay just barely behind NEC in 1988 at 0.3 percentage points. We forecast vendors outside of the top 10 to keep a constant market share of about 36 percent this year. In general, the vendors with smaller shares also tend to be those with lower-priced systems. The dollar market share for all PCs is shown in Table 5 and Figure 6.

Table 5

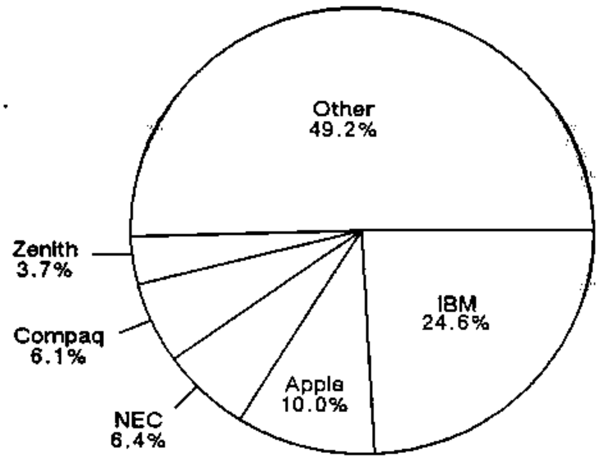
Estimated Worldwide Vendor Market Shares—If-Sold Value Basis
All Personal Computers
(1986–1988)

Vendor	1986	Vendor	1987	Vendor	1988
IBM	23.7%	IBM	25.7%	IBM	24.6%
Apple	6.4	Apple	9.7	Apple	10.0
NEC	5.7	NEC	6.1	NEC	6.4
Compaq	3.9	Compaq	5.1	Compaq	6.1
Panafacom	2.7	Zenith	3.7	Zenith	3.7
AT&T	2.4	Tandy	3.1	Tandy	3.4
Olivetti	2.3	Commodore	3.1	Olivetti	2.9
Tandy	2.1	Amstrad	3.0	Toshiba	2.4
Zenith	2.1	Olivetti	2.7	Commodore	2.3
Fujitsu	2.0	Toshiba	1.9	Amstrad	2.2
Other	46.7	Other	35.9	Other	36.0
Total	100.0%		100.0%		100.0%

Source: Dataquest
October 1988

Figure 6

**Estimated 1988 Worldwide Vendor Market Shares—If-Sold Value Basis
All Personal Computers**



Source: Dataquest
October 1988

Less than $1,000 Price Segment

Worldwide growth in the less than $1,000 segment is expected to turn around over the next five years. The CAGR in units is projected to be 12.1 percent, while growth in if-sold value will be somewhat stronger at 18.0 percent. We believe that the recovery in this segment, after three years of declining shipments, will result from the entry of a more powerful class of systems in this range, primarily MS-DOS-compatible models, previously found in the greater than $1,000 segment. The continued downward migration of products will contribute to rising ASPs in the segment, resulting in even healthier growth in if-sold value. At the same time, we expect those models currently at the low end of this segment to largely disappear over the next five years.

Market Share

Unit Share. Commodore remains the worldwide unit share leader, although its share has eroded dramatically from the 36.0 percent share Commodore owned in 1985 to an expected 25.5 percent share in 1988. Amstrad held second place from 1986 to 1987 at 18.7 percent share. However, the fastest rising vendor in the low-end market, Atari, is expected to pass Amstrad in 1988 to take the number two position with 17.0 percent of the total market share. Apple's share in this category is declining as a result of Apple's emphasis on higher ASP systems. The Other category's share has grown significantly in this segment, from 19.3 percent in 1986 to 27.2 percent in 1987, with further growth to more than 30.0 percent expected in 1988. Many of the systems in the Other classification are low-priced MS-DOS systems. Table 6 and Figure 7 show vendor unit market shares for the less than $1,000 segment.

Table 6

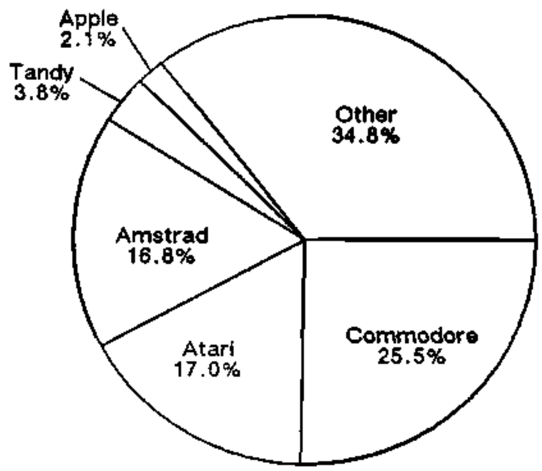
Estimated Worldwide Vendor Market Shares—Unit Basis
Personal Computers Less than $1,000
(1986–1988)

Vendor	1986	Vendor	1987	Vendor	1988
Commodore	30.0%	Commodore	24.9%	Commodore	25.5%
Amstrad	16.3	Amstrad	18.7	Atari	17.0
Atari	10.3	Atari	16.5	Amstrad	16.8
Apple	5.9	Tandy	4.9	Tandy	3.8
Tandy	4.1	Apple	3.1	Apple	2.1
Sinclair	4.9	Panasonic	1.2	Epson	1.2
Fujitsu	2.8	Sanyo	1.0	Sanyo	1.1
NEC	2.5	Epson	0.9	Franklin	0.9
Sharp	2.2	Franklin	0.8	Blue Chip	0.7
Acorn	1.7	Acorn	0.8	Acorn	0.7
Other	19.3	Other	27.2	Other	30.2
Total	100.0%		100.0%		100.0%

Source: Dataquest
October 1988

Figure 7

**Estimated 1988 Worldwide Vendor Market Shares—Unit Basis
Personal Computers Less than $1,000**



Source: Dataquest
October 1988

Dollar Share. Amstrad held the lead in dollar share in 1987 after passing Commodore in 1986. We expect Commodore to regain the lead in 1988 as Amstrad's share of the market drops. Although Commodore is expected to regain the number one position in 1988, we believe that its total share will decline. Atari and the Other category of low-end MS-DOS machines will soak up Commodore's and Amstrad's losses. Table 7 and Figure 8 show relative dollar market shares for the less than $1,000 segment.

Table 7

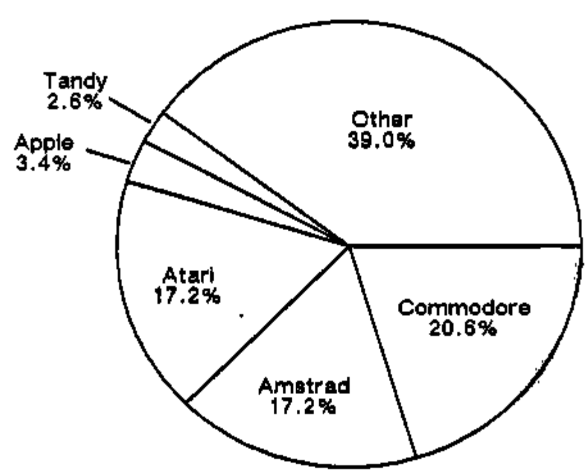
Estimated Worldwide Vendor Market Shares—If-Sold Value Basis
Personal Computers Less than $1,000
(1986–1988)

Vendor	1986	Vendor	1987	Vendor	1988
Amstrad	21.5%	Amstrad	21.9%	Commodore	20.6%
Commodore	13.9	Commodore	19.2	Amstrad	17.2
Atari	11.9	Atari	16.8	Atari	17.2
Apple	11.0	Apple	5.3	Apple	3.4
Sinclair	5.4	Tandy	3.9	Tandy	2.6
Fujitsu	4.0	Epson	1.3	Epson	1.7
NEC	3.7	Panasonic	1.3	Franklin	1.1
Sharp	3.5	Acorn	1.1	Acorn	0.8
Tandy	3.4	Franklin	1.1	Blue Chip	0.7
Acorn	2.3	NEC	0.9	Samsung	0.7
Other	19.4	Other	27.2	Other	34.0
Total	100.0%		100.0%		100.0%

Source: Dataquest
October 1988

Figure 8

Estimated 1988 Worldwide Vendor Market Shares—If-Sold Value Basis
Personal Computers Less than $1,000



Source: Dataquest
October 1988

Greater than $1,000 Price Segment

The greater than $1,000 segment is the fastest growing segment this year as new products drive PC consumption to unit shipment growth of 21 percent and revenue growth of 19 percent in 1988. Dataquest expects this segment to continue to grow through the forecast period. The growth will be driven mainly by continued technological improvement and software development such as new microprocessors, denser memories, and enhanced operating systems. We expect this segment to experience comparatively moderate growth from 1989 to 1992 as the industry matures and businesses absorb the new PC power purchased during the 1987 and 1988 boom.

Market Share

Unit Share. IBM dominates this segment with 20.0 percent of the total market. We expect IBM's share to drop a small amount in 1988 as companies such as Apple, Compaq, Tandy, and Zenith continue to penetrate the business PC market. The success of the new additions to Apple's Macintosh line of computers pushed Apple's market share up 2.8 percentage points from 1986 to 1987, representing a 31.0 percent increase. The most impressive rise in this segment was Zenith's move from tenth place in 1986 to fourth, passing Compaq, Tandy, Olivetti, and others to follow NEC. Table 8 and Figure 9 display unit market share for the greater than $1,000 segment.

Table 8

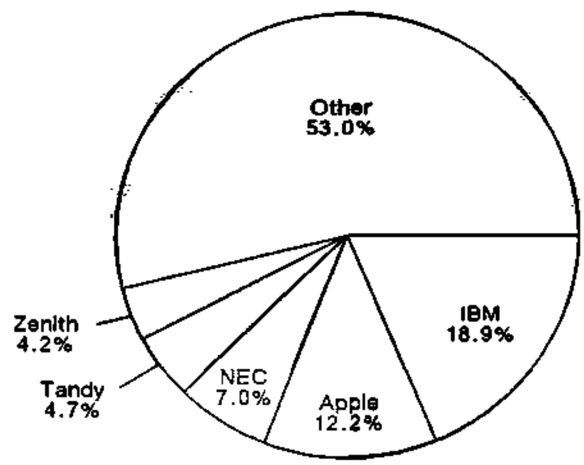
Estimated Worldwide Vendor Market Shares—Unit Basis
Personal Computers Greater than $1,000
(1986–1988)

Vendor	1986	Vendor	1987	Vendor	1988
IBM	20.2%	IBM	20.1%	IBM	18.9%
Apple	8.9	Apple	11.7	Apple	12.2
NEC	6.9	NEC	6.9	NEC	7.0
Tandy	3.9	Zenith	3.9	Tandy	4.7
Compaq	2.9	Tandy	3.8	Zenith	4.2
Olivetti	2.7	Compaq	3.5	Compaq	3.8
AT&T	2.4	Olivetti	3.1	Olivetti	3.1
Sanyo	2.3	Amstrad	3.1	Amstrad	3.0
Leading Edge	2.2	Commodore	2.8	Epson	2.3
Zenith	2.1	Leading Edge	2.3	Toshiba	2.3
Other	45.5	Other	38.8	Other	38.5
Total	100.0%		100.0%		100.0%

Source: Dataquest
October 1988

Figure 9

Estimated 1988 Worldwide Vendor Market Shares—Unit Basis
Personal Computers Greater than $1,000



Source: Dataquest
October 1988

Dollar Share. IBM's share in dollars is even more pronounced than its unit share in the greater than $1,000 segment. The introduction of IBM's PS/2 family helped raise IBM's overall ASP in 1987 and, consequently, its dollar market share. In 1988, price declines of the PS/2s and increased competition from Apple, Compaq, and Tandy will push IBM's share down a small amount. Apple passed NEC in 1987 to take the number two slot. Apple's dollar share grew 71.0 percent (4.2 percentage points) in 1987 as a result of the popularity of its Macintosh II and Macintosh SE. NEC and Compaq are expected to hold their respective third and fourth places in 1988. The Other category dropped dramatically in 1987 due to the move of low-end MS-DOS machines to the less than $1,000 price category. Dollar market shares for the greater than $1,000 segment are displayed in Table 9 and Figure 10.

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Table 9

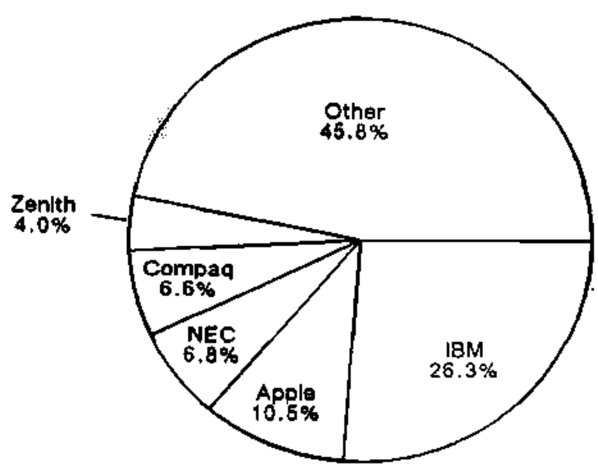
Estimated Worldwide Vendor Market Shares—If-Sold Value Basis
Personal Computers Greater than $1,000
(1986–1988)

Vendor	1986	Vendor	1987	Vendor	1988
IBM	26.1%	IBM	28.0%	IBM	26.3%
NEC	5.9	Apple	10.1	Apple	10.5
Apple	5.9	NEC	6.6	NEC	6.8
Compaq	4.3	Compaq	5.6	Compaq	6.6
Panafacom	3.0	Zenith	4.1	Zenith	4.0
AT&T	2.6	Olivetti	3.0	Tandy	3.4
Olivetti	2.6	Tandy	3.0	Olivetti	3.1
Zenith	2.3	Toshiba	2.1	Toshiba	2.5
Tandy	2.0	Epson	1.7	AT&T	1.9
Wang	1.9	Commodore	1.7	Epson	1.8
Other	43.4	Other	34.1	Other	33.1
Total	100.0%		100.0%		100.0%

Source: Dataquest
October 1988

Figure 10

Estimated 1988 Worldwide Vendor Market Shares—If-Sold Value Basis
Personal Computers Greater than $1,000



Source: Dataquest
October 1988

Shipments by Package Type

Desktop Systems

Desktop systems are the most popular configuration, accounting for 94 percent of all systems shipped worldwide in 1987. They will become more compact as they become more powerful. Dataquest expects desktop systems to continue to be the most popular personal computer configuration in 1992, although we forecast their market share to drop to 87 percent of all systems shipped worldwide. Table 10 and Figure 11 show Dataquest's forecast for PC shipments by package type.

Table 10

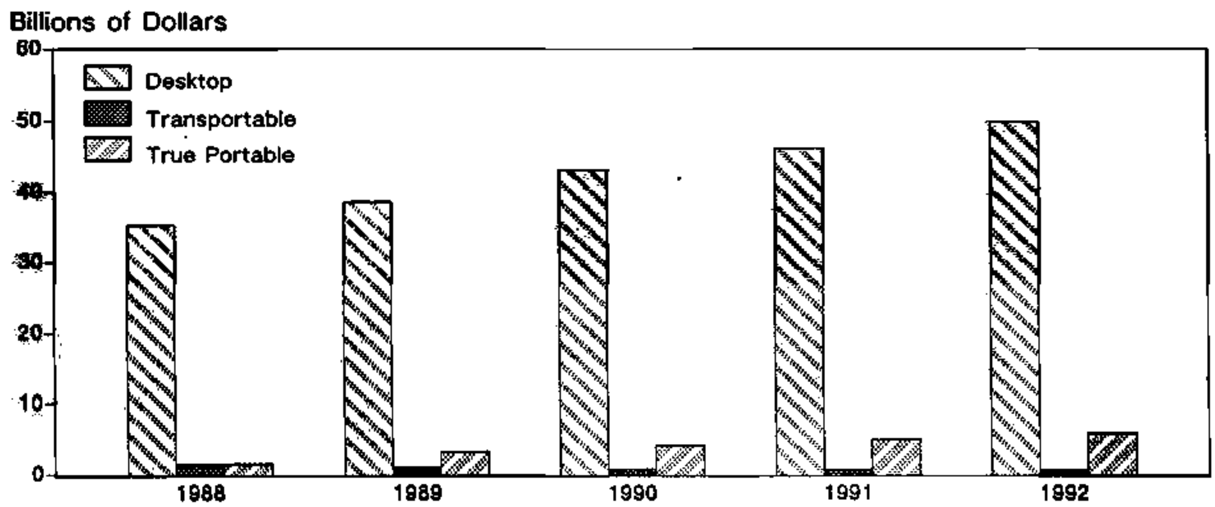
Estimated Worldwide Personal Computer Shipments by Package Type

	1988	1989	1990	1991	1992	CAGR 1988-1992
Desktop						
Units (M)	17.58	19.04	20.79	22.44	24.19	8.3%
If-Sold Value ($B)	35.35	38.69	43.22	46.24	49.88	9.0%
Transportable						
Units (M)	0.45	0.49	0.44	0.43	0.42	(1.7%)
If-Sold Value ($B)	1.65	1.17	0.98	0.93	0.85	(15.3%)
True Portable						
Units (M)	0.98	1.64	2.10	2.56	3.17	34.1%
If-Sold Value ($B)	1.63	3.32	4.24	5.05	5.93	38.1%
Total						
Units (M)	19.01	21.17	23.33	25.43	27.78	9.9%
If-Sold Value ($B)	38.63	43.18	48.44	52.22	56.66	10.0%

Source: Dataquest
October 1988

Figure 11

Worldwide Personal Computer Forecast by Package Type



Source: Dataquest
October 1988

Transportable Systems

Transportable systems are light and compact enough to be carried from place to place. They were first introduced in 1981 and peaked in year-to-year growth in 1983. The long-term growth rate for transportables is not too promising at a CAGR of negative 15.0 percent from 1988 to 1992. A new generation of powerful true portables is expected to take market share away from the transportable market. Dataquest expects 1988 to be the last year of revenue growth for transportables throughout the forecast period as the major players move to true portable systems. We forecast the transportables share of the total unit shipments to drop from 2.0 percent to 1.5 percent of the total in 1992.

The transportable market is dominated by the number one and number two players—Compaq and Toshiba, respectively. Compaq's unit market share grew from 35.0 percent in 1986 to 45.0 percent in 1987. Toshiba's market share growth in 1987 was even more dramatic. Toshiba moved from 1.8 percent share in 1986 to 22.6 percent share in 1987. Toshiba's success is due to the popularity of its portable T3100. Transportable unit and if-sold value vendor market share are displayed in Tables 11 and 12 and Figures 12 and 13.

Table 11

Estimated Worldwide Vendor Market Shares—Unit Basis
Transportable Personal Computers
(1986–1988)

Vendor	1986	Vendor	1987	Vendor	1988
Compaq	35.3%	Compaq	45.0%	Compaq	44.3
Panasonic	22.6	Toshiba	22.6	Toshiba	30.2
Sharp	6.8	Panasonic	12.9	Sharp	14.8
Cordata	6.2	Sharp	10.0	NEC	4.5
Zenith	4.9	HP	2.0	Samsung	5.6
Other	24.2	Other	7.5	Other	0.6
Total	100.0%		100.0%		100.0%

Source: Dataquest
October 1988

Table 12

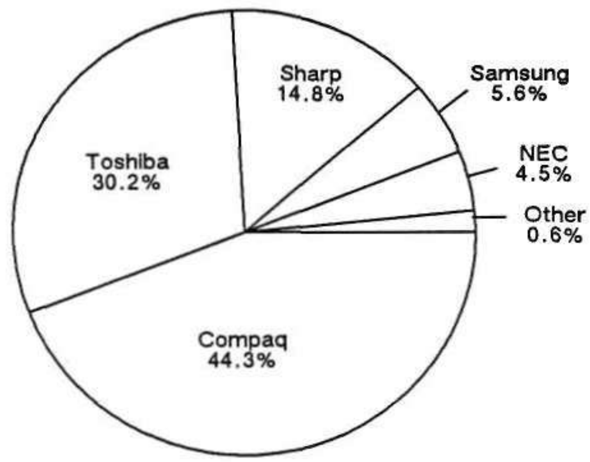
Estimated Worldwide Vendor Market Shares—If-Sold Value Basis
Transportable Personal Computers
(1986–1988)

Vendor	1986	Vendor	1987	Vendor	1988
Compaq	47.7%	Compaq	53.7%	Compaq	51.1%
Panasonic	17.0	Toshiba	23.9	Toshiba	31.7
Cordata	6.3	Panasonic	7.3	Sharp	9.7
Sharp	4.5	Sharp	7.2	NEC	4.0
Zenith	4.2	HP	3.7	Samsung	3.2
Other	20.3	Other	4.2	Other	0.3
Total	100.0%		100.0%		100.0%

Source: Dataquest
October 1988

Figure 12

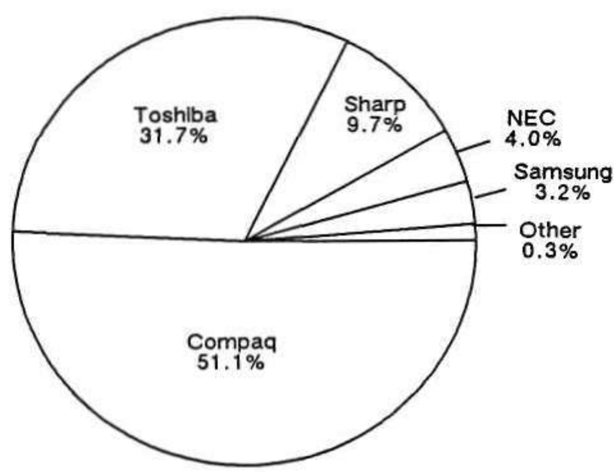
Estimated 1988 Worldwide Vendor Market Shares—Unit Basis
Transportable Personal Computers



Source: Dataquest
October 1988

Figure 13

Estimated 1988 Worldwide Vendor Market Shares—If-Sold Value Basis
Transportable Personal Computers



Source: Dataquest
October 1988

True Portables

Dataquest segments true portables into two categories: high-end and low-end true portables. High-end true portables are priced greater than $1,000; they typically are compatible with, and have computing capability equivalent to, desktop systems. Low-end true portables are distinguished from high-end true portables by their distinctly lower pricing.

True portables accounted for 3.8 percent of total PC shipments in 1987. We expect this share to grow to 11.4 percent of total shipments in 1992. Dataquest forecasts true portables to be the fastest growing segment in the PC market. Unit shipments are forecast to grow 51.5 percent in 1988 and at a 34.2 percent CAGR from 1988 to 1992. Revenue is expected to grow at an even healthier rate of 37.9 percent from 1988 to 1992.

Tables 13 through 16 and Figures 14 through 17 show low- and high-end true portable if-sold value and unit market share. The low end is dominated by Tandy and Epson. NEC's low-end share has dropped because the company is focusing on the high-end true portable market.

At the high end, Toshiba, Zenith, GRiD, and NEC are the dominant vendors. We believe that Zenith will pass Toshiba this year to take the number one position. However, both Zenith and Toshiba are expected to lose share to GRiD and to other vendors. We expect GRiD to gain market share through its merger with Tandy.

Table 13

Estimated Worldwide Vendor Market Shares—Unit Basis
High-End True Portable Personal Computers
(1986–1988)

Vendor	1986	Vendor	1987	Vendor	1988
Zenith	22.6%	Toshiba	23.7%	Zenith	22.3%
IBM	14.4	Zenith	23.5	Toshiba	22.2
Toshiba	11.1	GRiD	10.8	GRiD	12.4
Data General	9.1	NEC	9.4	NEC	8.8
HP	9.1	Datavue	6.8	Datavue	5.7
Other	33.7	Other	25.8	Other	28.6
Total	100.0%		100.0%		100.0%

Source: Dataquest
October 1988

Table 14

Estimated Worldwide Vendor Market Shares—If-Sold Value Basis High-End True Portable Personal Computers (1986-1988)

Vendor	1986	Vendor	1987	Vendor	1988
Zenith	21.4%	Toshiba	19.7%	Zenith	23.5%
IBM	14.0%	Zenith	26.8%	Toshiba	16.6%
Toshiba	9.5%	GRiD	12.6%	GRiD	18.4%
Data General	9.9%	NEC	9.4%	NEC	11.5%
GRiD	11.4%	Datavue	5.8%	Datavue	3.9%
Other	33.8%	Other	25.7%	Other	26.1%
Total	100.0%		100.0%		100.0%

Source: Dataquest
October 1988

Table 15

Estimated Worldwide Vendor Market Shares—Unit Basis Low-End True Portable Personal Computers (1986-1988)

Vendor	1986	Vendor	1987	Vendor	1988
Tandy	47.5%	Tandy	63.7%	Tandy	72.3%
NEC	30.4	Epson	28.6	Epson	24.6
Epson	22.1	NEC	7.7	NEC	3.1
Total	100.0%		100.0%		100.0%

Source: Dataquest
October 1988

Table 16

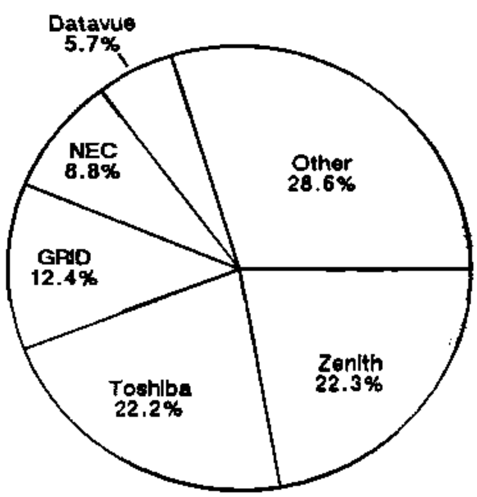
Estimated Worldwide Vendor Market Shares—If-Sold Value Basis
Low-End True Portable Personal Computers
(1986-1988)

Vendor	1986	Vendor	1987	Vendor	1988
Tandy	41.7%	Tandy	60.4%	Tandy	54.5%
NEC	38.4	Epson	29.3	Epson	38.1
Epson	19.9	NEC	10.3	NEC	7.4
Total	100.0%		100.0%		100.0%

Source: Dataquest
October 1988

Figure 14

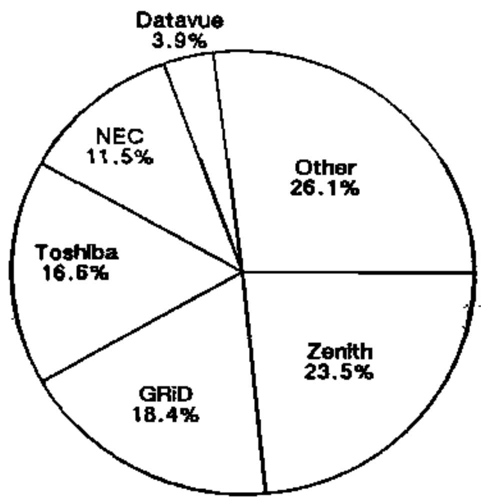
Worldwide 1988 Vendor Market Shares—Unit Basis
High-End True Portable Personal Computers



Source: Dataquest
October 1988

Figure 15

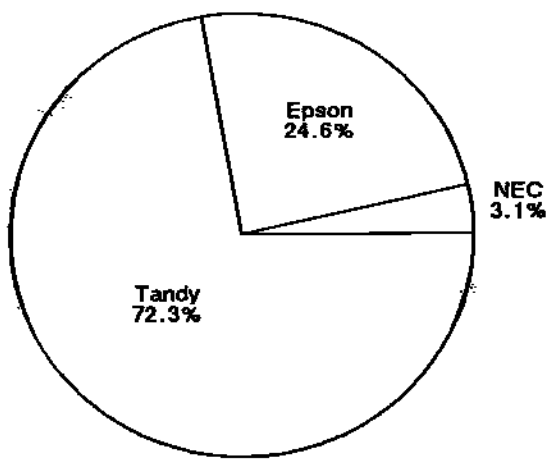
Worldwide 1988 Vendor Market Shares—If-Sold Value High-End True Portable Personal Computers



Source: Dataquest
October 1988

Figure 16

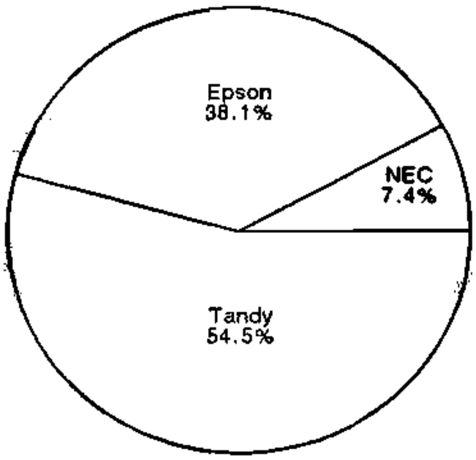
Worldwide 1988 Vendor Market Shares—Unit Basis Low-End True Portable Personal Computers



Source: Dataquest
October 1988

Figure 17

**Worldwide 1988 Vendor Market Shares—If-Sold Value Basis
Low-End True Portable Personal Computers**



Source: Dataquest
October 1988

TECHNOLOGY

Semiconductor manufacturers need to understand trends in current and future PC standards to plan their strategies for penetration of the PC market. To help facilitate these decisions, the following section gives our assessment of PC-shipments by bus architecture, microprocessor type, and average PC memory configurations.

PC Shipments by Bus Type

Table 17 shows Dataquest's estimates of PC shipments by bus type. Dataquest expects the growth of the Micro Channel bus-based PCs to be fairly rapid over the next four years at a 60 percent CAGR. However, we do not expect Micro Channel to completely replace the PC XT/AT-bus systems that are the standard today. In fact, we expect that by 1992 microchannel-bus systems will make up 36 percent of the total while PC XT/AT bus-based systems will make up 34 percent of the total and other bus architectures will comprise the remaining 30 percent. We expect that Micro Channel machines will continue to gain market share into the 1990s.

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Table 17a

Worldwide PC Shipment Forecast by Bus Type
(Millions of Units)

	1987	1988	1989	1990	1991	1992
Micro Channel	0.8	1.5	3.3	5.4	7.2	9.9
PC XT/AT	8.4	10.1	10.9	10.4	10.0	9.5
Other	7.6	7.4	0.7	7.5	8.2	8.4
Total	16.8	19.0	21.2	23.3	25.4	27.8

Source: Dataquest
October 1988

Table 17b

Worldwide PC Shipment Forecast by Bus Type
(Percent of Total)

	1987	1988	1989	1990	1991	1992
Micro Channel	4.8%	7.9%	15.6%	23.2%	28.3%	35.6%
PC XT/AT	50.0	53.2	51.4	44.6	39.4	34.2
Other	45.2	38.9	33.0	32.2	32.3	30.2
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Source: Dataquest
October 1988

PC Shipments by Microprocessor Type

Future developments in microprocessors will have a profound effect on the personal computer industry. 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. Table 18 presents Dataquest's worldwide PC forecast, segmented by microprocessor type.

Table 18

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
October 1988

Trends in Personal Computers

PC Memory Demand

The personal computer boom in 1987/1988 coupled with the move from 256-Kbit to 1-Mbit DRAMs by semiconductor manufacturers marked the importance of DRAMs to PC manufacturers by limiting PC vendors' volumes to the availability of memories. We believe that DRAMs will be increasingly important to PC manufacturers--if not because of dependence upon competitors for the part, then because of the sheer size of future PC main memory. Table 19 displays Dataquest's estimate of average PC memory configurations from 1987 through 1992. Growth in main memory will be driven by OS/2 acceptance and the increased use of business applications software that uses large amounts of RAM for data manipulation and graphics generation.

Table 19

Estimated Average PC Memory Configuration

	1987	1988	1989	1990	1991	1992
PCs Less than $1,000 (Mbyte/System)	0.50	0.64	1.00	1.50	2.25	3.00
PCs Greater than $1,000 (Mbyte/System)	0.64	1.00	2.00	4.00	6.00	8.00

Source: Dataquest
October 1988

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Trends in 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.

Although the fastest-growing and therefore the healthiest segment of the computer market, the workstation industry went through considerable turmoil in 1989. Unlike the PC industry, which seemed to fragment as it grew, the workstation industry seems to be consolidating in the face of staggering growth. Much of this consolidation can be attributed to the "growing pains" associated with a rapidly growing, rapidly evolving market.

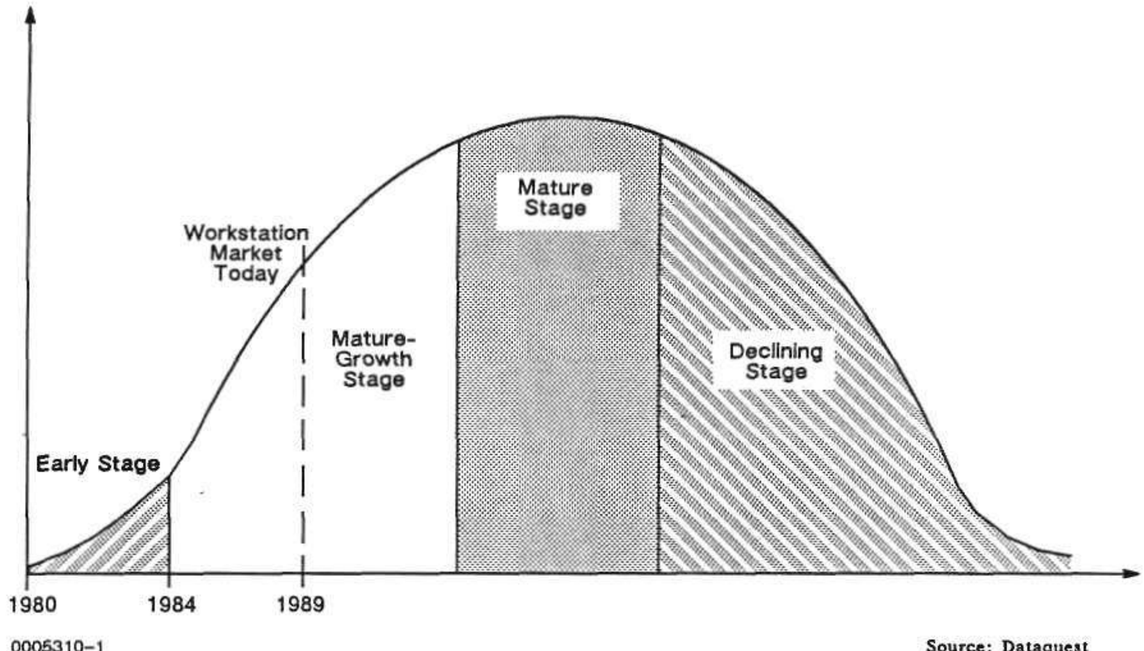
MARKET ANALYSIS

State of the Market

Dataquest believes that the technical workstation market is in the growth phase of its product life cycle. Figure 1 shows the typical product life cycle, including the current position of the technical workstation. This rapid growth period, which occurred in the software, personal computer, and multiuser microcomputer systems industries, is now occurring in the technical workstation industry. The industry leaders have each shipped in excess of $1 billion worth of systems. Start-up companies have come and gone. The market has grown large enough to attract the larger computer companies (e.g., Digital, Hewlett-Packard, IBM). Japanese vendors, having established a foothold, are now moving to expand their market share. The total installed base of systems is now valued at more than $14 billion, with shipments of more than 700,000 systems to date. Technical workstations have evolved from a specialized niche into the mainstream of computing.

Figure 1

Technical Workstation Market Development Cycle

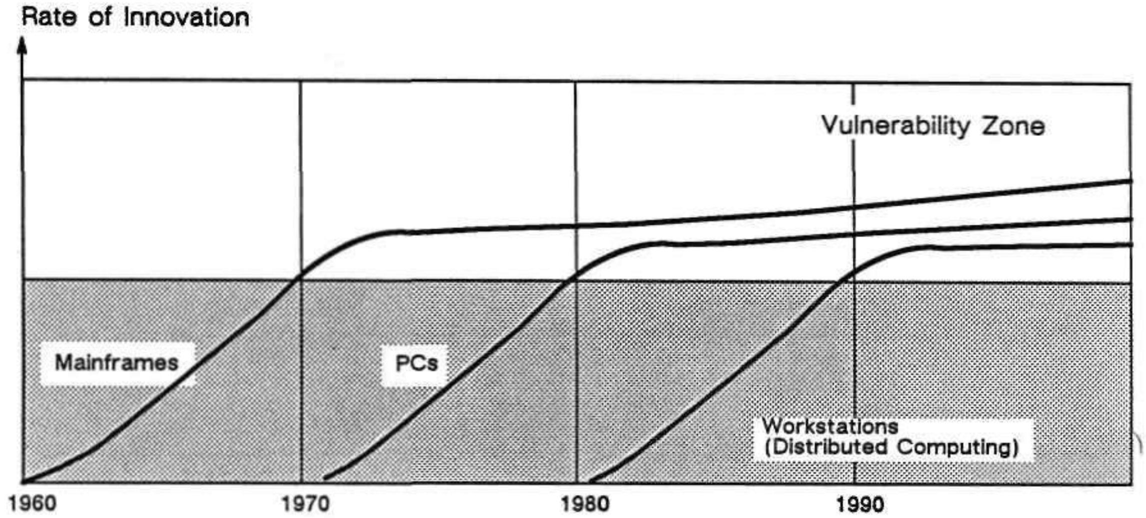


Source: Dataquest November 1989

Industries tend to become vulnerable to widespread competition once the rate of technological innovation slows. This is illustrated in Figure 2. A slowing rate of innovation renders a market harder to defend, which often leads to a flood of new competitors. Unique products can help build a defensible niche for a company, but once the underlying technology becomes understood by many, new competitors tend to exploit that market niche. Within the traditional technical workstation segment, this rate of technical innovation has begun to slow. Once this happens, the emphasis tends to shift to low-cost manufacturing, and Far-East manufacturers enter the market.

Figure 2

Rate of Technological Innovation



Source: Sun Microsystems Inc.

The Case for Market Entry

With the mainstream market dominated by, in order of rank, Sun, Hewlett-Packard, and Digital, and with IBM casting its shadow over the entire market, why would anyone enter the market at this point? Computer vendors are realizing the following:

- The "engineer's PC" is the technical workstation; to play in the engineering computer systems market, a vendor must offer a workstation.
- 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 within that segment.
- Technical workstations are the leading architectures of future network-based computing systems.

Trends in Workstations

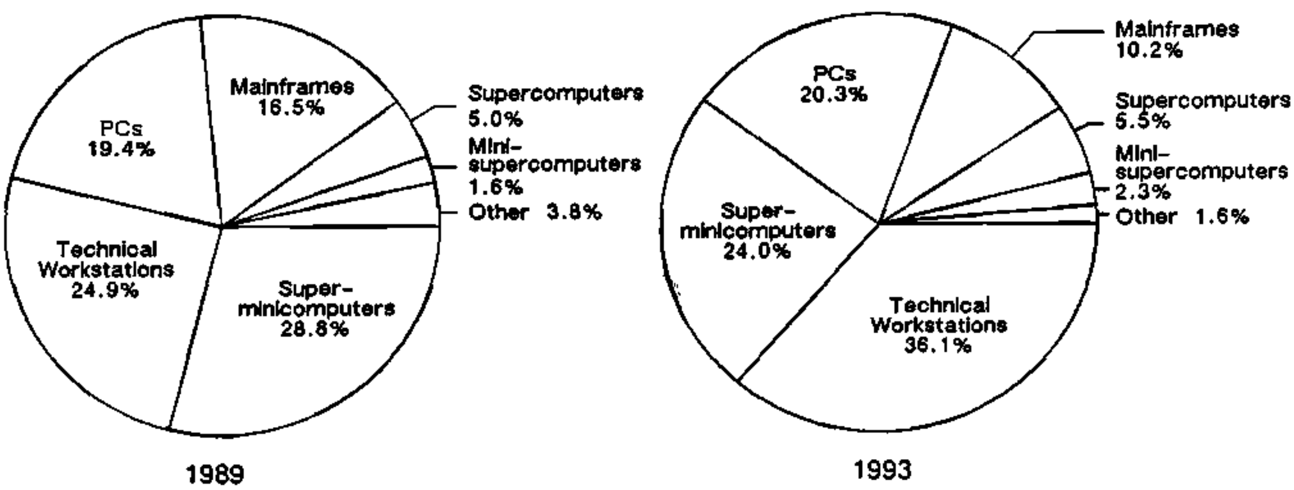
Size of the Market

The technical workstation market first emerged in 1980 and grew to nearly $6 billion by 1989. The 1988 vendor ranking by revenue was Sun, Digital, Hewlett-Packard, and Apollo. The combined HP and Apollo numbers narrowly edge out Sun for the top spot, however. Dataquest expects the technical workstation market to grow to more than $16 billion by 1993, with a 28.5 percent compound annual growth rate (CAGR) from 1989 through 1993.

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 24.9 percent of the total market revenue in 1989 to 36.1 percent by 1993.

Figure 3

Product Segment Analysis



0005310-3

Source: Dataquest November 1989

Trends in Workstations

Although 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. Tables 1 and 2, along with Figures 4 and 5, present the technical workstation factory revenue and unit shipment historical data and forecasts for 1984 through 1993.

Table 1

Technical Workstation History
Factory Revenue and Unit Shipments

	1984	1985	1986	1987	1988	1989*	CAGR
Revenue ($M)	$ 473	$ 941	$1,563	$2,700	$4,315	$5,955	66.0%
Shipments	12.9	32.5	62.8	119.2	191.8	303	88.0%
Average Selling Price ($K)	$36.7	$29.0	$ 24.9	$ 22.7	$ 22.5	$ 19.7	(11.7%)
Cumulative Unit Shipments	20.1	52.6	115.4	234.6	426.4	729.4	

*Preliminary

Table 2

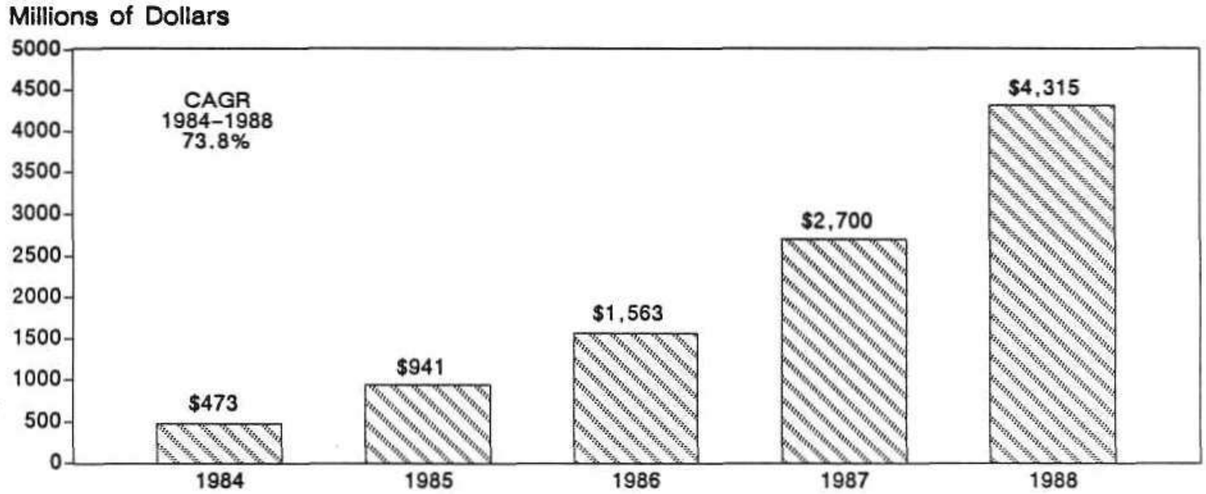
Technical Workstation Forecast
Factory Revenue and Unit Shipments

	1989	1990	1991	1992	1993
Revenue ($M)	$5,955	$8,060	$10,530	$13,430	$16,240
Unit Shipments (K)	303	467	700	943	1,216
Average Selling Price ($K)	$ 19.7	$ 17.3	$ 15.0	$ 14.2	$ 13.4

Source: Dataquest
November 1989

Figure 4

Technical Workstation History
Estimated Vendor Revenue (1984–1988)

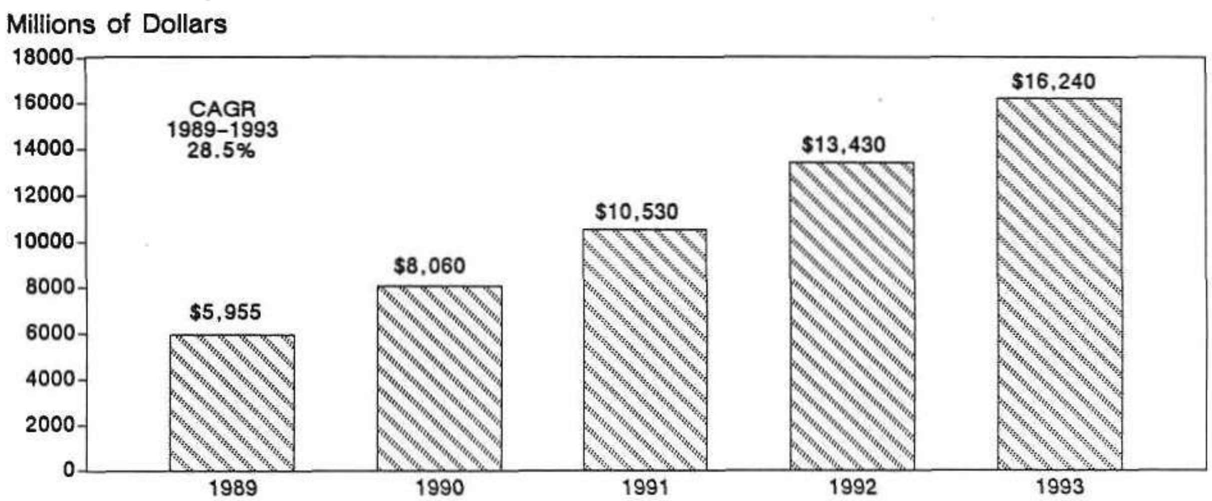


0005310-4

Source: Dataquest
November 1989

Figure 5

Technical Workstation Forecast
Estimated Vendor Revenue (1989–1993)



0005310-5

Source: Dataquest
November 1989

The vendors' 1986, 1987, and 1988 market shares are listed in Table 3 and shown in Figures 6 and 7. These show both unit and revenue based market shares. The top three (or four) vendors—Sun, Digital, Hewlett-Packard (and Apollo), hold 73.8 percent of revenue and 80.1 percent of unit shipments for the entire workstation segment. We note the following:

- For the second year in a row, Sun Microsystems was the biggest market share gainer, with a 3.1 percent increase. Sun is followed by Sony Microsystems with a 1.7 percent gain and Intergraph with a 1.2 percent gain.
- Apollo fell from number 2 to number 4 in 1988 before being acquired by number 3, Hewlett-Packard. Combined, these two companies would have ranked first in 1988; however, both lost share in 1987 and in 1988.
- The biggest market share losers were Apollo with 3.7 percent, IBM with 1.1 percent, and Hewlett-Packard with 0.6 percent.

Table 3

Technical Workstation Market Share
(Percent of Total)

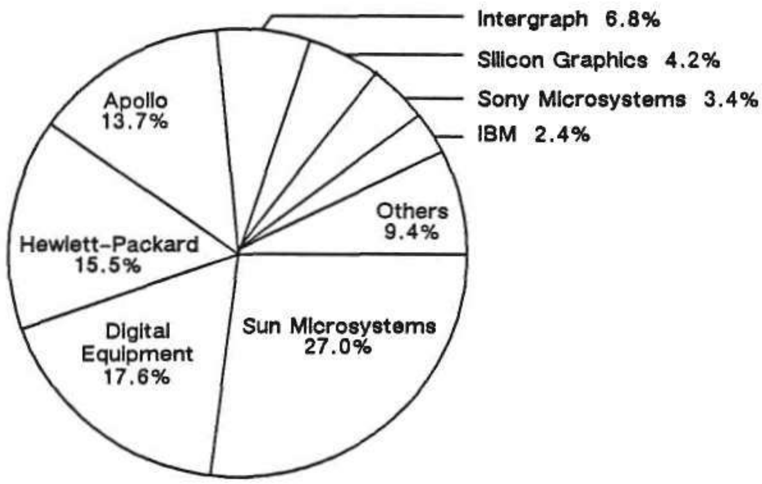
	Revenue 1986	1987	1988	Units 1986	1987	1988
Sun Microsystems	20.2%	23.9%	27.0%	25.6%	26.9%	32.8%
Hewlett-Packard	19.8	16.1	15.5	23.9	15.1	10.6
Apollo	21.4	17.4	13.7	24.0	19.3	15.5
Digital Equipment	13.6	17.2	17.6	11.2	19.0	21.2
Intergraph	N/A	5.6	6.8	N/A	3.8	4.7
Silicon Graphics	3.3	3.7	4.2	1.9	2.1	2.6
Sony Microsystems	1.2	1.7	3.4	0.9	2.4	3.1
IBM	2.4	3.5	2.4	2.4	2.9	1.6
Other	18.1	10.9	9.4	10.1	8.5	7.9
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

N/A = Not Available

Source: Dataquest
November 1989

Figure 6

Estimated 1988 Workstation
Market Share—Revenue
(Percent of Total)



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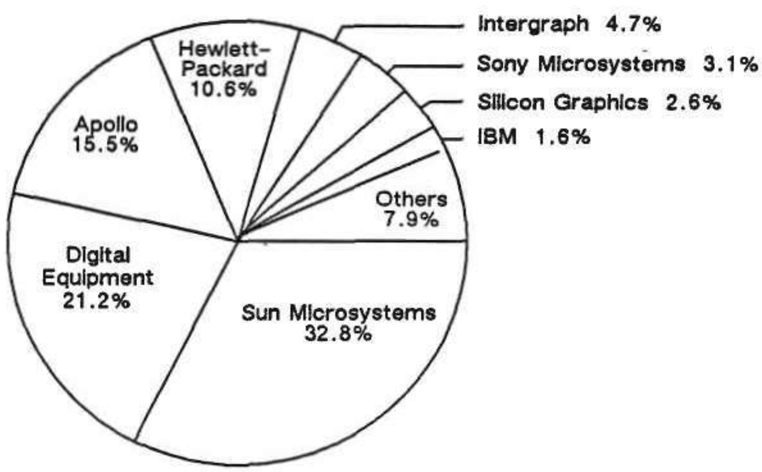
Source: Dataquest
November 1989

Figure 7

Estimated 1988 Workstation
Market Share—Units
(Percent of Total)



0005310-7

Source: Dataquest
November 1989

Trends in Workstations

New Segmentation Expected

Interactive distributed processing is a new way of computing, and we expect continued penetration beyond engineering and technical applications. We believe that the widening range of user requirements will translate into a greater variety of system configurations over a broader price range. In the past, most workstations were priced between $15,000 and $60,000. Recently introduced products, however, have stretched this market span in both directions.

We believe that the market has split into five distinct segments, as described in Table 4 and illustrated in Figure 8. Figures 9 and 10 illustrate the impact these segments will have on existing markets between 1989 and 1993 in terms of revenue and unit shipments, respectively.

Table 4

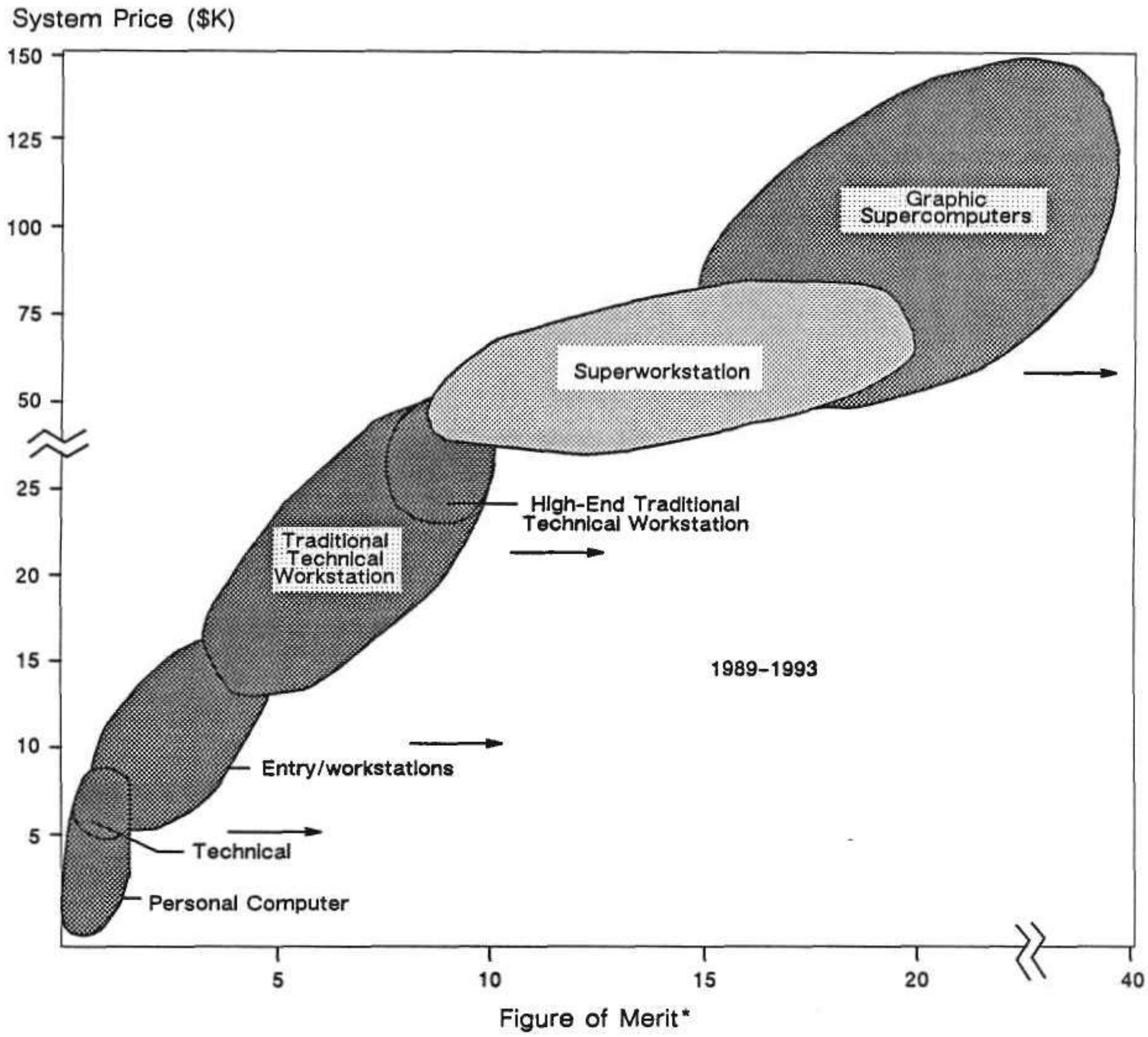
New Workstation Market Segmentation

Segment	Description	Approximate Price Range
Entry	Technical PC	$5,000 to $15,000
Low End	Entry workstation	$8,000 to $18,000
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
November 1989

Figure 8

Technical Workstation—New Segmentation
Estimated Price/Performance Positioning
1989–1993



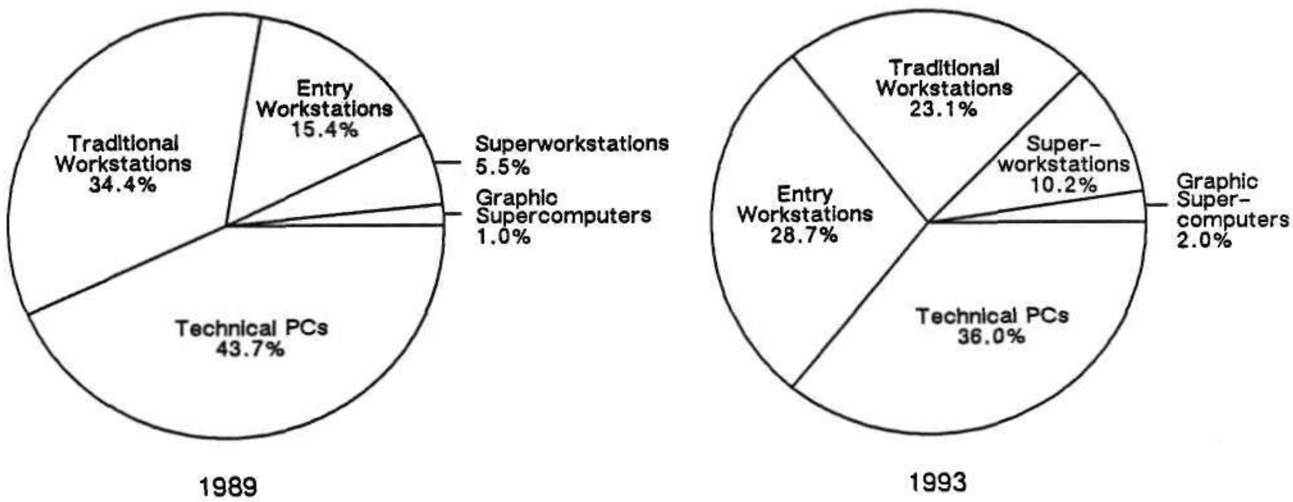
*Based on mips, mflops, mbytes, vectors, and polygons-per-second

0005310-8

Source: Dataquest
November 1989

Figure 9

Technical PCs and Workstations—All Segments
Estimated Revenue by Segment

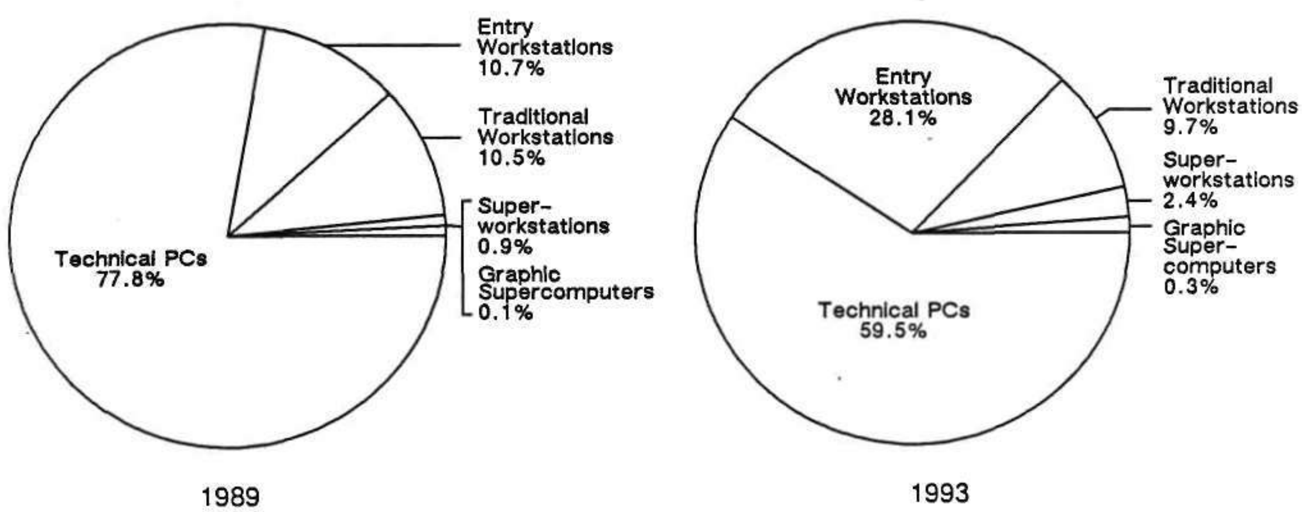


0005310-9

Source: Dataquest
November 1989

Figure 10

Technical PCs and Workstations—All Segments
Estimated Shipments by Segment



0005310-10

Source: Dataquest
November 1989

This market split is driven by the upward migration of low-priced PC technology and by the emergence of high-performance workstations based on advanced computer, graphics, and VLSI technologies. These forces could potentially cause major product restructuring over the next few years. The marketing strategies and selling dynamics associated with each of these segments are likely to grow more and more different and distinct. Table 5 compares the performance of each of the emerging workstation categories.

Table 5

Technical Personal Computers and Workstations—Classification

Feature	Technical Personal Computers	Entry-Level Workstations	Technical Workstations	Super-workstations	Graphics Supercomputers
CPU Performance (mips)*	12	2-12	4-15	8-20	20-40
CPU Performance (mflops-DP)	1	0.5-1.5	0.5-2.0	2.0-16.0	16.0-50.0
Floating-Point Coprocessor	Optional	Yes	Yes	Yes	Yes
Main Memory (Mbytes)	1-16	4-16	8-64	8-128	16-1,024
Typical Disk Storage (Mbytes)	20-160	40-600	80-600	600-1,300	1,024+
Screen Size (Inches)	12-19	12-19	12-19	15-19	19
Number of Colors Displayable	16-256	16-256	256-496	256-16,700	256-16,700
Typical Pixel Resolution	640 x 480 1,024 x 768	1,024 x 768 1,280 x 1,024	1,100 x 900- 1,280 x 1,024	1,280 x 1,024	1,280 x 1,024
2-D Vector Transforms/ Second (est.)	50-100K	65-400K	100-500K	100-500K	100-500K
3-D Vector Transforms/ Second (est.)	Optional	Optional	100-150K	100-300K	100-600K
Gouraud Shaded Polygons/ Second (est.)	N/A	N/A	2-10K	10-25K	25-150K
LAN (Mbps)	Optional	10	10	10-125	10-1,000+
Price ($K)	$10	$5-$15	$15-$50	$40-$80	$75-$150

*Single CPU
N/A = Not Available

Source: Dataquest
November 1989

Trends in Workstations

TECHNOLOGY

Technical workstation manufacturers are strongly pursuing the use of the latest technology. Users tend to face computing tasks that require greater performance than is currently available with current technology and therefore are willing to pay premium prices for the latest in computing solutions. This places unusual pressure on vendors to offer the latest technology. The rapid pace of technological advancement requires large capital investments for companies to stay ahead. Increasing product complexity and decreasing product life cycles have moved many vendors into high-risk positions. In such an environment, engineering or production delays can translate directly into market share loss.

As the data processing requirements of the system continues to increase, a systems architecture trend toward independent subsystems has emerged. These subsystems effectively off-load the CPU, enhancing total system performance. We expect these independent subsystems to be rich in ASIC, memory, and application-specific microprocessor products.

Today, vendors use a mix of standard, off-the-shelf microprocessors and proprietary products. Because customers are so sensitive to compute-power, microprocessor selection can be key to system competitiveness. Processor approaches range from standard CISC processors to RISC processors developed by a variety of semiconductor and computer companies, such as Sun's SPARC, MIPS' R2000/R3000, Intel's i860, Motorola's 88000, Intergraph's Clipper, AMD's 29000, HP's Precision Architecture, and Apollo's PRISM.

Many applications use extensive floating-point calculations, necessitating the use of a coprocessor. Workstations that offer VLSI-based floating-point units will enjoy a clear performance advantage over their competition.

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 database servers on networks, leaving the interactive portion of the applications software to run simultaneously on the workstation.

Microprocessors

We expect the trend toward high-performance RISC architectures to continue as the technology becomes better understood. Some examples of RISC-based systems are as follows:

- Sun's new line of SPARCstations
- Silicon Graphic's line of R2000/3000-based IRIS workstations
- Intergraph's Clipper-based workstations
- Opus Systems' 88000-based compute platform

Trends in Workstations

Most of the installed base of technical workstations still use Motorola 68000 family or Intel 80X86 family microprocessors. Past product differentiation was accomplished through graphics, software and networking features. As vendors experiment with alternate compute engines, hardware product differentiation will become an increasingly important issue, making microprocessor selection a high-stakes strategic decision.

Memories

Video, cache, and main memory sizes, once a serious limitation due to high memory costs, are rapidly becoming a nonissue with the advent of affordable memory chips. Although 1Mb DRAMs are now only about one-half the cost of a year ago, they still constitute a large portion of total system cost. In fact, the trend toward more and more bits of memory per system could overwhelm the trend toward ever-lower cost per bit. In the long term, we expect the percentage dollar content of memory devices within workstations to rise over time.

Bus Structure Trends

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

- Digital's Q-bus (VAXStation)
- Motorola's VME bus (Apollo and Sun)
- The PC AT bus
- The SCSI bus

We expect this trend to continue due to the high availability of peripherals in the open market and to meet the needs of users and OEMs requiring specialized hardware that is not available from system vendors. The VME and PC AT buses have replaced most Multibus-based products. Sun Microsystems, which is promoting its Nubus architecture, is the exception to this rule.

Graphics Display Trends

Specialized graphics components off-load the main processor, enhancing total system throughput. The trends are as follows:

- Prices on high-resolution graphics displays are declining 15 to 20 percent per year.
- System vendors will be able to offer larger display memories that will enhance graphics system performance as prices and availability of DRAMs and VRAMs continue to improve.

- The price premium for color displays continues to shrink. We believe that color displays will become standard on more and more workstations. By 1991, Dataquest estimates that 65 percent of all systems shipped 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 between workstations and most high-end PCs.
- Vendors are scrambling to design and incorporate ASIC engines to process:
  - Shading algorithms (e.g., flat, Fong, Garaud, et al.)
  - Rendering
  - Geometric transforming

Networking Trends

Ethernet networking with technical workstations is almost universal now, and Dataquest expects this trend to persist through the forecast period. The Ethernet requirement is driven by the user community's strong, broad-based support for this standard. Other networking trends include the following:

- The use of advanced VLSI technology continues to reduce node connect costs, contributing to the decline in total system prices.
- Fiber-optic technology is expected to gain market acceptance more slowly than many vendors anticipate.
  - Copper-based coaxial cabling continues to serve most applications adequately.
  - In-line taps are difficult and costly.
  - Twisted-pair technology continues to achieve higher data rates.

Operating Systems

Most workstation vendors offer the UNIX operating system either as the primary operating system or as a cooperating system. Vendors promoting proprietary operating systems must provide a means of interfacing to UNIX to enable file transfers in order to satisfy key user demands. This is due to the following:

- Users have a high resistance to learning a new operating system.
- Universities are teaching UNIX; therefore, many potential new hires are pretrained in UNIX.

- Many government and military organizations, as well as 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 and unless the operating system has significant technology advantages over UNIX, UNIX will be the operating system of choice.

UNIX

Only two vendors in the technical workstation market offer operating systems that are not UNIX derivatives: Apollo's AEGIS and Digital's VAX/VMS. Both vendors have elected to support UNIX in addition to supporting their own operating systems.

UNIX is clearly the most widely offered operating system for technical workstations. Not only do the vast majority of workstations use UNIX, but with Digital finally embracing it early last year, the path is cleared for near-complete UNIX domination in the technical workstation market. The best indication of this can be found in the industry's current operating systems debate: Vendors have spent the last 12 months posturing over which version of UNIX should become the next industry standard.

DOS and OS/2

DOS runs on workstation coprocessors and is an important sales item, because much of the users' time is spent running productivity software such as word processing, database, and spread sheet programs. The OS/2 application base has not yet grown large enough to be an issue in this market at this time. DOS is expected to remain important for several years.

TECHNOLOGY SUMMARY

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

- Advanced RISC and CISC 32-bit microprocessors (i.e., Motorola 88000 and 68040, Intel 80486 and i860, MIPS R2000 and R3000, Sun SPARC, HP Precision Architecture and PRISM, Intergraph Clipper)

- Advanced floating-point and vector processing units

- High-density DRAMs packed into memory modules using surface-mount technology

Trends in Workstations

- Low-cost, high-capacity disk drives
- Local area network (LAN) controllers in VLSI silicon
- Fiber-optic networks rated at 80 to 120 Mbps
- VLSI graphics controllers and processors
- 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 into the personal computer area where price is a critical selection criterion. Networking will include fiber-optic technology, and graphics will include real-time, 3-D modeling that the average person may view as a photograph.

Because technical workstations often are a leading indicator of PC technology and because this is the fastest-growing segment of the entire computer market, semiconductor manufacturers should monitor this market closely, not only for its own potential, but for insights into other computer segments as well.

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

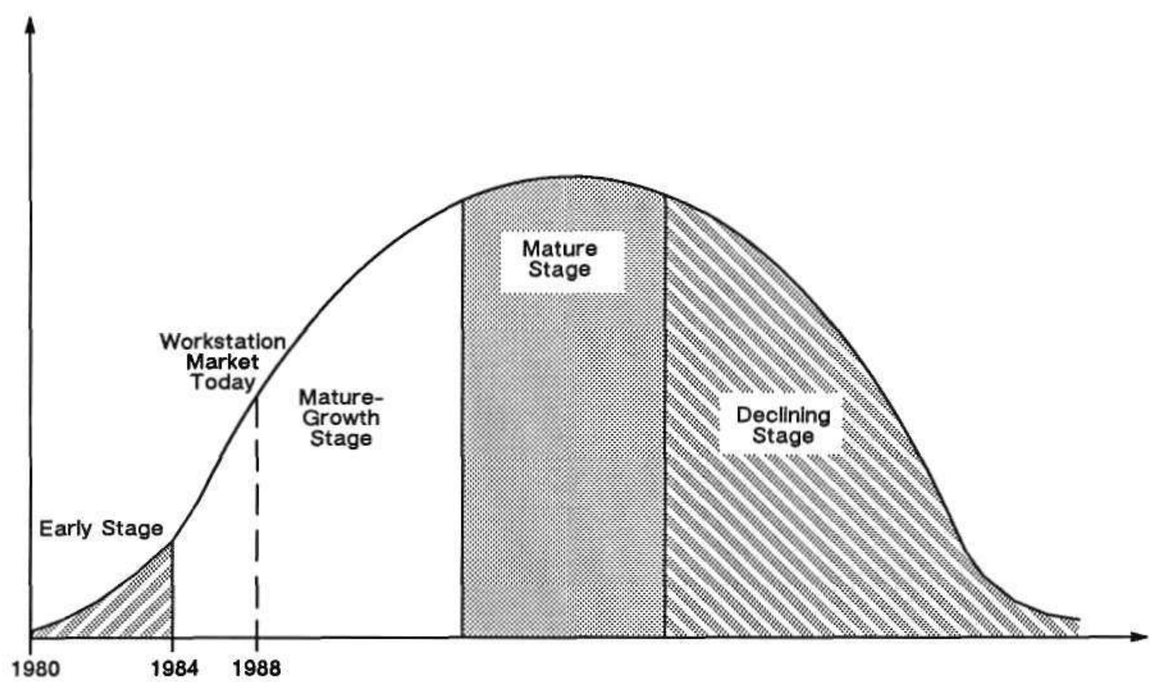
MARKET ANALYSIS

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



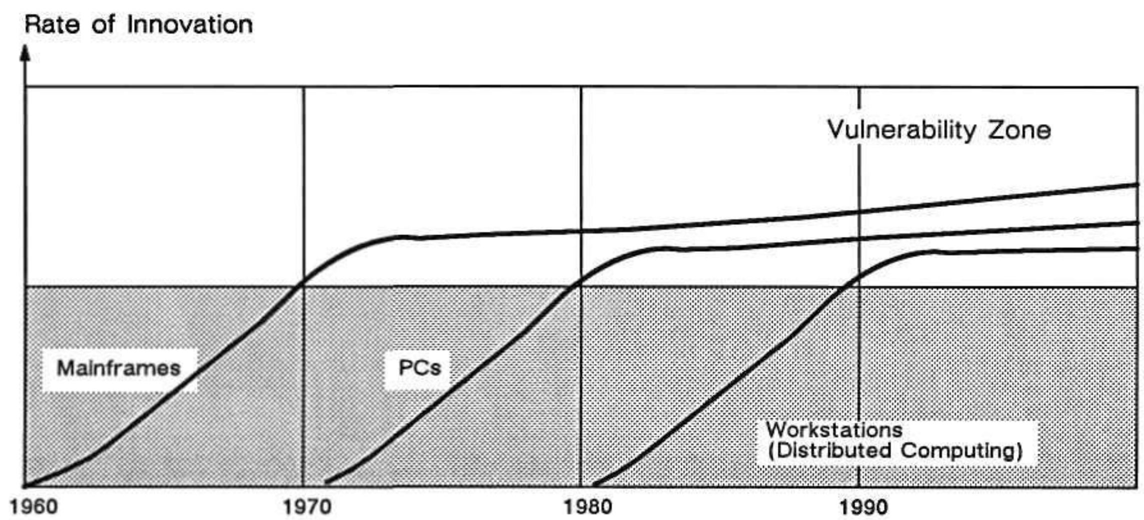
Source: Dataquest September 1988

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.

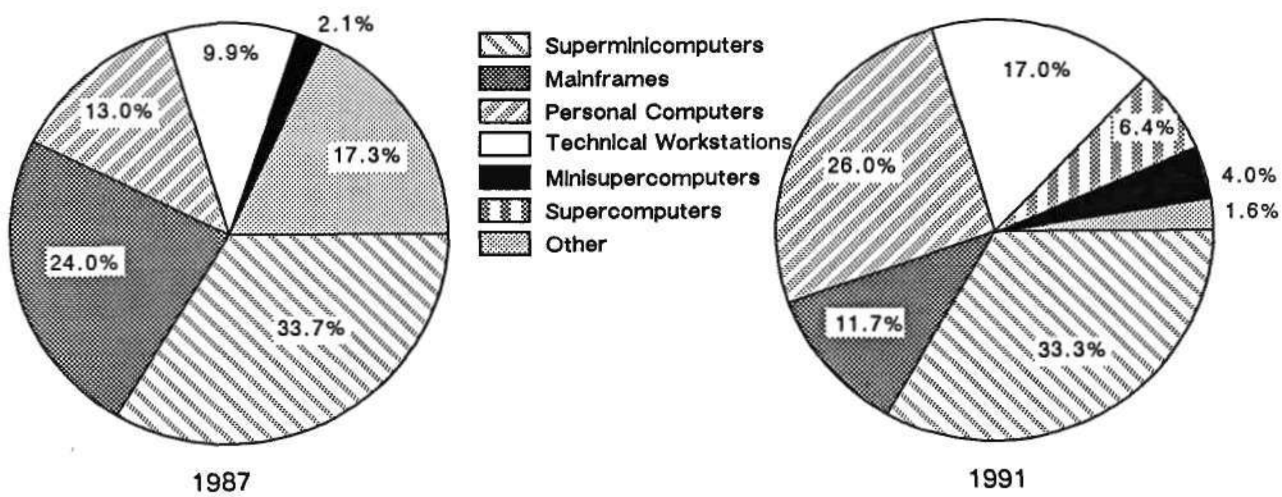
Size of the Market

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)

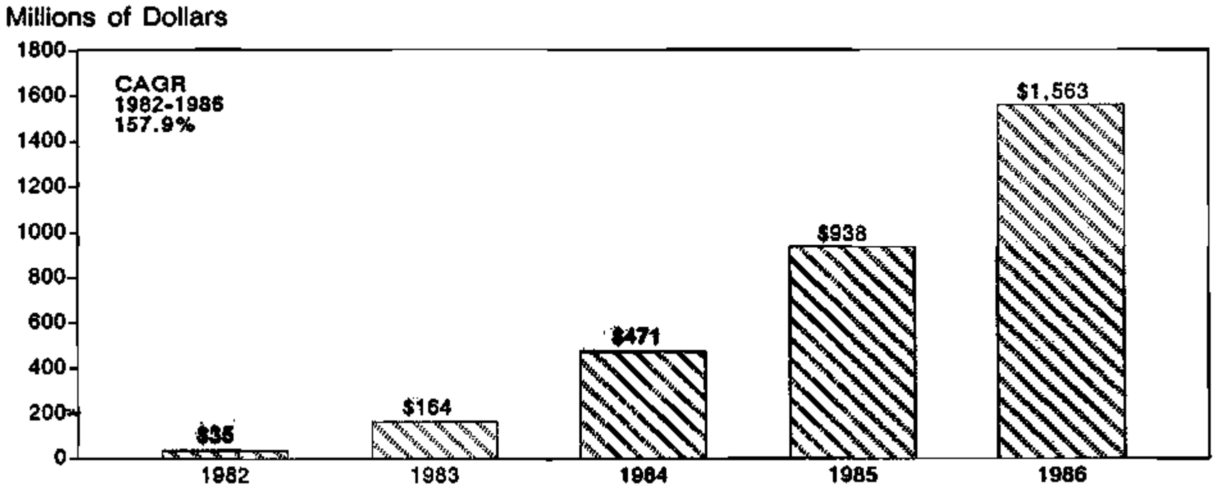
	1987	1988	1989	1990	1991	CAGR 1987-1991
Revenue ($M)*	$2,092	$2,835	$3,781	$ 5,172	$ 6,336	30.0%
Percent Change	38%	35%	30%	27%	28%	
Shipments (K Units)*	95	168	291	455	627	60.4%
Percent Change	55%	78%	72%	56%	38%	
Total Cumulative Shipments (K Units)	208.5	378.0	667.0	1,145.0	1,817.0	71.9%
Average Selling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

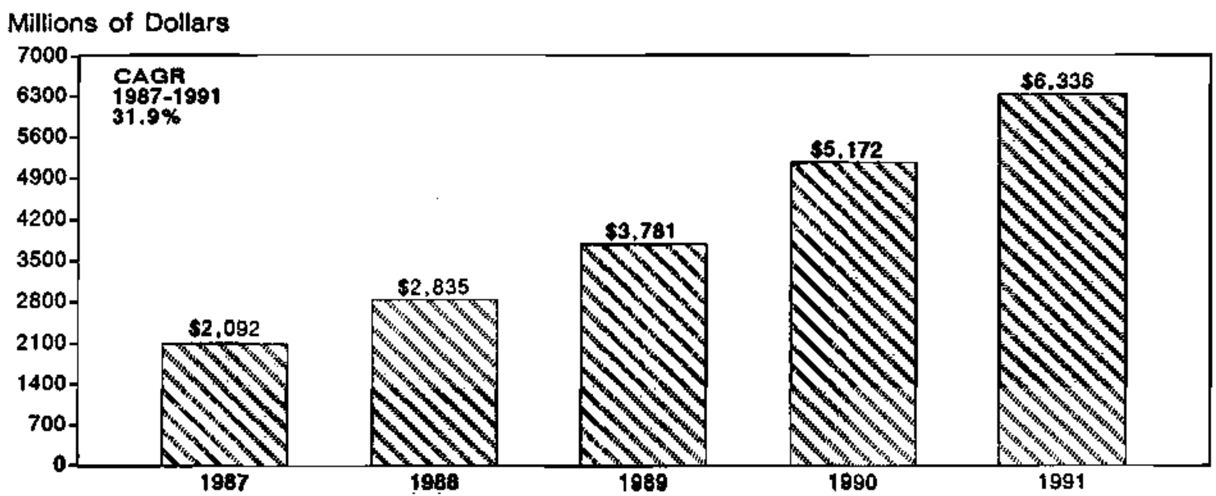
Technical Workstation History
Estimated Vendor Revenue
(1982–1986)



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

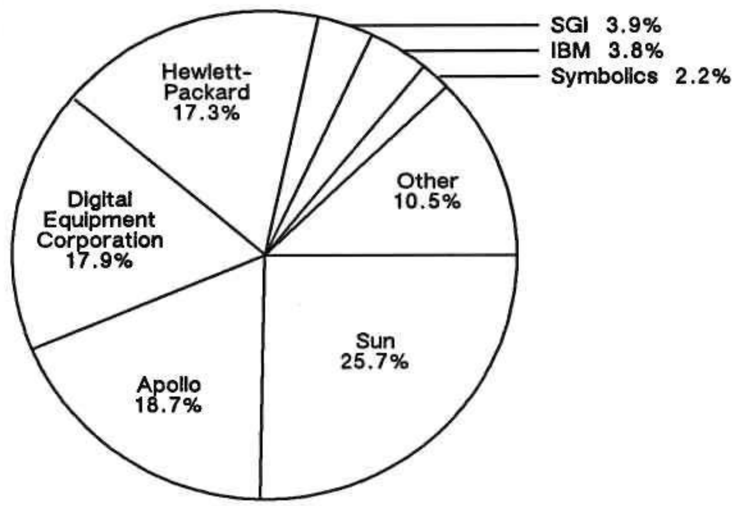
Estimated Technical Workstation
Market Share
(Percent of Total)

	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

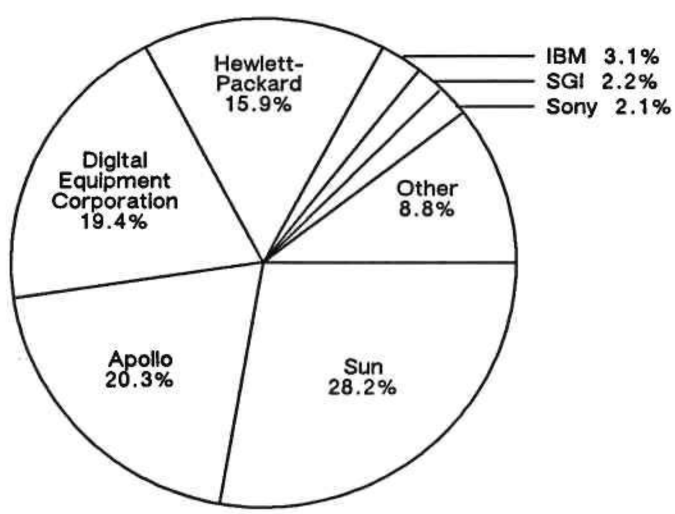
Estimated 1987 Revenue Workstation
Market Share
(Percent of Total)



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

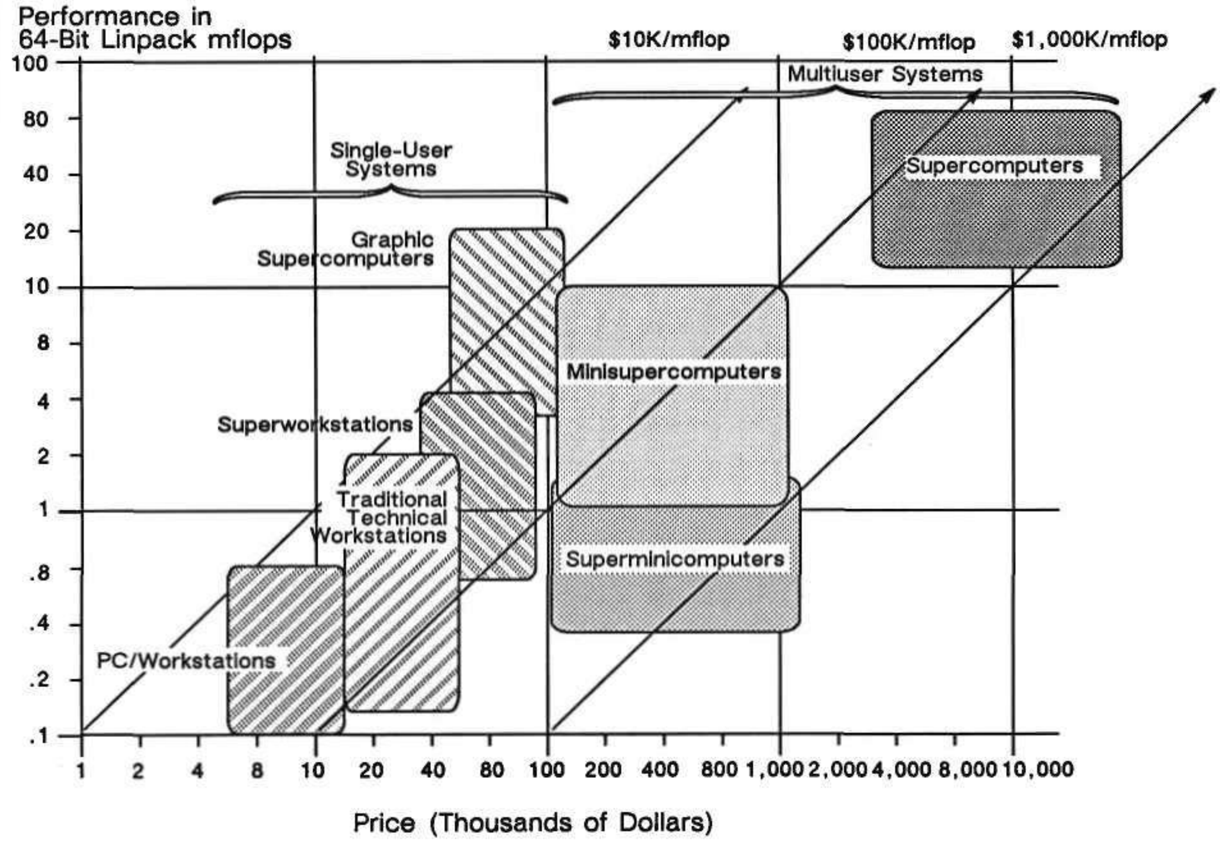
New Workstation Market Segmentation

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

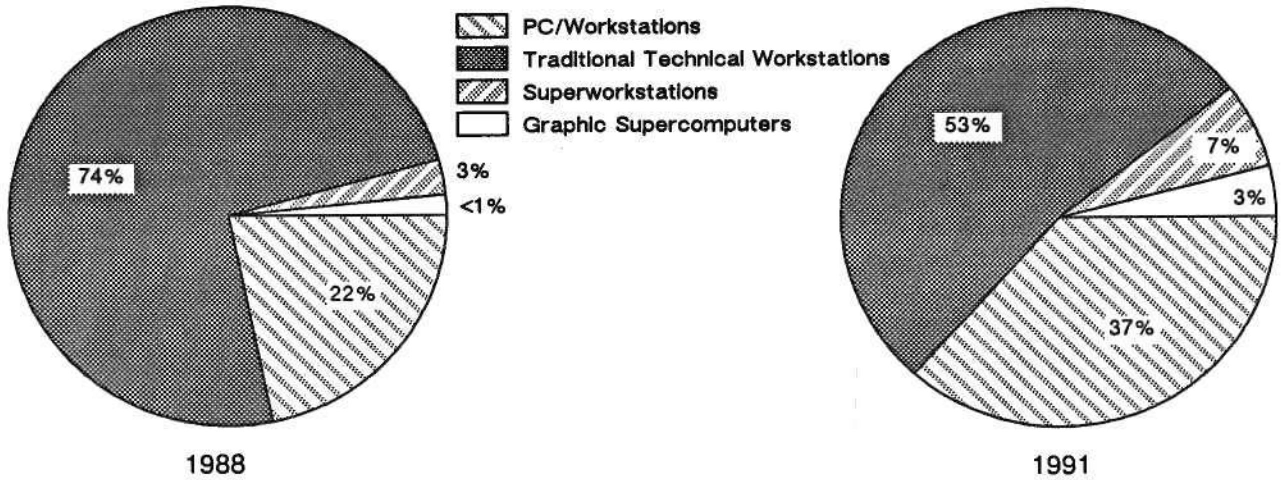
Forecast Workstation Price/Performance Comparison (Double-Precision LINPACK mflops)



Source: Dataquest September 1988

Figure 9

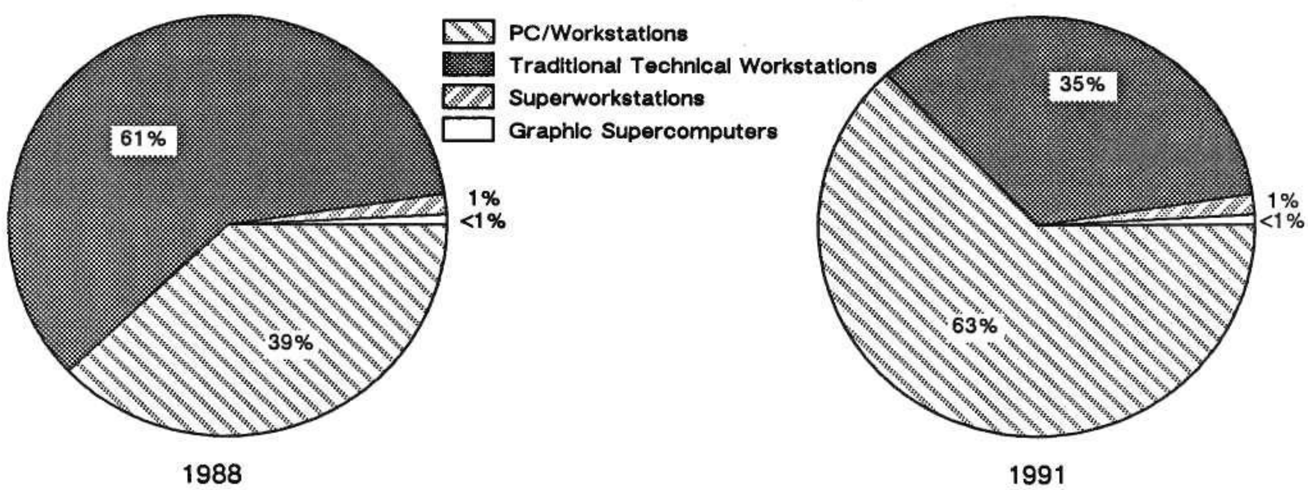
Technical Workstations—All Segments
Estimated Revenue by Segment
1988 and 1991



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

Trends in Technical Workstations

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.

Trends in Electronic Printers

MARKET OVERVIEW

Throughout the 1980s, the printer market has been characterized by violent swings in year-to-year growth rates of both unit shipments and industry if-sold value (ISV). As competing technologies have pushed average selling prices (ASPs) downward, and unit shipments have risen and fallen with the fortunes of the PC industry, the printer market has moved from double-digit growth in the early 1980s to negative growth in 1985 and 1986 and then back to double-digit growth in 1987. However, 1988 and 1989 marked a transition to a more stable, sustainable growth pattern, with unit shipments growing between 11 and 14 percent and ISVs essentially flat. As seen in Table 1, Dataquest expects the industry to maintain a stable growth pattern through 1994.

Worldwide printer shipments amounted to 17.5 million units in 1989, as shown in Figure 1. Figure 2 shows that Europe has pulled ahead of North America as the largest-consuming region, accounting for 44 percent of both dollar volume and unit volume. By 1994, Dataquest expects the worldwide market to exceed $28 billion on unit shipments of over 24 million. The geographic distribution of revenue and unit shipments is expected to remain relatively stable.

Table 1

Worldwide Printer Shipment Forecast

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Units (K)	9,784	10,280	13,839	15,704	17,544	19,689	21,183	22,153	23,150	24,225
Growth Rate		5.1%	34.6%	13.5%	11.7%	12.2%	7.6%	4.6%	4.5%	4.6%
ASP ($)	1,147	1,230	1,163	1,162	1,194	1,213	1,202	1,196	1,199	1,191
Growth Rate		7.2%	(5.5%)	0	2.8%	1.6%	(1.0%)	(1.0%)	0	(1.0%)
ISV ($B)	11,222	12,644	16,095	18,248	20,948	23,883	25,462	26,495	27,757	28,852
Growth Rate		12.7%	27.3%	13.4%	14.8%	14.0%	6.6%	4.1%	4.8%	3.9%

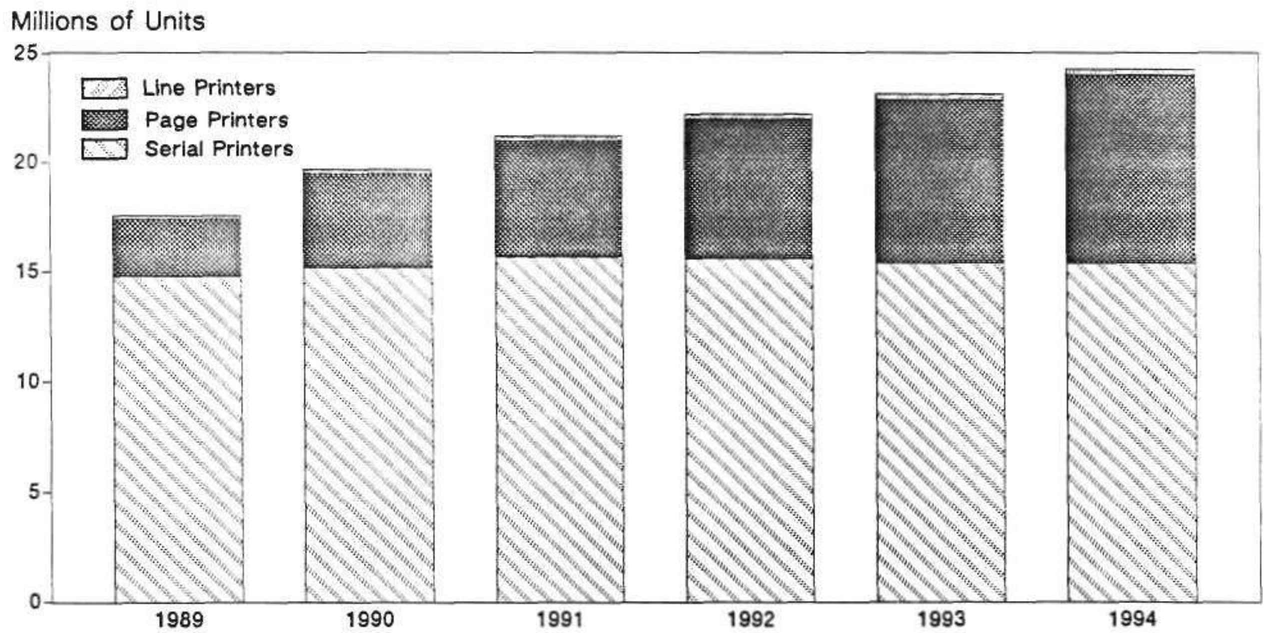
Source: Dataquest (October 1990)

The continued steady growth in printer demand is fueled primarily by the current stable growth patterns of the PC industry. Dataquest estimates the 1989 worldwide PC market at 22.2 million units. Other factors contributing to the continued growth of the North American printer market include the following:

- Integrated system sales for applications such as desktop publishing, presentation graphics, and high-resolution technical applications
- A surge in nonimpact printer sales, led by laser and ink jet technologies
- Continued price/performance improvements
- Continued improvements in and development of distribution channels and product support

Figure 1

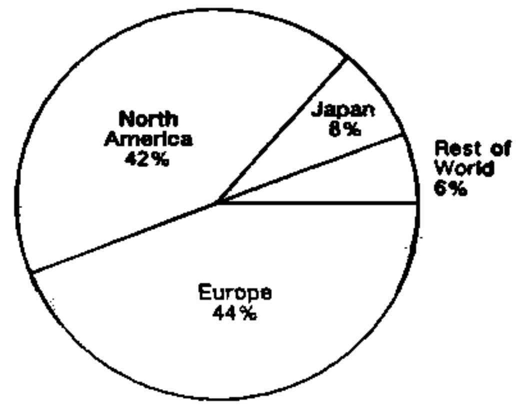
Worldwide Printer Market Forecast (Millions of Units)



Source: Dataquest (October 1990)

Figure 2

Worldwide Printer Demand Forecast
1989



Total = 17.5 Million Units ($14.8 Million)

Source: Dataquest (October 1990)

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

Serial Printers

Dataquest expects serial printers to continue to account for the majority of unit shipments through 1994. In 1989, serial printers accounted for 84 percent of all printers shipped. This percentage is expected to decline to approximately 64 percent by 1994. This decline is even more apparent when viewed in a revenue context. Serial printers currently account for only 49 percent of industry revenue and are expected to decline to 36 percent by 1994.

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 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.

Table 2

Worldwide Printer Shipment Forecast by Major Segments

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	CAGR 1990-1994
Shipments (Thousands of Units)											
Serial Printers	9,401	9,611	12,607	13,860	14,751	15,233	15,685	15,552	15,419	15,422	0.3%
Line Printers	200	196	180	197	187	197	216	234	247	255	6.6%
Page Printers	183	473	1,052	1,647	2,606	4,259	5,282	6,368	7,484	8,548	19.0%
If-Sold Value (Millions of Dollars)											
Serial Printers	7,119	7,154	8,922	9,671	10,274	10,830	11,086	10,979	10,787	10,474	(0.8%)
Line Printers	2,380	2,454	2,199	2,458	2,311	2,330	2,405	2,408	2,515	2,492	1.7%
Page Printers	1,722	3,040	4,973	6,119	8,364	10,715	11,980	13,111	14,453	15,876	10.3%
ASP ($)											
Serial Printers	757	744	708	698	696	711	707	706	700	679	(1.1%)
Line Printers	11,907	12,539	12,229	12,495	12,384	11,813	11,123	10,307	10,175	9,792	(4.6%)
Page Printers	9,398	6,428	4,728	3,715	3,209	2,516	2,268	2,059	1,931	1,857	(7.3%)

Source: Dataquest (October 1990)

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—1989 to 1994

General Trends

Competitive pressures continue to build, coming not only from similar products, but also from competing technologies. ASPs continue to slide as low-cost page and ink jet put pressure on dot matrix and other older printing technologies.

Software Trends

The primary applications for serial printers are in business and personal productivity. Spreadsheets, database management, and word processing are the most popular, followed by a rapidly growing demand for graphics packages. Spreadsheet and database applications require wide carriage and do not require correspondence quality, 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 printers.

Graphics applications software is becoming more prevalent and user friendly. Dot matrix printers are likely candidates for these applications because of the dot addressability required by graphics programs. Thermal resistive and some ink jet printers also offer dot addressability.

Feature Trends

With the exception of fully formed character printers, most manufacturers offer 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, and 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 dot matrix printers; the speeds are typically listed as draft, correspondence, and near-letter quality or letter quality. A new letter-quality market has emerged, consisting 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 popular feature. Nonimpact technologies typically have a noise level of less than 49 dBa. Dot matrix printers are currently 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 and wide area, allow efficient sharing of printers at the work group or departmental area. On all levels, more attention is being directed toward the details of the word processing application.

Impact versus Nonimpact Printers

In 1989, nonimpact printers accounted for 26 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 66 percent over the forecast period.

Impact Technology

Serial, Impact, Fully Formed (SIFF)

Competing technologies are rapidly pushing the SIFF segment toward the end of its product life, with both unit sales and ISV declining rapidly. Leading companies in this market include Brother, IBM, NEC, Qume, and Xerox.

Serial, Impact, Dot Matrix (SIDM)

SIDM printers continue to dominate the market, capturing over 97 percent of all impact printers and the majority of all unit shipments in 1989. Dataquest expects this grip to weaken over the next four years as nonimpact technologies, particularly thermal transfer and ink jet, become more popular. Most SIDM printers shipped today are of Japanese origin.

High-end dot matrix printers represent the fastest-growing segment of this mature product group. Greatly improved print quality afforded by the 24-pin head, along with the low cost of manufacture resulting from high-production volumes, have enabled dot matrix printer manufacturers to capture a large and growing portion of the personal printer market. Manufacturers can now offer competitive quality at a low price point while minimizing speed, noise, and print quality trade-offs.

The highest growth during the forecast period will continue to come from high-resolution (24-wire) SIDM printers. Total ISV of all SIDM printers is expected to decline through 1994; however, the high-speed, high-resolution segment will see positive growth. Major manufacturers participating in this market include Epson, Okidata, and Star Micronics.

Nonimpact Technology

Serial, Nonimpact, Direct Thermal (SNDT)

The SNDT segment continued to decline, with unit shipments and ISVs falling steadily. Dataquest expects SNDT printer shipments to decline throughout the forecast period. Price erosion due to competition from other technologies should cause the ISV to decline rapidly over the same period. The leading companies in this market include Canon, 3M, and Texas Instruments.

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 showed some promise of becoming a low-cost, reliable output device for the home market. Initial growth was fueled by competition with SIFF technology; however, SNTT is now on a negative growth curve due to competition with low-end page printers and high-end SIDM technologies. Major manufacturers in this market include Brother, Canon, Okidata, and TEC.

Serial, Nonimpact, Ink Jet (SNIJ)

The promise that SNIJ technology has held for more than 30 years began to be realized recently. In 1984, SNIJ shipments grew more than twentyfold from 1983 levels. After a two-year marketwide drop, SNIJ printers have regained their momentum, growing rapidly from 1987 to the present. The versatility of SNIJ printers makes them suitable for various applications requiring speed, color, graphics, and letter-quality printing. The SNIJ printer is likely to become the low-cost alternative to the page printer, offering near-laser quality to the individual user at an affordable price. Dataquest anticipates further intense activity in the SNIJ printer market as more manufacturers introduce products with enhanced features at varying price/performance points. The companies that lead in this market include Canon, Hewlett-Packard, and Siemens.

LINE PRINTERS

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 80 columns or more

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—1989 to 1994

Line, Impact Printers

The transition from centralized to decentralized processing has necessitated a similar transition in printing. The effect of this has been to reduce the demand for higher-duty-cycle printers and 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, while 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, and performance improvements have caused near-zero preventive maintenance to become 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 continue to gradually lose market share to page, nonimpact, plain paper (PNPP) technologies because PNPP technologies offer new applications potential based on the following capabilities:

- Ability to print on cut-sheet paper
- Improved price/performance
- High print quality
- Graphics capabilities

Line, impact, dot matrix (LIDM) technology is expected to bridge line and PNPP technologies because of its graphics capabilities. This is evident in the growing number of applications using LIDM printers for printing bar codes, graphics, and on-line form generation. Price/performance ratios for LIDM printers continue to improve.

Line, Nonimpact Printers

The newly evolved line, nonimpact printer market is currently dominated by products aimed at high-performance niche markets. Applications demanding high-quality, color output, such as CAD/CAM/CAE IC design and layout and solids modeling, drive this market.

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 current shipment volumes 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 become negligible.

Impact Technology

Line, Impact Fully Formed (LIFF)

LIFF printer shipments declined again in 1989. Once a cost-effective technology solution, LIFF has been rendered increasingly obsolete by competing technologies.

The decline of LIFF printers can be attributed to two competing technologies: page printers, which offer line printer emulation, and line, impact, dot matrix printers, which offer enhanced flexibility. Major manufacturers in this market include Centronics, Dataproducts, and IBM.

Line, Impact, Dot Matrix (LIDM)

Although this market is not expected to grow, the inherent flexibility of any dot-based printing method is expected to prolong the life of this printer market through 1994. Contributing to the health of this product family are a number of new, higher-performance products being brought to market. Efficient form and paper handling will keep this class of printers a viable alternative in terms of features and performance, in spite of strides made by page and serial printers. Major manufacturers in this segment include CIE Terminals, Hewlett-Packard, IBM, Mannesmann-Tally, and Printronix.

Price erosion for the entire segment is expected to be minimal, and both shipments and revenue are forecast to be stable over the forecast period.

Nonimpact Technology

Line, Nonimpact, Direct Thermal (LNDT)

LNDT special-applications printers have virtually disappeared in both shipments and ISV as alternative technologies begin to offer features previously unique to LNDT printing.

Line, Nonimpact, Thermal Transfer (LNTT)

Much of LNTT printing's potential remains to be realized. Performance limitations, high consumables costs, and special paper requirements combine to discourage widespread, high-volume acceptance of this technology. Balanced against these current limitations are the excellent color capabilities made possible by LNTT technology. These factors make LNTT a fast-growing niche technology in a limited market. Manufacturers participating in this market include Calcomp, Mitsubishi, Seiko, Shinko, and Toshiba.

PAGE PRINTERS

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—1989 to 1994

Dataquest foresees greater acceptance of nonimpact printers as an alternative to impact printers. We further expect to see continued new product introductions at aggressive price/performance points.

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

Dataquest expects continued development of software and interfaces for nonimpact technologies to increase functionality. Color research should fuel continued rapid growth in this most dynamic market segment.

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 continue to undergo a rapid evolution in terms of price, performance, functionality, applications, and market penetration. The PNPP printer market, which constituted less than 15 percent of unit shipments but 40 percent of industry revenue (ISV) for the printer market in 1989, is expected to account for approximately 35 percent of unit shipments and 55 percent of industry revenue by 1994.

Unit shipments are projected to grow at an impressive 19 percent annually over the next five years. The 1- to 20-ppm segment, which accounted for 95 percent of 1989 unit shipments, should continue to dominate this product family, accounting for the lion's share of growth.

CONTENT TRENDS

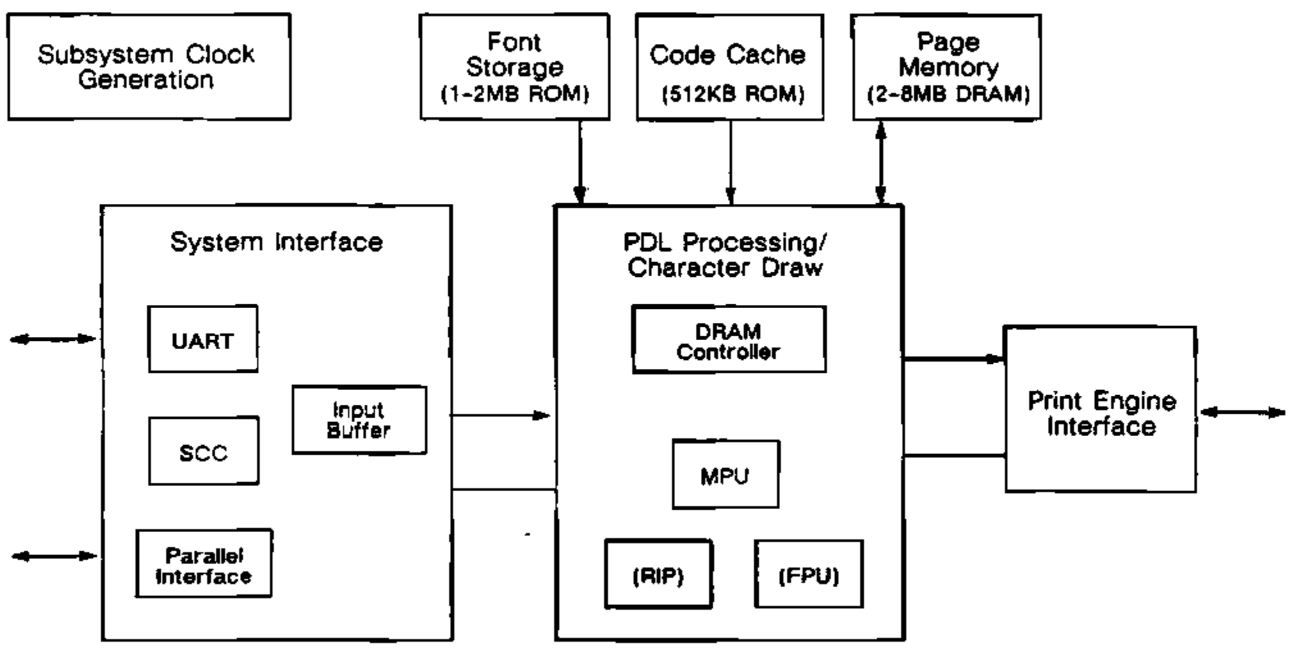
Market acceptance of controller-based printers has been enthusiastic. The fundamental difference in semiconductor content caused by the controller board leads us to project strong growth in memory and application-specific processing processor components in both laser and ink jet printers for the foreseeable future.

Figure 3 shows a general block diagram for a page printer controller.

The rich semiconductor content of page and other intelligent printer types leads us to forecast a high rate of growth for this application market. Figure 4 shows the total semiconductor demand forecast by printer class.

Figure 3

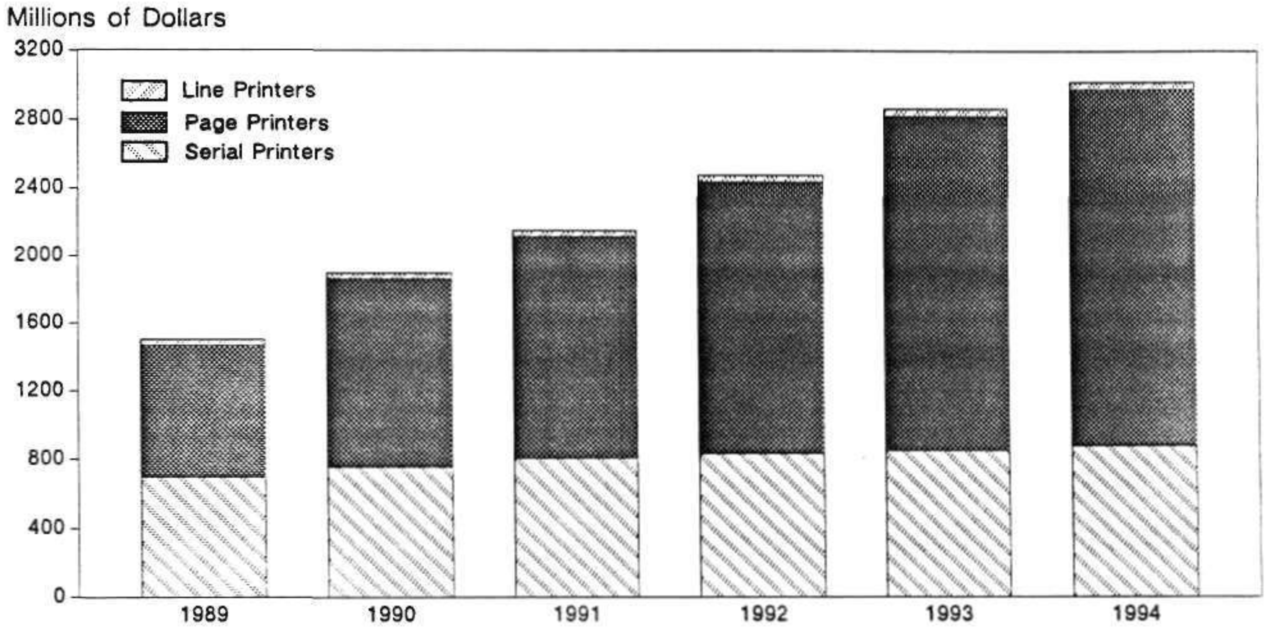
Laser Printer Controller Block Diagram



Source: Dataquest (October 1990)

Figure 4

Printer Semiconductor Market
(Millions of Dollars)



Source: Dataquest (October 1990)

SUPPLIER BASE

Table 3 shows the industry leaders within the growth segments of the printer industry. Of these segments, the two with the greatest long-term promise, page and ink jet, are dominated by companies whose presence in the traditional impact markets is negligible to nonexistent. This presents an interesting competitive situation to semiconductor suppliers looking for design wins in the new, high-growth, nonimpact segments. Although the leaders in traditional technologies are likely candidates for entry into the page and ink jet segments, the substantial technology differences represent formidable entry barriers for companies with traditional technology strength in their mechanical, impact expertise. It remains to be seen whether or not the dot matrix leaders can successfully make the transition to nonimpact, controller-based products.

Table 3

Segment Leaders

24+ Pin SIDM	Ink Jet	Page
Epson	HP	HP
Okidata	Kodak	Apple
NEC	Canon	DEC
IBM	Dataproducts	Canon
TEC/Apple	Epson	Kyocera
Toshiba		NEC
Panasonic		

Source: Dataquest (October 1990)

CONCLUSIONS

At first glance, the printer market appears healthy but unexciting, forecast to grow at just over 5 percent annually during the next five years. This top-level view can be deceiving, however, because it masks the explosive growth expected from the high-quality (24-pin) dot matrix, ink jet, and page printers. Combined, these three segments are expected to realize compound annual growth rates (CAGRs) of over 20 percent in unit shipments and 15 percent revenue growth through 1994.

The page printer (commonly referred to as laser printer) segment clearly has the most explosive growth potential of all printer types. With its ability to interpret and implement a page description language (PDL), the page printer offers users quantum leaps in printing quality, functionality, and flexibility.

But growth in unit volume does not tell the whole story. Because page printers are fundamentally different from prior printing technologies (page printers are "smart" peripherals, which implement higher-level instructions and then act as controller to the print engine), their semiconductor content is much richer. *Dataquest foresees expanding opportunities in memory and specialized processing products within the controller portion of page and other intelligent printers.*

Still small in relation to the other segments, the rapidly emerging ink jet segment is coming on fast. Serial ink jet printers are making substantial inroads at the expense of dot matrix and other impact technologies. But the really explosive potential for this technology is in the middle ground between the performance and feature-limited dot matrix and the still pricey laser printer. Laser quality products such as HP's DeskJet series, which implements a PDL and offers many of the features and capabilities associated with laser printers, have given rise to the phrase "poor man's laser printer" in reference to this very promising market segment.

Trends in Electronic Printers

MARKET OVERVIEW

Throughout this decade, the North American printer market has been characterized by violent swings in the year-to-year growth rates of both unit shipments and industry if-sold values (ISVs). As competing technologies have pushed average selling prices (ASPs) ever downward, and unit shipments have risen and fallen with the fortunes of the PC industry, the North American printer market has moved from double-digit growth in the early 1980s to negative growth in 1985 and 1986, and back to double-digit growth in 1987. However, 1988 marked a transition to a more stable, sustainable compound annual growth rate (CAGR), with unit shipments growing less than 11 percent and ISVs growing 7.2 percent. As seen in Table 1, Dataquest expects the industry to maintain a stable growth pattern through 1993.

Table 1

Estimated North American Market
All Electronic Printers

	1986	1987	1988	1993	CAGR 1988-1993
Units (K)	4,943	6,925	7,657	10,696	6.9%
ASP ($)	$1,209	$1,094	$1,060	$ 1,125	1.2%
ISV ($M)	$5,977	$7,576	$8,119	$12,029	8.2%

Source: Dataquest
July 1989

Worldwide printer shipments amounted to 15.1 million units and $17.74 billion, as shown in Figure 1. North America continues to be the largest consumer, accounting for 45.7 percent of dollar volume and slightly more than half of unit shipments. By 1993, Dataquest expects the worldwide market to exceed $25 billion on unit shipments of more than 21 million. The percentage distribution of revenue and unit shipments should remain relatively stable.

The continued steady growth in printer demand is fueled primarily by the current stable growth patterns of the PC industry. Dataquest estimates the 1988 North American PC market to be at 10.7 million units. Other factors contributing to the continued growth of the North American printer market include the following:

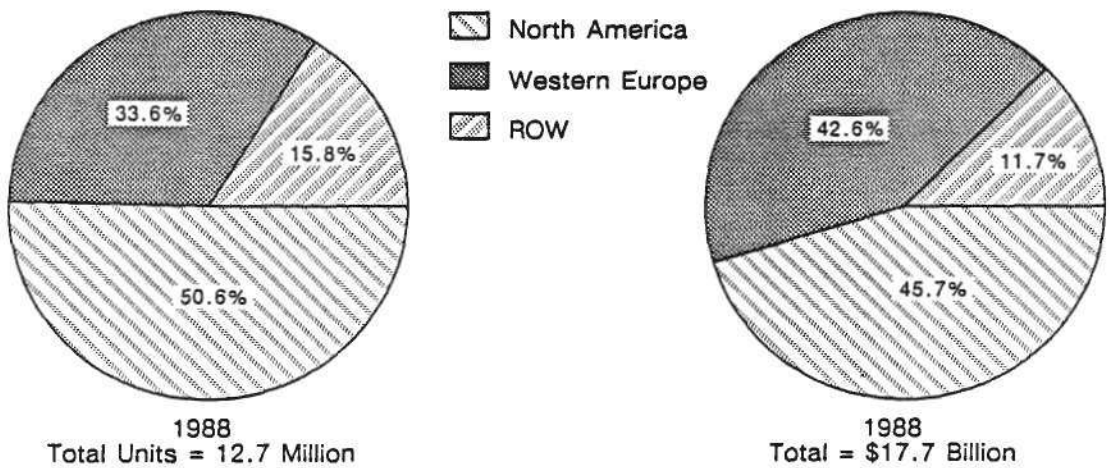
- Integrated system sales for applications such as desktop publishing, presentation graphics, and high-resolution technical applications

- A surge in nonimpact printer sales, led by laser and ink jet technologies

- Continued price/performance improvements
- Continued improvements in and development of distribution channels and product support

Figure 1

Worldwide Printer Demand Forecast
(Millions of Units)



0004338-1

Source: Dataquest
July 1989

SEGMENT ANALYSIS

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

Trends in Electronic Printers

Dataquest expects serial printers to continue to account for the majority of unit shipments through 1993. In 1988, serial printers accounted for 86 percent of all printers shipped. This percentage is expected to decline to approximately 73 percent by 1993. This decline is even more apparent when viewed in a revenue context. Serial printers currently account for only 45 percent of industry revenue, and that figure is expected to decline to 33 percent by 1993.

Table 2

Estimated North American Market
All Electronic Printers
Shipments (Thousands of Units)

	1986	1987	1988	1993	CAGR 1988-1993
Serial Printers	4,508	6,135	6,558	7,762	3.4%
Line Printers	120	116	120	155	5.3%
Page Printers	315	674	978	2,779	23.2%

If-Sold Value (Millions of Dollars)

	1986	1987	1988	1993	CAGR 1988-1993
Serial Printers	2,745	3,456	3,635	3,968	1.8%
Line Printers	1,487	1,334	1,331	1,335	0
Page Printers	1,745	2,786	3,153	6,726	16.4%

Average Selling Price (Dollars)

	1986	1987	1988	1993	CAGR 1988-1993
Serial Printers	609	563	554	511	(1.6%)
Line Printers	12,420	11,516	11,097	8,616	(4.9%)
Page Printers	5,548	4,132	3,223	2,420	(5.6%)

Source: Dataquest
July 1989

Impact versus Nonimpact Printers

In 1988, nonimpact printers accounted for 19 percent of unit shipments. A number of manufacturers are expected to continue introducing nonimpact technologies such as thermal transfer and ink jet, increasing nonimpact printers' market share to 41 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 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.

Dataquest categorizes the serial printer market by one of the following imaging technologies:

- 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—1988 to 1993

General Trends

Competitive pressures continue to build, coming not only from similar products, but also from competing technologies. ASPs continue to slide as ink jet and 24-wire dot matrix technologies put pressure on other technologies.

Trends in Electronic Printers

Software Trends

The primary applications for serial printers are in business and personal productivity. Spreadsheets, data base management, and word processing are the most popular applications, followed by a rapidly growing demand for graphics packages. Spreadsheet and data base applications require a wide carriage and do not require correspondence quality, 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 printers.

Graphics applications software is becoming more prevalent and user-friendly. Dot matrix printers are likely candidates for these applications because of the dot addressability required by graphics programs. Thermal resistive and some ink jet printers also offer dot addressability.

Feature Trends

With the exception of fully formed character printers, most manufacturers offer 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 of 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 now are standard on most dot matrix printers; the speeds typically are listed as draft, correspondence, near-letter quality, or letter quality. A new letter-quality market has emerged, consisting 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. Dot matrix printers currently are achieving noise levels of less than 55 dBA. Fully formed printers have had limited success in reducing noise levels.

Connectivity and increased implementation of networks, both local and wide area, allow efficient sharing of printers at the work group or departmental area. On all levels, more attention is being directed toward the details of the word processing application.

Impact Technology

Serial, Impact, Fully Formed (SIFF)

Table 3 shows Dataquest's unit shipments and ISV forecast for SIFF printers. Competing technologies are rapidly pushing the SIFF segment toward the end of its product life, with both unit sales and ISV declining by more than 60 percent in 1988. Leading companies in this market include Brother, IBM, NEC, Qume, and Xerox.

Table 3

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

	1986	1987	1988	1993	CAGR 1988-1993
Units (K)	310	232	87	47	(10.7%)
ASP ($K)	798	756	677	655	(0.6%)
ISV ($M)	247	175	59	33	(11.3%)

Source: Dataquest
July 1989

Serial, Impact, Dot Matrix (SIDM)

SIDM printers continue to dominate the market, capturing 97 percent of all impact printers and 78 percent of all unit shipments in 1988. Dataquest expects this grip to weaken over the next four years, with SIDM shipments accounting for only 58 percent of unit shipments in 1993, as nonimpact technologies, particularly thermal transfer and ink jet, become more popular. Most SIDM printers shipped in 1988 were of Japanese origin.

High-end dot matrix printers represent the fastest-growing segment of the mature SIDM product group. Greatly improved print quality afforded by the 24-pin head, along with the low cost of manufacture resulting from high production volumes, have enabled dot matrix printer manufacturers to capture a large and growing portion of the personal printer market. Manufacturers now can offer competitive quality at a low price, while minimizing speed, noise, and print quality trade-offs.

Table 4 shows Dataquest's shipment and ISV forecast for SIDM printers. The highest growth over the forecast period should continue to come from high-resolution (24-wire) SIDM printers. The total ISV of all SIDM printers is expected to decline at a negative 0.9 percent growth rate through 1993; however, we expect the high-speed, high-resolution segment to show positive growth. Major manufacturers participating in this market include Epson, Okidata, and Star Micronics.

Table 4

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

	1986	1987	1988	1993	CAGR 1988-1993
Units (K)	3,761	5,456	5,989	6,176	0.6%
ASP ($K)	601	553	547	508	(1.5%)
ISV ($M)	2,262	3,016	3,276	3,135	(0.9%)

Source: Dataquest
July 1989

Nonimpact Technologies

Serial, Nonimpact, Direct Thermal (SNDT)

The SNDT segment continued its decline in 1988, with unit shipments falling 12 percent and ISV falling 21 percent (see Table 5). Dataquest expects SNDT printer shipments to decline at an 11.7 percent CAGR through 1993. Price erosion due to competition from other technologies should cause the ISV to decline at 16.1 percent rate over 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)

	1986	1987	1988	1993	CAGR 1988-1993
Units (K)	97	65	57	31	(11.7%)
ASP ($K)	500	450	400	350	(2.6%)
ISV ($M)	49	29	23	11	(16.1%)

Source: Dataquest
July 1989

Serial, Nonimpact, Thermal Transfer (SNTT)

The first full year of volume shipments of printers that embodied SNTT printing technologies was 1984. Most of these printers were sold with home computers and showed some promise of becoming a low-cost, reliable output device for the home market. Initial growth was fueled by competition with SIFF technology; however, SNTT now is on a negative growth curve because of competition with low-end page printers and high-end SIDM technologies. Table 6 summarizes Dataquest's forecast for SNTT printers through 1993. Major manufacturers in this market include Brother, Canon, Okidata, and TEC.

Table 6

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

	1986	1987	1988	1993	CAGR 1988-1993
Units (K)	216	167	80	54	(7.6%)
ASP ($K)	538	715	665	904	6.4%
ISV ($M)	116	120	53	48	(1.7%)

Source: Dataquest
July 1989

Serial, Nonimpact, Ink Jet (SNIJ)

The promise that SNIJ technology has held for more than 30 years began to be realized in recent years. In 1984, SNIJ shipments grew more than twentyfold from 1983 levels. After a two-year marketwide drop, SNIJ printers have regained their momentum, growing by 72 percent in 1987 and by 60 percent in 1988 (see Table 7). The versatility of SNIJ printers makes them suitable for various applications requiring speed, color, graphics, and letter-quality printing. The SNIJ printer is likely to become the low-cost alternative to the page printer, offering near-laser quality to the individual user at an affordable price. Dataquest anticipates further intense activity in the SNIJ printer market as more manufacturers introduce products with enhanced features at varying price/performance points. The leading companies in this market include Canon, Hewlett-Packard, and Siemens.

Table 7

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

	1986	1987	1988	1993	CAGR 1988-1993
Units (K)	125	215	345	1,452	33.3%
ASP ($K)	570	537	647	511	(4.6%)
ISV ($M)	$71	115	223	742	27.1%

Source: Dataquest
July 1989

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:

- A printer with a printhead that covers a full line of the printed page and a striking mechanism that prints one full line at a time
- A printer with an electronic device that produces hard copy from computer-generated data that have been buffered for printing one line at a time
- A printer that produces hard copy in formats of 80 columns or more

Dataquest categorizes the line printer market according to the printing technology. These technologies include the following:

- Impact technologies—Line, impact, fully formed (LIFF) and line, impact, dot matrix (LIDM)
- Nonimpact technologies—Line, nonimpact, direct thermal (LNDT); line, nonimpact, thermal transfer (LNTT); ink jet; and any other nonimpact technology capable of buffering and printing one line at a time

Trends in Electronic Printers

Trends—1988 to 1993

Line, Impact Printers

The transition from centralized to decentralized processing has necessitated a similar transition in printing. This in turn has reduced the demand for higher duty cycle printers and created a need for printers in applications other than those in the computer room. High-speed printers continue to be used in computer rooms serving data processing applications, while midspeed printers can be found in distributed printing networks, where they are used as shared resources.

Recent gains have been made in reducing hardware costs, while performance improvements have caused near-zero preventive maintenance to become the norm. Improvements also have 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 continue gradually losing market share to page, nonimpact, plain paper (PNPP) technologies, because PNPP technologies offer new applications potential based on the following capabilities:

- Ability to print on cut-sheet paper
- Improved price/performance
- High print quality
- Graphics capabilities

LIDM technology is expected to bridge line and PNPP technologies because of its graphics capabilities. This is evident in the growing number of applications using LIDM printers for printing bar codes, graphics, and on-line form generation. Price/performance ratios for LIDM printers continue to improve.

Line, Nonimpact Printers

The newly evolved line, nonimpact printer market presently is dominated by products aimed at high-performance niche markets. Applications demanding high-quality color output, such as CAD/CAM/CAE, IC design and layout, and solids modeling, drive this market.

The following factors make line, nonimpact technologies unsuitable 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 exceed 450 lpm
- Lack of software support for driving color applications

This market currently is dominated by Japanese manufacturers, and current shipment volumes remain low. LNTT printers are expected to gradually increase in shipments over the next five years; LNDT printer shipments gradually will decline until shipment levels become negligible.

Impact Technology

Line, Impact, Fully Formed (LIFF)

LIFF printer shipments declined again in 1988. Once a cost-effective technology solution, LIFF has been rendered increasingly obsolete by competing technologies. Dataquest's forecasts of LIFF printer shipments and ISVs are shown in Table 8.

The decline of LIFF printers can be attributed to two competing technologies: page printers, which offer line printer emulation; and line, impact, dot matrix printers, which offer enhanced flexibility. Major manufacturers in this market include Centronics, Dataproducts, and IBM.

Table 8

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

	1986	1987	1988	1993	CAGR 1988-1993
Units (K)	63	50	41	36	(2.7%)
ASP ($K)	16,448	16,267	17,292	16,509	(0.9%)
ISV ($M)	1,031	812	703	587	(3.6%)

Source: Dataquest
July 1989

Line, Impact, Dot Matrix (LIDM)

Although this market is not expected to grow, the inherent flexibility of any dot-based printing method is expected to prolong the life of this printer market through 1993. Contributing to the health of this product family are several new, higher-performance products that are currently being brought to market. Efficient form and paper handling will keep this class of printers a viable alternative in terms of features and performance, in spite of strides in progress made by page and serial printers. Major manufacturers in this segment include CIE Terminals, Hewlett-Packard, IBM, Mannesmann Tally, and Printronix.

Dataquest's forecasts of shipments and ISV over the 1988-1993 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 this period.

Table 9

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

	1986	1987	1988	1993	CAGR 1988-1993
Units (K)	53	53	59	57	(0.7%)
ASP ($K)	7,921	8,010	8,588	8,309	(0.7%)
ISV ($M)	421	420	$505	472	(1.3%)

Source: Dataquest
July 1989

Nonimpact Technology

Line, Nonimpact, Direct Thermal (LNDT)

LNDT special-applications printers have virtually disappeared in both shipments and ISV (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)

	1986	1987	1988	1993	CAGR 1988-1993
Units (K)	0.10	0.03	0	0	N/A
ASP ($K)	4,000	3,030	N/A	N/A	N/A
ISV ($M)	0.4	0.1	N/A	N/A	N/A

Source: Dataquest
July 1989

Line, Nonimpact, Thermal Transfer (LNTT)

Much of LNTT printing's potential has not yet been realized. Performance limitations, high consumables costs, and special paper requirements combine to discourage widespread high-volume acceptance of this technology. Balanced against these present limitations are the excellent color capabilities made possible by LNTT technology. These factors make LNTT a fast-growing niche technology in a limited market (see Table 11). 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)

	1986	1987	1988	1993	CAGR 1988-1993
Units (K)	3.7	13.4	20.5	62.6	25.0%
ASP ($K)	9,081	7,582	6,004	4,415	(6.0%)
ISV ($M)	34	102	123	276	17.6%

Source: Dataquest
July 1989

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—1988 to 1993

Dataquest foresees greater acceptance of nonimpact printers as an alternative to impact printers. We further expect to see continued new product introductions at aggressive price/performance points.

Trends in Electronic Printers

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

Dataquest anticipates continued development of software and interfaces for nonimpact technologies to increase functionality. Color research should fuel continued rapid growth in this extremely dynamic market segment.

PNPP Printers

PNPP printer technologies include the following:

- Electrophotography
  - Laser
  - Light-emitting diode (LED)
  - Liquid crystal shutter (LCS)
- Ionography
- Magnetography
- Ink jet

PNPP printers continue to undergo a rapid evolution in terms of price, performance, functionality, applications, and market penetration. The PNPP printer market, which constituted less than 13 percent of unit shipments but 38.9 percent of industry revenue (ISV) for the printer market in 1988, is forecast to account for approximately 26 percent of unit shipments and 56 percent of industry revenue by 1993. Table 12 shows unit shipment and ISV forecasts for all PNPP printer segments.

Table 12

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

	1986	1987	1988	1993	CAGR 1988-1993
Units (K)	315	674	978	2,779	23.2%
ASP ($K)	5,548	4,132	3,223	2,420	(5.6%)
ISV ($M)	1,745	2,786	3,153	6,726	16.4%

Source: Dataquest
July 1989

Unit shipments are projected to grow at an impressive 23.2 percent CAGR annually during the next five years. The 1–20 ppm segment, which accounted for 94.4 percent of 1988 unit shipments, should continue to dominate this product family, accounting for the lion's share of growth.

DATAQUEST CONCLUSIONS

At first glance, the North American printer market appears healthy, but unexciting, growing at just 6.9 percent annually during the next five years. This top-level view can be deceiving, however, as it masks the explosive growth expected from the high-quality (24-pin) dot matrix, ink jet, and page printers (see Table 13). Combined, these three segments are expected to realize CAGR of more than 20 percent in unit shipments and 15 percent revenue growth through 1993.

The page printer segment, commonly known as the laser printer segment, is clearly the most explosive of all printer types. With its ability to interpret and implement a page description language (PDL), the page printer offers users a quantum leap in printing quality and flexibility. But growth in unit volume does not tell the whole story. Because page printers are fundamentally different from prior printing technologies (page printers are "smart" peripherals, which implement higher-level instructions and then act as a controller to the print engine), their semiconductor content is much richer. Dataquest foresees expanding opportunities in memory and specialized processing products within the controller portion of page printers.

Table 13

Estimated North American Printer Market
Units (Thousands)

	1986	1987	1988	1993
Nonimpact				
Serial, ink jet	125.00	215.00	345.00	1,452.00
Serial, thermal transfer	216.00	167.00	80.00	54.00
Serial, direct thermal	97.00	65.00	57.00	31.00
Line, thermal transfer	3.70	13.40	20.50	62.60
Line, direct thermal	0.10	0.03	0	0
Page, plain paper	315.00	674.00	978.00	2,779.00
Total	756.80	1,134.43	1,480.50	4,378.60

(Continued)

Table 13 (Continued)

Estimated North American Printer Market
Units (Thousands)

	1986	1987	1988	1993
Impact				
Serial, fully formed	310.00	232.00	87.00	47.00
Serial, dot matrix	3,761.00	5,456.00	5,989.00	6,176.00
Line, dot matrix	53.00	53.00	59.00	57.00
Line, fully formed	63.00	50.00	41.00	36.00
Total	4,187.00	5,791.00	6,176.00	6,316.00
Total, All Printers	4,943.80	6,925.43	7,656.50	10,694.60
Percent nonimpact	15.31%	16.38%	19.34%	40.94%
Percent impact	84.69%	83.62%	80.66%	59.06%

ISV (Millions of Dollars)

	1986	1987	1988	1993
Nonimpact				
Serial, ink jet	71.00	115.00	223.00	742.00
Serial, thermal transfer	116.00	120.00	53.00	48.00
Serial, direct thermal	49.00	29.00	23.00	11.00
Line, thermal transfer	34.00	102.00	123.00	276.00
Line, direct thermal	0.40	0.10	0	0
Page, plain paper	1,745.00	2,786.00	3,153.00	6,726.00
Total	2,015.40	3,152.10	3,575.00	7,803.00
Impact				
Serial, fully formed	247.00	175.00	59.00	33.00
Serial, dot matrix	2,262.00	3,016.00	3,276.00	3,135.00
Line, dot matrix	421.00	420.00	505.00	472.00
Line, fully formed	1,031.00	812.00	703.00	587.00
Total	3,961.00	4,423.00	4,543.00	4,227.00
Total, All Printers	5,976.40	7,575.10	8,118.00	12,030.00
Percent nonimpact	33.72%	41.61%	44.04%	64.86%
Percent impact	66.28%	58.39%	55.96%	35.14%

Source: Dataquest
July 1989

Still small in relation to the other segments, the newly emerging ink jet segment is coming on fast. Serial, ink jet printers are making substantial inroads at the expense of dot matrix and other impact technologies. But the most explosive potential for this technology is in the middle ground between the performance- and feature-limited dot matrix, and the still pricey laser printer. "Laser quality" products, such as HP's DeskJet series, which implement a PDL and offer many of the features and capabilities associated with laser printers, have given rise to the phrase, "poor man's laser printer."

Content Trends

Market acceptance of controller-based printers has been enthusiastic. The fundamental difference in semiconductor content caused by the controller board leads us to project strong growth in memory and applications-specific processing applications in both laser and ink jet printers for the foreseeable future.

Supplier Base

Table 14 shows the industry leaders within the growth segments of the printer industry. Of these segments, the two with the greatest long-term promise, page and ink jet, are dominated by companies whose presence in the traditional impact markets is negligible to nonexistent. This presents an interesting competitive situation to semiconductor suppliers looking for design wins in the new, high-growth, nonimpact segments. While the leaders in traditional technologies are likely candidates for entry into the page and ink jet segments, the substantial technology differences represent formidable entry barriers for companies with traditional technology strengths in the mechanical, impact area. It remains to be seen whether the dot matrix leaders can successfully make the transition to nonimpact, controller-based products.

Table 14

Segment Leaders

24+ Pin SIDM	Ink Jet	Page
Epson	HP	HP
Okidata	Eastman Kodak	Apple
NEC	Canon	
IBM		Digital
	Dataproducts	Canon
TEC/Apple	Epson	Kyocera
Toshiba		NEC
Panasonic		

Source: Dataquest
July 1989

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Trends in Disk Drives

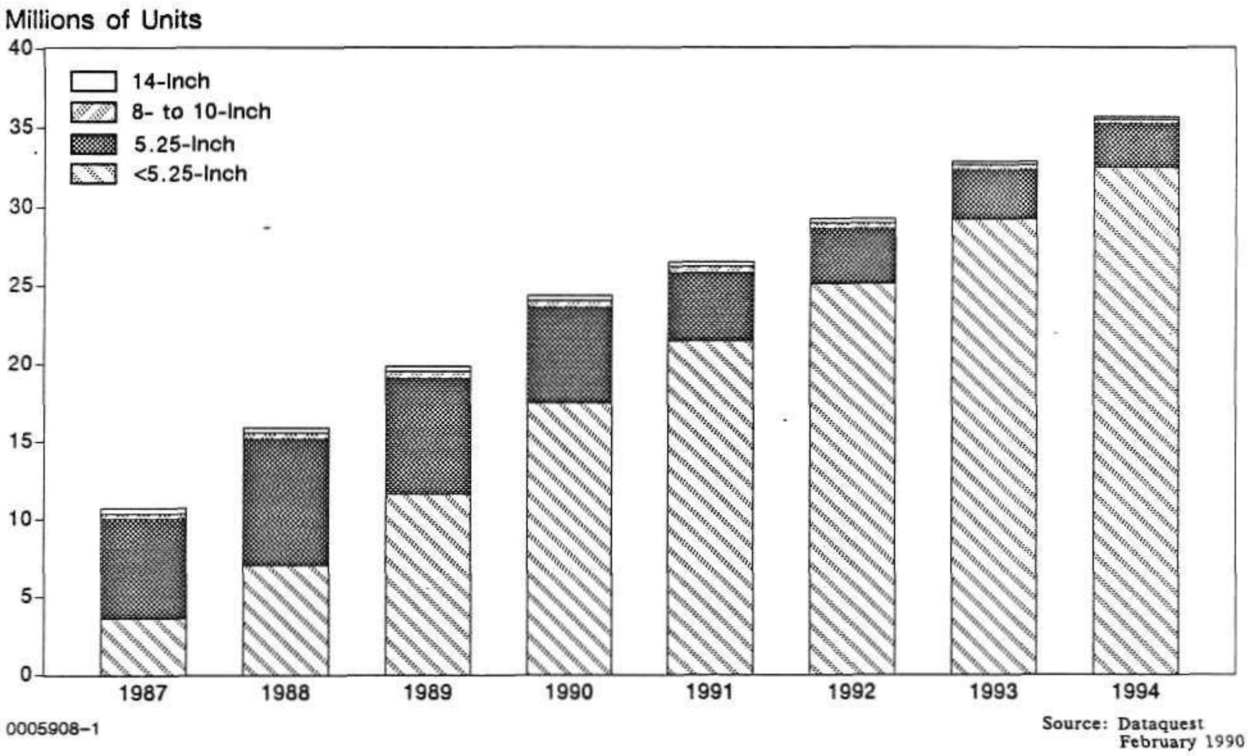
INTRODUCTION

Few electronic products have seen more rapid technological development and more market volatility over the past few years than rigid disk drives. Spurred by new computer architectures, operating systems, and applications software, demands abound for faster, denser, and more reliable storage devices in ever-smaller form factors.

As seen in Figure 1, the single-user market, with its heavy demand for 3.5- and 5.25-inch form factors, consumes the bulk of disk drive shipments and therefore drives much of the industry's technology development. This section will focus on the small form factor segments of the market.

Figure 1

Worldwide Rigid Disk Drive Shipments
Millions of Units



Trends in Disk Drives

Industry turbulence showed no signs of subsiding during the past 12 months. Some of the highlights are as follows:

- The big news of 1988: overcapacity; for 1989: no relief yet. The PC slowdown everyone was waiting for showed itself in the low-end clone business first, drying up the retail channel.

- MiniScribe, caught flat-footed by inventory build-up in the retail channel, was hit so hard that it may never fully recover.

- Seagate, caught in a similar situation, not only righted itself quickly but boldly acquired CDC's Imprimis division. The acquisition not only doubled Seagate's market share but positioned the company as a performance and technology leader as well as a low-cost producer. The possible technology, manufacturing, and distribution synergies are likely to make competitors a little queasy.

- Vendors that are not selling into the mainstream PC marketplace found safe havens in such segments as workstations and portables. Conner Peripherals, for example, shrugged off all talk of an industry slowdown and kept right on selling to the healthiest portion of the market.

- "Intelligent" drives, with built-in small computer systems interface (SCSI) or AT controllers, continued quietly displacing the traditional "dumb" ST412 drives, nearly doubling their market penetration from 1987 to 1989. This is largely because of the leadership position being taken by PC industry front-runners Apple, Compaq, and IBM. Table 1 provides Dataquest's worldwide forecast for small rigid disk drives.

Table 1

Worldwide Small Rigid Disk Drive Market (Thousands of Units Shipped)

	1987	1988	1989	1990	1991	1992	1993	1994
<5.25-Inch	3,642	7,006	11,585	17,480	21,422	25,138	29,200	32,500
5.25-Inch	6,368	8,155	7,464	6,095	4,390	3,480	3,142	2,740
Total	10,010	15,161	19,049	23,575	25,812	28,618	32,342	35,240

Source: Dataquest February 1990

Trends in Disk Drives

MARKET BACKGROUND

In addition to fulfilling the requirements of higher capacity, faster I/O, and ever-lower cost per bit, the industry must also concern itself with the integration of the drive into the computer system. This function has traditionally been fulfilled by controller companies. Combining expertise in magnetic disk control with an understanding of host I/O functions, these companies have worked closely with systems integrators/manufacturers to incorporate the latest high-performance/high-density devices into their systems.

The need for such middlemen springs from the continuing evolution of disk drive technology and a lack of standards among operating systems. Before the development of the personal computer and the small rigid disk drive, third-party operating systems were rare and proprietary I/O channels and protocols were common. Developing turnkey systems often required unique combinations of CPUs, I/O peripherals, and software glue, all with special interfacing requirements. The controller supplier also added considerable value in addressing compatibility issues across the various drive models and systems standards.

But the inevitable process of circuit consolidation, along with the standardization of certain peripherals bus standards, argues for the gradual decline of these controller houses and the emergence of "smart" disk drives with embedded control circuitry. The benefits of eliminating the controller card in favor of the smart drive are as follows:

- The combination of embedded control drives and a standardized peripherals bus forces the issue of compatibility onto a single party--the drive manufacturer.
- Application-specific standard integrated circuits now can greatly reduce the cost of the controller function, enabling drive manufacturers to offer a better value for the complete subsystem.
- Drive manufacturers not only have control over the performance of the entire subsystem but capture all of the revenue as well.
- High-level interface buses allow systems integrators to configure systems with a variety of smart peripherals.

FUNCTIONS

The disk drive subsystem can be divided into the following four functional blocks:

- Mechanical control
- Data read/write and conversion

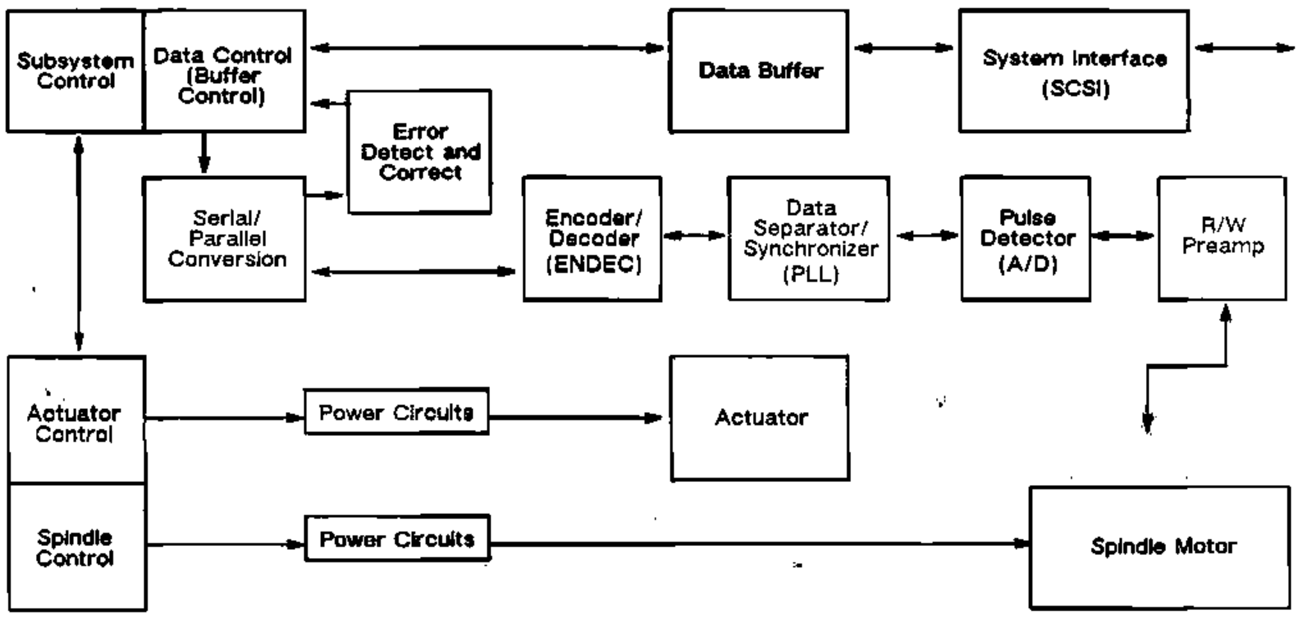
- Subsystem control, including data buffering
- Subsystem interface

The first two blocks are usually included within the drive electronics; the latter two are found on a controller card or embedded within the intelligent drive.

Figure 2 shows a general block diagram of the complete drive subsystem.

Figure 2

Disk Drive Block Diagram



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Source: Dataquest
February 1990

Because magnetic storage is essentially an analog phenomenon, the first task in reading data from a disk is to boost this low-level analog signal to a readable level. This is accomplished by the use of a read/write preamplifier. This higher-level analog signal is then converted to digital by the pulse detector.

Once the data is digitized, the data synchronizer separates clock pulses from data pulses. The serial stream of data usually encoded in either an Modified Frequency Modulation (MFM) or run-length limited (RLL) encoding scheme is then decoded by the encoder/decoder (ENDEC).

Although represented here as separate functional blocks, the serial/parallel conversion, the error detect and correct, and the buffer control functions are rapidly being consolidated into a single data control chip.

The subsystem control function covers the coordination of data control with mechanical control, which in turn is implemented by a combination of motor control and power circuits.

Finally, systems interface logic is rapidly being compressed to one or two chip implementations that handle all of the bus protocol. These usually require some driver devices along with a small SRAM for buffer memory.

Just as there are no hard and fast rules for the partitioning of these functions, there is no firm rule as to whether the data controller occupies a separate card or is embedded within the drive itself. Current trends, however, point to the eventual elimination of the controller card in favor of an intelligent drive with a minimum chip count.

STORAGE DENSITY PROGRESSION AS A DRIVING FORCE

Controller design has long been a very specialized area because of the unique properties of magnetic recording and the timing requirements for digital data integrity. The problems associated with maintaining data integrity increase significantly as higher capacity designs push the limits of magnetic technology. Bit jitter increases, requiring closer phase-lock loop monitoring; media defects increase substantially, forcing more elaborate defect mapping; data rates usually increase between device and host I/O channels; signal strength begins to drop off as demagnetization between adjacent fields increases; error detection and correction becomes extremely critical as data encoding schemes are implemented to increase effective bit densities. Regardless of the increasingly difficult challenge of getting more out of less, market demand for increased density, as illustrated in Figure 3, continues to push for more and continued innovation. The major changes in disk drive design needed to accommodate these trends, and their implications, are discussed in the following subsections.

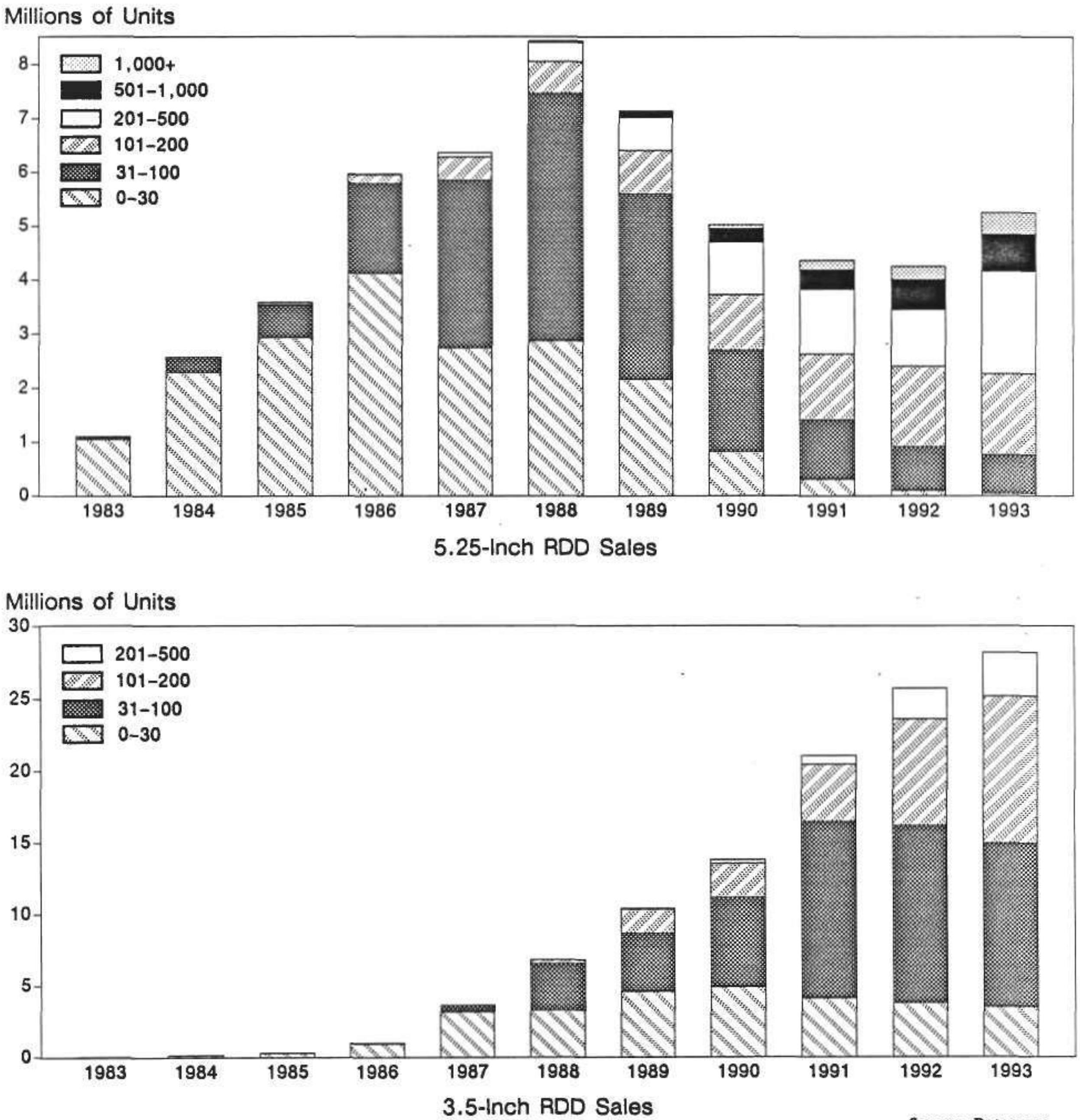
Small Drive Size

Efforts to reduce the physical size of disk drives led to the 5.25-inch, the 3.5-inch, and the 2.5-inch drives. These small dimensions did not allow for the initial inclusion of control functions, such as data separation, within the drive. Similarly, the small size made adoption of the SMD interface difficult and led to the development of a more compact interface, such as the original 5.25-inch rigid disk drive interface (the ST412), which was derived from a flexible disk drive interface.

Many of the small disk drives currently being shipped include embedded controllers, which is made possible by the increasing levels of integration being offered by semiconductor manufacturers. It is now possible to fit onto a few chips those functions that required an entire controller card a few years ago.

Figure 3

Average Capacity of Fixed Media Disk Drives
Average Mbytes/Drive
Large and Small Drives 1980–1995



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Source: Dataquest
February 1990

Most of these smart disk drives have either the SCSI or the AT interface implemented within the drive. Dataquest expects the trend toward full host bus integration into small rigid disks to continue. We further expect the SCSI to become the predominant interface standard for storage products used in single-user PCs.

Increased Areal Density

In order to keep pace with continually growing PC data storage requirements, the drive industry continues to push areal densities by increasing both track and linear bit densities. Increased track density is principally achieved by using more precise head-positioning techniques, often through closed-loop voice-coil positioners. Specially recorded servo data are also commonly used to allow the positioner to more closely lock onto tracks. The requirement for smaller packaging makes embedded data servos preferable to the dedicated surface servos commonly used in larger drives.

Increased bit density is accomplished by squeezing flux charges more closely together, which requires closer clocking by the controller. Growing use is made of data coding schemes to increase bit density. Such schemes increase data recording efficiency but require very sophisticated media defect mapping, error checking, and correction algorithms. These features can impose severe overhead on the system if they are not built into the controller's processing capabilities.

Higher Data Rates

Higher data rates are sought, particularly for real-time data processing. Faster data rates can be achieved at the drive level by increasing the linear density, but these changes require wider bandwidth in the controller and more critical timing between disk data transfers and the host system. System bus contention among devices also tends to increase significantly as data rates increase.

Faster Access Times

Faster access is achieved by improvements in head positioning at the drive level. Both voice-coil positioners and improved stepper-motor positioning are used for track access using buffered, burst-mode seeks. Early 5.25-inch drives used stepper motors only and waited for individual step pulses from the controller to the stepper motor.

Data formatting also affects access time when data sectors are interleaved, requiring multiple rotations of the disk to read the entire track. Data throughput is significantly improved from elimination of the interleave factor. Such 1:1 interleaving requires high-speed data separation and precise data throttling between the controller and the host CPU. Although many low-cost applications use interleave factors of 3:1 or 4:1, the trend among after-market controller manufacturers is clearly toward using noninterleaved sectoring for performance enhancements. The use of semiconductor memory as a data caching intelligent drives and controllers will become a popular means of reducing access times.

Trends in Disk Drives

SYSTEM INTEGRATION TRENDS AS A DRIVING FORCE

Interfaces

A key element in system integration of high-capacity disk drives is the wide range of interfaces available at both the device and host I/O level. In the following discussions, the most popular interfaces are described. The emphasis is on trends in device interfaces for small rigid disk drives.

ST412/ST506

The ST412 is the native interface for the small disk drive. It was developed by Seagate for its model ST506, the first 5.25-inch rigid disk drive and quickly gained universal acceptance by other drive manufacturers. Drives using this interface perform none of the data separation and encoding/decoding functions shown in Figure 1. The ST412 interface is based on the floppy disk interface and is often called the floppy-extended interface. The drive data rate is specified at 5 Mbits per second and data are encoded using MFM, both of which limit drive performance.

Controllers that use RLL encoding techniques can increase data capacity and throughput by approximately 50 percent over MFM encoding.

ESDI

The enhanced small device interface (ESDI) is a high-performance disk interface developed for the 5.25-inch disk drive by several companies. Maxtor was an early adopter of the ESDI, and numerous other manufacturers such as Control Data, Fujitsu, Hitachi, Micropolis, MiniScribe, and Siemens are also supporting the interface. The ESDI is somewhat like the SMD interface used for large disk drives in that the data separation functions reside on the disk. Unlike the SMD interface, however, the ESDI has fewer interface lines to accommodate the small size of 5.25-inch drives (34 control and 20 data lines for the ESDI versus 60 control and 26 data lines for the SMD) and, consequently, is less expensive to implement. Data are transferred from the ESDI disk as sanitized NRZ data with a synchronous clock rather than encoding data, allowing flexible selection of various encoding schemes by drive manufacturers. The actual encoding scheme used on the drive remains transparent to the controller. The drive serial data rate can be as high as 24 Mbps (Mbits per second) with ESDI.

SCSI

The SCSI is an ANSI-standardized version of the SASI that includes several enhancements to the SASI specification. The SCSI not only supports disk drives, it also supports tape drives, printers, optical disks, and various other peripheral devices. (The SCSI provides for a user-definable command set that allows users to incorporate commands unique to a user's device.) Multiple hosts are also addressable, and SCSI specifications include a full command set for communications between "initiators" and "targets." Both asynchronous and synchronous modes for data transfer have been specified. Asynchronous SCSI, with a maximum data rate of 1.2 Mbytes per second (MBps), is the predominant transfer mode currently being used. Synchronous SCSI has a maximum data transfer rate of 4 MBps, which will probably increase significantly under SCSI II.

The SCSI is as much an architecture as an interface. It provides a dedicated 16-bit I/O bus (8-bit data bus and 8-bit control bus) that can be accessed by up to eight hosts and can support up to eight SCSI devices. Note that these hosts can be either single devices with on-board SCSI or SCSI controllers that in turn support multiple drives. Thus, large system integrators concerned with the eight-device SCSI limitation may prefer to use the flexibility of board-level controllers, whereas the simplicity offered by intelligent SCSI devices may be preferable for smaller systems. SCSI II will feature a full 16-bit data bus option.

IPI

The intelligent peripheral interface (IPI) offers higher performance than the SCSI, supporting a data rate of up to 10 MBps. The IPI has a 16-bit data bus versus the current 8-bit SCSI data bus. The IPI is defined at four levels, which allows users considerable flexibility in its implementation, but also means that considerable industry investment is necessary before the IPI gains strong momentum. In general, IPI development is not nearly as extensive as SCSI development, and it appears to be focused on large systems. The first major systems company to endorse IPI through its use is IBM, which uses IP I-3 for high-performance direct-access storage device (DASD) on the 9370 computer.

AT

A rather new intelligent interface standard, the AT interface, has been popularized by Conner Peripherals and Compaq Computers. As a lower-cost alternative to SCSI, the AT interface has enjoyed rapid acceptance, as several PC vendors have followed Compaq's lead. As of this writing, Dataquest believes that several disk drive manufacturers are developing AT interface products.

Proprietary

In the proprietary interface area, two of the major systems participants seem to have been moving in opposite directions. IBM, which has always championed an open architecture in its PC-based systems, developed a proprietary drive interface for its PS/2 systems. Apple, on the other hand, has adopted SCSI for the Macintosh, opening its architecture. As of this writing, there is considerable speculation that IBM will announce the adoption of the SCSI interface for future PCs.

The large disk arena, in which Digital Equipment has the Digital storage architecture (DSA) and its associated standard disk interconnect (SDI) and IBM has the IBM control-unit-to-disk interface (CUDI), has been dominated by the proprietary approach as systems companies have attempted to maintain control over the storage devices sold for use in their systems. But this use of proprietary interfaces seems to be a luxury for only the largest systems companies. Systems markets are very cost-sensitive, and low-cost OEM drives, especially intelligent drives that allow high performance and design flexibility, allow smaller system manufacturers to download responsibilities for drive management systems and to concentrate their limited engineering resources on system development work. Dataquest believes that all system manufacturers have examined or are now examining the SCSI bus and architecture as a possible feature for future systems.

In the 3.5-inch and 5.25-inch arenas, most captive manufacturers seem to be supporting standard interfaces. IBM's own captively manufactured 5.25-inch drives use standard OEM interfaces (ST412). This allows easy multiple-drive sourcing in the event that internal manufacturing problems develop, and it could allow the products to be sold in OEM markets in the future.

SYSTEMS DESIGN GOALS AS A KEY TO SUCCESSFUL INTEGRATION

Systems integrators generally have three design goals when integrating disk drives into systems: low cost, flexibility, and performance. Depending on the desired system characteristics, the priority of these goals varies considerably among manufacturers. However, these goals are not necessarily in complete conflict and can be implemented in many ways. Similarly, they affect the selection and development of interfaces, both host I/O bus interfaces and drive interfaces.

Low-Cost Goal

The low-cost goal is one of achieving the lowest possible cost for the complete storage subsystem. This goal is clearly seen in general-purpose personal computers and in the ST412-type disk drives. The ST412 interface stripped all intelligence off the drive in order to achieve a generic device interface that could be manufactured in high volumes at low cost. Packaging limitations of the early 5.25-inch drives also made the basic ST412 interface attractive. This configuration will not always have the lowest total cost, however. Packaging capabilities have increased as a result of VLSI controller chip and surface mount technologies, drastically reducing the cost of fully integrated, intelligent controllers. Another motive for embedded controllers is the competition among disk drive manufacturers. The overcrowding in the disk drive market has caused manufacturers to attempt to achieve product differentiation by moving to intelligent devices, with the beneficial outcome of lower prices. The prices for embedded versus standalone drive/controller combinations are listed in Table 2. Fierce competition has driven these prices down sharply during the past year.

Table 2

Cost of Implementation
Estimated End-User Price for a 40MB Drive with Controller

Drive/Controller	Price
5.25-Inch, ST412-Type Drive with Separate Controller Board (40MB)	$ 475
Drive Only	$ 400
Controller Board Only	$ 75
5.25-Inch ESDI Drive with Controller (170MB)	$1,850
Drive Only	$1,700
Controller Board Only	$ 150
3.5-Inch SCSI Drive with Embedded Controller (40MB)	$ 585

Source: Dataquest
February 1990

Acceptance of the SCSI and its predecessor, the SASI, has been widespread among system integrators and has provided standard intelligent interface specifications for controller manufacturers. This has created the potential for high-volume production, making the embedded controller an economical alternative to the ST412 board-level controller combination. In addition, the SCSI's flexibility allows system designers to use it for a wide range of systems, and their familiarity with it saves valuable design time.

Low-cost objectives depend very much on volume. No-frill, commodity-like designs work best for price-sensitive systems markets. The installed base of systems plays a key part in determining which host on I/O bus controller is designed for. The most popular systems provide the greatest potential for third-party controller sales; they stimulate the design of new controllers, which often increases the popularity of the system. The IBM PC and its compatibles, with an installed base of more than 55 million systems, have been so successful that most controller manufacturers, and now drive manufacturers, are targeting products directly at the PC bus. Among generic open-bus systems, VME, Multibus II, and SCSI are the leading contenders for future host buses. Support of SCSI by both IBM and Apple make this the leading candidate.

Trends in Disk Drives

Design Flexibility

Design flexibility, a major goal of the many larger system manufacturers, has the underlying objective of achieving device independence. This flexibility implies moving sufficient intelligence from the host to the drive controller so that the interface to the host does not require host knowledge of the specific physical attributes of individual disk drives. Although device independence adds complexity to the controller, it simplifies the host operating system software. The greatest benefit of device independence is that it allows changes to be made to the storage makeup of the system without forcing changes in system software.

Constant improvements in storage devices have made the integration of new disk drives a continual challenge for system manufacturers and integrators. Systems can be kept more competitive by frequently upgrading the disk drives offered. Device independence allows such upgrades to be done more quickly and frequently. A key element in the achievement of device independence is the adoption of intelligent interfaces, either through the use of a standard interface like the SCSI or via development of proprietary intelligent interfaces.

Unfortunately, because of the many options available under SCSI, complete interdrive compatibility is not yet a reality, as drive manufacturers tend to implement different options. SCSI II seeks to address this issue, thereby increasing the level of compatibility.

PERFORMANCE

Improving I/O system performance requires addressing the familiar issue of the I/O bottleneck and related architectural dilemmas. Maximizing host I/O bus efficiency is the most common approach to performance enhancement. From the storage perspective, this means minimizing the bus time used for disk transfers. Techniques commonly used to achieve this goal include disk caching, concurrent multiple disk seeks, command queuing, and prefetching of data sectors in anticipation of host requests. Data transfers frequently occur in full file increments in burst mode at full bus speed rather than sector by sector.

These types of performance improvements require intimate knowledge of the host operating system. Consequently, companies offering high-performance controllers generally have optimized their products for specific host systems and operating systems, and the target markets for such products tend to be rather narrow. The optimal interface for each design goal is shown in Table 3.

Table 3

Design Goal versus Interface Type

Design Goal	Interface Type	Interface Examples
Low Cost	Native or Device	ST412
Flexibility	Intelligent or System	SCSI (Proprietary)
Performance	High Performance	ESDI

Source: Dataquest
February 1990

SEMICONDUCTOR DESIGN AND PACKAGING CAPABILITIES AS A DRIVING FORCE IN CONTROLLER TRENDS

Critical to the success of a disk drive, particularly the smaller form-factor models, is the availability of reliable VLSI chip sets for the controller. Reductions in the size and cost of the controller board are imperative in the high-volume, cost-sensitive drive market. The trend from multiple-board to single-board to embedded controllers can be directly related to advances in the level of integration on available ICs. The issues of design time, flexibility, space availability, and cost are changing the way chip companies interact with this market. The following subsections will examine these issues with a focus on the shift from board level to embedded control.

Design Time

The original controllers were designed using standard logic to augment a standard (usually 8-bit) microcontroller. This design allowed for a great deal of flexibility, although it is clearly impractical by today's standards.

The emergence of chip sets allowed drive designers to implement their particular interface in significantly shorter period of time than with standard logic. As standards emerged and as greater degrees of integration became possible, the number of devices required to implement all functions has declined steadily.

Semicustom and application-specific standard products are rapidly displacing lower integration devices. The most common implementation of these devices seems to be a CMOS cell-based device. Design times for these devices are declining quickly as design methodologies continue to become more powerful.

Trends in Disk Drives

Flexibility

The most obvious compromise involved in going from a multichip to a one-chip solution is flexibility. By maximizing the number of functions on one VLSI device, flexibility is reduced for optimization with specific drives. Using a single-chip interface for interfaces such as the SMD and ESDI may be difficult because these interfaces encode data on the drive rather than on the controller. Drive designers using these interfaces require the flexibility of being able to select various data encoding schemes and, therefore, often require a separate encoding/decoding chip. Although a multiple-chip solution has an advantage here, improved design techniques may allow easier modification of custom one-chip controllers, even very late in the process.

Standard chip sets are also now designed with programmable features. These features allow for the support of a variety of disk drives and data rates.

Space Availability

As drives become ever smaller, the amount of available space is redefined with each successive form factor. The move toward embedded controllers in smaller drives has been made possible by the high degree of integration now available with current semiconductor technology. A logical extension of this trend would be to assume an eventual one-chip implementation. Although this implementation is possible for the logic portion of the circuit, there are other circuit elements that cannot easily be integrated onto a single VLSI device (e.g., drivers and memory devices).

More apparent is the importance of surface-mount technology (SMT). SMT is rapidly becoming a necessity as both available printed circuit board real estate and the number of components per board continue to decrease. Compared with through-hole insertion techniques, surface mounting can reduce overall part size by more than 50 percent. An additional benefit of SMT is the potential for improving reliability, because SMT shortens signal lines and thereby reduces interference. Those devices that cannot be integrated into chip sets because of power and drive considerations have moved to surface mount.

Cost

One-chip and multiple-chip solutions are price competitive; determining which to employ is influenced by individual system needs as well as by price. Nevertheless, the disk drive market is a high-volume, cost-competitive one, and any possible savings in controller chip cost can only help margins and sales of the overall system.

Trends in Disk Drives

AN OPPORTUNITY AND A CHALLENGE FOR SEMICONDUCTOR MANUFACTURERS

Opportunities exist for ASIC and standard chip producers to sell products to both disk drive manufacturers and drive controller manufacturers as the market continues to shift from controller boards to intelligent drives. Although small drive manufacturers generally have expertise in the areas of mechanical design and analog electronics, they often lack expertise in complete controller design and implementation.

The challenge is for semiconductor manufacturers to develop expertise in the unique aspects of disk controller design, have a complementary relationship with drive manufacturers, and understand the diverse needs of the controller market. Chip manufacturers that demonstrate a clear understanding of market needs and can deliver well-conceived, application-specific solutions will be well positioned to take advantage of this expanding market.

DATAQUEST SUMMARY AND CONCLUSIONS—THE DATAQUEST SCENARIO FOR SMALL DISK CONTROLLERS

Based on the projected interface trends for small disk drives of all capacities, it is possible to project a possible scenario for demand for embedded controllers. Table 4 lists Dataquest's projections for aggregate percentages of disk drive shipments by interface type.

Table 4

Estimated Percentage of 3.5– and 5.25–Inch Rigid Disk Drives by Interface

Interface Type	1987	1988	1989	1990	1991	1992	1993	1994
Low-End Interface (ST-506/412)	74%	62%	49%	37%	22%	17%	13%	10%
High-End Interface (ESDI)	4%	5%	9%	10%	12%	11%	10%	10%
Intelligent Interface (SCSI)	12%	18%	22%	26%	33%	37%	39%	40%
Intelligent Interface (Proprietary and AT)	10%	15%	20%	27%	33%	35%	38%	40%

Source: Dataquest
February 1990

For cost-sensitive applications, intelligent drives with embedded controllers make good sense. They will be less costly than separate drive controllers because they eliminate several components: a printed circuit board, usually a microprocessor, cables and connectors, and drivers/receivers. In addition, this parts reduction should simplify the integrator's testing procedures and improve reliability. On the negative side, the current SCSI bus can only address eight devices, limiting the total number of peripherals to eight if intelligent drives with embedded controllers are used. Another disadvantage for some systems integrators is that the integrator does not know the uncorrected drive error rates. Standalone controllers offer integrators the flexibility to fine-tune specific disk I/O system requirements. Controller manufacturers generally can maintain a performance edge over embedded controllers and can more easily accommodate special features required for particular customer applications.

A number of drives introduced during the past few years offer embedded controllers, and Dataquest expects this trend in SCSI-type drives to continue. We believe that by 1991, two-thirds of the small drives will have on-board controllers. The remaining one-third will use board-level controllers, which will provide multidevice control capabilities. Some controllers will control up to four disk drives, whereas some will control different types of devices such as rigid/flexible drive combinations or rigid/optical drive combinations. A projection for board-level controller demand can be derived for any assumptions about the aggregate average number of drives per controller. Based on the following assumptions, Dataquest has provided projections for worldwide controller shipments in Table 5.

Table 5

Estimated Worldwide Controller Market (Thousands of Units)

	1987	1988	1989	1990	1991	1992	1993	1994
Drives Shipped	10,010	15,160	19,049	23,575	25,812	28,618	32,342	35,240
with embedded controller	2,202	5,003	8,001	12,495	17,036	20,605	24,903	28,192
board-level controller	7,808	10,157	11,048	11,080	8,776	8,013	7,439	7,048
Average Drives/Controller	1.01	1.02	1.02	1.03	1.03	1.04	1.04	1.05
Controller Boards Shipped	7,730	9,958	10,832	10,758	8,520	7,705	7,153	6,712
Total Controllers Shipped	9,933	14,961	18,832	23,252	25,556	28,310	32,056	34,904

Source: Dataquest
February 1990

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As previously mentioned, there is a strong move among manufacturers toward accepting standard intelligent interfaces that are essentially programmable to allow easy modification for enhanced disk drives. Dataquest believes that the SCSI could become the dominant intelligent interface and that most systems manufacturers have projects in development that use the SCSI. The great flexibility of the SCSI architecture accounts for its popularity. The SCSI is currently being implemented in the following three ways:

- Embedded controllers are the emerging approach for low-cost systems.
- SCSI controllers for ESDI drives are widely available.
- Synchronous SCSI chip sets that offer a very fast data rate of 4 MBps are available for integrators.

Clearly then, the embedded controller can coexist with existing drive interfaces. In our opinion, the threat that all controllers will eventually move onto the drives, leaving controller manufacturers with the less profitable job of providing simple host adapters, is overstated. Although the board-level market will be affected by embedded controllers, the board-level controller market should not begin declining until 1991 and will not disappear in the foreseeable future.

The estimated potential dollar values for semiconductor devices in the small disk drive and controller markets are shown in Table 6. They are based on Dataquest's projection for the percentage breakout by interface type.

Table 6

Estimated Semiconductor Revenue for Worldwide Disk Drive Market and Associated Controller Boards (Small Disk Drives)

	1987	1988	1989	1990	1991	1992	1993	1994
Total Drive Units (K)	10,010	15,161	19,049	23,575	25,812	28,618	32,342	35,240
ST412 Units	7,407	9,400	9,334	8,723	5,679	4,865	4,204	3,524
Drive Revenue ($M)	2,304	2,303	2,277	2,128	1,607	1,474	1,514	1,374
I/O Ratio (%)	5.6	6.7	6.3	5.7	4.5	4.0	3.3	3.0
Drive Semi. Content	129	154	144	121	73	59	50	41
Controller Units	7,262	9,216	9,151	8,552	5,567	4,770	4,122	3,455
Controller Revenue	327	373	334	281	164	127	99	74
I/O Ratio (%)	77.1	78.0	76.3	76.3	79.7	85.0	92.5	100.7
Controller Semi.	252.0	291.2	254.4	214.0	130.9	107.7	91.2	74.9
Total ST412 Semi. ($M)	381	445	398	335	204	167	142	116
ESDI Units	400.4	758.1	1,714.0	2,358.0	3,097.0	3,148.0	3,234.0	3,524.0
Drive Revenue ($M)	490.5	823	1,686	2,316	2,802	2,770	2,879	3,073
I/O Ratio (%)	2.1	2.3	2.3	2.0	2.0	1.9	1.8	1.8
Drive Semi. Content	11	19	38	47	56	53	53	57
Controller Units	392.5	743.2	1,681	2,311	3,037	3,086	3,171	3,455
Controller Revenue ($M)	31	54	109	135	159	146	135	132
I/O Ratio (%)	70.3	69.7	70.5	68.9	70.5	77.5	88.7	100.5
Controller Semi.	22	37	77	93	112	113	120	133
Total ESDI Semi. ($M)	33	56	115	140	168	166	173	190
SCSI Units	1,201	2,729	4,191	6,130	8,518	10,589	12,613	14,096
Drive Revenue ($M)	630.6	1,233	1,521	1,955	2,504	3,304	4,099	4,511
I/O Ratio (%)	12.4	13.9	16.0	15.2	14.4	12.9	11.9	12.3
Drive Semi. Content	78.44	171.8	242.7	298.2	360.5	425.7	486.9	555
AT & Proprietary Units	1,001	2,274	3,810	6,365	8,518	10,016	12,290	14,096
Drive Revenue ($M)	524.5	1,028	1,383	2,031	2,504	3,125	3,994	4,511
I/O Ratio (%)	12.5	13.9	16.0	15.2	14.4	12.9	11.9	12.3
Drive Semi. Content	65.37	143.2	220.6	309.7	360.5	407.7	474.4	555

Source: Dataquest
February 1990

Trends in Disk Drives

Besides our forecast for increased unit shipments, anticipated average capacity per drive sold will grow steadily, as shown in Table 7. This growth, when multiplied by Dataquest's estimated average selling price (ASP) per Mbyte of memory, shown in Table 8, results in the estimated total ASPs per drive type seen in Table 9.

Table 7

Estimated Average Capacity Per Drive

	1987	1988	1989	1990	1991	1992	1993	1994
Low End (ST412)	31	40	60	95	135	190	310	500
High End (ESDI)	140	170	240	360	500	700	975	1,700
Intelligent	45	80	100	170	240	380	520	800

Source: Dataquest
February 1990

Table 8

Estimated Drive and Board ASPs

	1987	1988	1989	1990	1991	1992	1993	1994
Disk Drive ASPs ($/MB)								
Low End (ST412)	$10.03	$ 6.12	$ 4.07	$ 2.57	$ 2.10	$ 1.59	$ 1.16	$ 0.78
High End (ESDI)	$ 8.75	$ 6.39	$ 4.10	$ 2.73	$ 1.81	$ 1.26	$ 0.91	$ 0.51
Intelligent	$11.67	$ 5.65	$ 3.63	$ 1.88	$ 1.22	$ 0.82	$ 0.62	$ 0.40
Board ASPs								
Low End (ST412)	$45.00	$41.00	$36.00	$33.00	$30.00	$27.00	$24.00	$22.00
High End (ESDI)	$80.00	$72.00	$65.00	$58.00	$52.00	$47.00	$43.00	$35.00

Source: Dataquest
February 1990

Table 9

Estimated Total Factory ASPs
3.5- and 5.25-Inch Disk Drives
($/MB x Average Capacity)

	1987	1988	1989	1990	1991	1992	1993	1994
Low End (ST412)	$ 311.0	$ 245.0	$244.0	$244.0	$283.0	$303.0	$360.0	$390.0
High End (ESDI)	$1,225.0	$1,086.0	$984.0	$983.0	$905.0	$880.0	$890.0	$872.0
Intelligent	$ 525.0	$ 452.0	$363.0	$319.0	$294.0	$312.0	$325.0	$320.0

Source: Dataquest
February 1990

Based on the trend toward higher performance, along with the move to consolidation of functions in a smaller, smarter drive, we believe that the greatest IC opportunities exist for high-performance, applications-specific products. Analog and discrete suppliers also should concentrate on low-power, surface-mount products to serve the needs of drive manufacturers facing severe space and power constraints.

Trends in Smart Cards

INTRODUCTION

Developments in the fast-moving smart card market continue to unfold, pushing the market forward. Although available technology continues to improve and new opportunities to apply the smart card concept continue to appear, market acceptance and penetration are still quite limited. Dataquest expects the smart card industry to expand steadily over the next few years, as the potential market seems to be just emerging.

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 will affect the semiconductor industry. Given the exceptionally broad market base, there is ample evidence to suggest that the smart card market could one day be one of the largest, if not the largest, end-user markets for semiconductors. Simply put, ICs are what make smart cards smart; they are the reason this market exists.

BACKGROUND

In 1975, the development of smart cards began in France with work on cards containing ICs. During the late 1970s and early 1980s, the French carried out a multimillion dollar rebuilding of their national technological infrastructure. Chip cards were put into use in new pay phone systems, point-of-sale banking networks, and videotext networks.

Today, largely because of government support and involvement, most of the smart card market lies in France and other European countries. There are approximately 50 million smart cards currently in use worldwide, 80 percent of which are memory only, the other 20 percent contain both memory and processing power. In the United States, however, smart cards have been surprisingly slow to emerge. Some of the reasons for this are a lack of standards and government support and no major company in the financial community pursuing the use of smart cards. In the United States, which has the largest single potential market, there has been a noticeable absence of participation among domestic IC manufacturers. Motorola and General Instruments are the only exceptions.

THE SMART CARD VERSUS THE MAGNETIC STRIP

The smart card is typically 85.7mm x 54mm x 0.76mm—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 performed by the integrated circuits within the card itself, relieving the host computer of those duties. The estimated cost of a smart card typically ranges from as low as $3.00 to as high as $50.00; while the cost of magnetic-strip cards range from $0.04 to $0.50. But ICs offer several advantages over the traditional magnetic strip, the most important being the ability to process information. 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 cost-effective card use in already established markets (for example, by reducing credit card misuse and fraud).

These advantages can quickly justify the added cost of the smart card, particularly in cases where losses can be avoided. MasterCard and VISA suffered a combined loss of more than $2 billion from fraud and credit abuse in 1986 alone. Assuming an average cost of $20 per card, a 50 percent reduction in these losses defrays the cost of 100 million cards in the first year alone!

Cards with magnetic strips do not have the power to execute programming instructions internally, and the cost of putting all card readers on-line would be prohibitive. Thus, it is difficult to couple magnetic-strip storage with computational capability. The smart card combines computing power and storage, providing a level of 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 strip 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.

Further smart card benefits include the following:

- Application adaptability
- Increased operational complexity
- Reductions in processing cost per transaction

Trends in Smart Cards

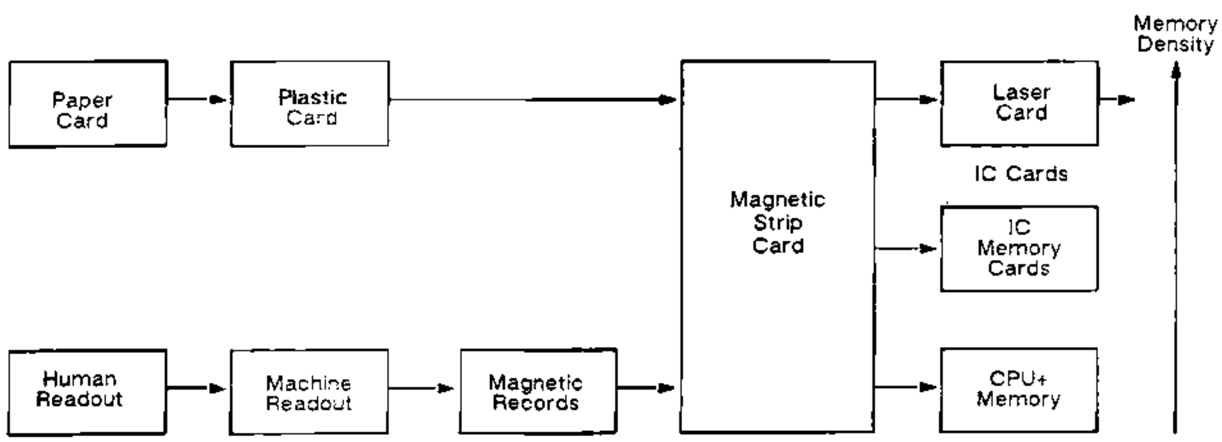
A recent report on the IC card was published as a result of a joint study conducted by the Groupement Carte Bleue, Bank of America, The Royal Bank of Canada, and VISA International. This study compared smart card technology to magnetic strip technology and assessed how smart cards would influence VISA's payment study. Several "desirable features" were mentioned that cannot be implemented with the current magnetic strip technology:

- Selective on-line authorization
- PIN use at the point of sale
- Protection from electrically couterfeited cards
- More reliable electronic media
- New off-line terminal-based services

We believe new service offerings are 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 magnetic strip card, but rather an evolutionary step in the plastic card business.

Figure 1

Card Technological Evolution



0003148-1

Source: Dataquest March 1989

Trends in Smart Cards

U.S. MARKET ACTIVITY

Within the smart card market, the current focus is on nonfinancial, niche-market applications. These markets currently are pushing the smart card industry forward. However, it will be the emergence of financial applications, such as smart bank cards, that will fuel the boom in U.S. smart card activity. MasterCard International and VISA International, with very different philosophies, strategies, and approaches to the market, will be leading the way.

MasterCard: Taking the Early Lead

Things changed in 1985 when MasterCard International formally announced its smart card 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.

MasterCard's primary reasons for evaluating the smart card technology included:

- Concern over losses
- Belief these losses will continue
- The ongoing desire to reduce systems operating expenses

Table 1 profiles MasterCard's operating expense distribution. (Dataquest estimates that the combined MasterCard and VISA losses of $2 billion in 1986 will total $4.1 billion by 1993.)

Table 1

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
March 1989

Trends in Smart Cards

The projected major cost savings provided by the smart card technology are expected to be realized 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, projected at $2 billion in 1993 for VISA and MasterCard authorization expenses alone

MasterCard's stated design criteria include the following:

- Each manufacturer, issuer, and card system must have separate security keys so that a compromise at any one point does not jeopardize the 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 the existing component costs that use magnetic strip technology.
- The cost of the processes to support IC card use must also be below or near that of existing magnetic strip technology.

MasterCard sees the next challenge as making 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 the following three primary conclusions from the pilot:

- The smart card has surpassed the magnetic strip 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.

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 strip with coded information on paper (cardboard) cards
1968/1969	Introduction of the magnetic strip on plastic cards
Aug. 1979	MasterCard members permitted to put magnetic strips 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 strips 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
Feb. 1988	Independent consulting firm hired by VISA and MasterCard rules smart bank cards are not a cost-effective solution at this time

Source: MasterCard International
Dataquest
March 1989

The VISA Approach

VISA International's strategy for smart cards is quite different from that of MasterCard. VISA believes that the technology is currently in place to improve current bank card services and to provide new services that can produce incremental income. It believes that the current system works and that operating costs and fraud losses can be reduced. Further reductions in these operating expenses would then be insufficient to justify the conversion expenses. This philosophy differs dramatically with that of MasterCard, which justifies smart card implementation on the basis of reduced losses and authorization costs, which it believes to be inherent under the current 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. Because the card acts as a terminal as well, it becomes a delivery system, eliminating the need for installation of a variety of terminals 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."

INDEPENDENT CONSULTANT SIDES WITH VISA

The current battle between MasterCard and VISA has ended—at least for the near future. The decision came on February 24, 1988, from the independent consulting firm of Booz-Allen and Hamilton. The consulting firm's study was jointly sponsored by MasterCard and VISA. The decision was made not to proceed with the use of smart bank cards in the United States at this time. The issue had been debated since 1985 when MasterCard first introduced its new smart card. This decision is seen as an admission by MasterCard that VISA was correct in their assertion that the smart bank card was not justified in the United States at the time of the study.

MasterCard had wanted to develop a joint study and pilot of a smart card in the United States; however, when MasterCard took its plan to VISA, VISA suggested the Booz-Allen study be conducted prior to discussing the project. Although MasterCard has put off the implementation of a U.S. smart bank card, it will continue to test and expand the card outside the United States where a few factors favor it. First, communication costs are higher and less reliable than in the United States. Also, personal identification numbers (PINs) are more readily accepted outside the United States.

Booz-Allen's findings and recommendations will likely delay the entrance of smart bank cards into the mainstream of the U.S. financial industry until at least 1993. Meanwhile, the struggle will continue in the international markets. Increasingly, we are seeing U.S. banks being purchased by foreign financial corporations with considerable investment and interest in smart cards. This may eventually prove to be the vehicle by which this technology finally penetrates the U.S. market.

VISA'S SUPERSMART CARD

In June 1988, VISA began tests of its "SuperSmart Card." This card is the size of the standard magnetic strip card but is far more powerful. The system features a transducer that emits a signal similar to that transmitted by a conventional credit card with a magnetic strip when passed through a card-reading terminal. The system will allow its new SuperSmart cards to be used in existing credit- and debit-card point-of-sale (POS) networks. The card will reduce the time required to verify transactions by performing internally many of the functions now performed remotely across POS networks. One enormous advantage is that when implemented, the system will let the merchants use the same reader for both magnetic and SuperSmart cards. The systems introduced by competitors such as MasterCard would require merchants to purchase new card readers costing a few hundred dollars each.

The SuperSmart card acts as a multipurpose pocket terminal. It acts as a standalone cash card, passbook, and point-of-sale card, as well as functioning in automatic teller machines (ATMs). In conjunction with Nippon Telegraph and Telephone Corp. (NTT), the cards can be used to automatically dial telephone numbers and to pay for ticket reservations made over the phone. Also, with a small keyboard and display, the card will serve as a clock, calculator, currency converter, and notepad. The card contains an 8-bit microprocessor, 16K bytes of ROM, 8K bytes of data memory, and data encryption circuitry to support high-speed encryption and authentication. The 8K-byte data memory is a CMOS static RAM that can be written to and read from with low power and low voltage. The card not only meets International Standards Organization (ISO) standards for the size of a standard credit card, but it will also meet the ISO's bending property standard, which requires the card to function with a distortion of 20mm over its length and 10mm over its width.

The tests of the SuperSmart card VISA, which began in June 1988, will evaluate the responses of customers in Japan, Europe, and the United States. The tests will be completed this spring, and if the results are positive as VISA expects them to be, the cards could be widely available by 1993. In accordance with the Booz-Allen decision, VISA, for the time being, will support the magnetic strip cards but will be prepared to introduce their SuperSmart cards in a few years.

Trends in Smart Cards

MASTERCARD AND VISA SELECT JAPANESE FOR EEPROM

VISA has selected Toshiba Corp. to supply potentially more than a million of its SuperSmart cards. Using a new "flash" EEPROM chip, Toshiba will deliver the cards to 10,000 VISA affiliate financial accounts around the world. VISA picked Toshiba's new CMOS 256K "flash" EEPROM, which surmounted previous chip size constraints to offer electrically reprogrammable chips with the same dimensions as the higher priced EPROM ultraviolet programmable devices. Its financial rival, MasterCard, reportedly has gone to Casio Inc. of Japan for similar "flash" EEPROM smart cards. The VISA order alone will bring Toshiba several hundred million dollars over the next few years. The MasterCard deal with Casio will bring Casio approximately the same amount.

The Semiconductor Industry Association (SIA) charged—and the U.S. International Trade Commission ruled two years ago—that four Japanese chip makers were guilty of dumping EPROMs in the U.S. market. After the Japanese firms signed EPROM antidumping agreements included in the U.S.-Japan Semiconductor Trade Pact, those firms reduced the intensity of their EPROM marketing efforts in the United States. Toshiba, along with other Japanese chip firms, concentrated on developing new EEPROM devices, coming out recently with its new CMOS "flash" EEPROM chip. Toshiba claims that this chip surpasses older EPROM technology at a far lower cost while offering the ease of electrical programming.

Dataquest believes that Toshiba and other Japanese EEPROM makers will attempt to capitalize on these large smart card orders to establish a substantial EEPROM market presence in the United States, preempting the efforts of such domestic manufacturers as Seeq, Xicor, National Semiconductor, and Intel. These U.S. firms must monitor the development of this technology if they are to be positioned to participate in the high-volume business that is sure to come eventually.

MAJOR APPLICATIONS BETWEEN NOW AND 1993

If smart bank cards are not in the immediate future in the United States, then what will be the major applications between now and 1993? For the first time in its history, the smart card industry as a whole is paying more attention to the niche market than to bank cards. New companies and products are entering the market with specific target applications. This is true despite the fact that less than 100,000 IC cards were issued in the United States in 1987. Most of these cards were issued by the United States Department of Agriculture (USDA) to track peanut and tobacco crop subsidies. The following are the markets that are drawing the most IC card attention:

- Information security (22)
- Medical records and insurance (20)
- Government tracking and inventory control (16)
- Physical security (12)
- Gaming and promotions (5)

The number in parentheses indicates the number of organizations (vendors and integrators) listed in the PIN IC Card Industry directory involved in the respective applications areas.

Overall, smart cards have hundreds of individual applications. Specific areas that Dataquest has seen addressed and from which we expect future smart card activity include the following:

- Software program cartridges (for diskless laptop PCs)
- Fleet fuel management
- New auto warranty and service records
- Insurance policy records, claims, and transactions
- Government programs such as welfare, medicare, and social security
- Academic records
- Computer storage
- Process control
- Hotel ID, records, and billing
- Driving licenses
- Commuter passes

STANDARDS

A concern expressed at recent Smart Cards Applications and Technology (SCAT) and ISSA conferences is the need for smart card standards. Vendor and user applications approaches vary widely. Vendors offer different solutions to problems, and as a result, users are confused and, therefore, slower to adopt smart cards. After all, to have financial giants VISA and MasterCard going in different directions would make no sense for the industry. Industry standards are one way to reduce user confusion and raise user comfort levels. And while smart card standards are more complex than magnetic strip standards, it is encouraging to note that it took seven years before standards for magnetic strip technology were adopted. Today, a decade later, over one billion magnetic strip cards are in circulation for financial transactions alone.

The International Standards Organization (ISO) is currently dealing with approving standards. The international standard for smart cards, ISO 7816, is in the final stage for approval. With the first two parts of ISO 7816 approved and published, and with part three being circulated for approval, those companies that have been holding back from introducing smart cards may find that the time is right to shift into gear. One such company, NEC (Tokyo), has decided to wait for the standard before producing any cards but is conducting engineering development work on ICs for the cards. Although it is difficult to say how long it will take to sign off part three of the standard, once it is signed off, there will be no more excuses for not making the cards and pushing them into service.

AT&T'S ENTRANCE—FUTURE IMPACTS?

This past year AT&T introduced a new smart card that is sure to have a pronounced impact on smart card developement. The AT&T card differs from traditional smart cards in that it has no electrical contact points. The absence of contact points enhances durability greatly, as these cards will resist water, dirt, grease, and static electricity far better than previous cards. These noncontact cards are estimated to cost between $15 and $35, compared to an average of as low as $5 for traditional smart cards and about 10 cents or less for a magnetic strip card. The AT&T card contains an operating system with EEPROM reusable memory that permits multiple applications to coexist within the same card. Also, the information on the card is protected by a multitiered security system to make unauthorized access extremely difficult if not impossible. AT&T is targeting its card to health care systems, equipment and personal record keeping for government and corporate systems, and security applications.

AT&T has clearly taken the lead in smart card technology. Still, with both its advanced technology and the AT&T label, the card will need plenty of help. First, with the French and many U.S. companies well established, AT&T is a relative latecomer to the field. Second, the unique AT&T technology presents standards difficulties.

Dataquest believes that the contact and noncontact technologies can coexist. And while noncontact and contact technologies are disputed, one point is clear—AT&T's entrance into the smart card industry is another step toward eventual widespread acceptance of this technology. AT&T's entrance will increase people's confidence in this technology and increase their readiness to apply it.

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. However, the technology has faced setbacks in read/write hardware, that 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. Dataquest believes that development activity to address this problem is currently underway. Because of their low cost—estimated at $3—and large storage capacity, Drexler aims for the LaserCards to beat out smart cards for applications such as personal identification, medical record keeping, and banking. However, for the time being, 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.

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 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 the Japanese industrial policy at work; competition is said to be fierce. By 1988, over 200 Japanese organizations were involved with pilot tests involving fare systems, factory controls, pay phones, game and home computer systems, and banking. The Japanese have developed a very broad array of cards and applications.

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 skill 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 of this is part of the coordination and cooperation that is being brought to bear on the Japanese focus on this market. Table 3 lists known smart card vendors; the list has tripled in the last several years, with most of the known participants coming from Japan.

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

(Continued)

Table 3 (Continued)

Smart Card Vendors

Vendor	Geographic Region (by Parent Company)
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
MicroCard 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
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
Valvo	West Germany

Source: Dataquest
March 1989

In Japan, ongoing tests revolve around applications in the following areas:

- Cashless shopping
- Banking(including home banking)
- Medicine
- Software storage
- Media services
- Credit transactions
- Security

SMART CARD ACTIVITY: THE YEAR IN REVIEW

Dataquest believes that the 1987 through 1988 time frame for smart cards can be summed up by four major points:

- Continued progress in the U.S. market
- Continued Japanese thrust
- Market legitimization
- Rapidly growing products and markets

Table 4 shows the surge of smart card activity in recent years. It is Dataquest's compilation of smart card tests, including those that have been completed and those that are currently under way. Other activities are past the test phase and have reached commercial viability, as evidenced by Datakey, Incorporated, a Burnsville, Minnesota, company 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, Datakey products contain ICs that have been used in a myriad of applications; several of these applications are as follows:

- Kidney analysis
- Process control
- Vehicle fleet fuel management
- Security

Table 4

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 MicroCard Technologies Casio MicroCard	United States	1985
Pay Phones	Telecom Ministry (PTT) Paymatek	France	1982
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

(Continued)

Table 4 (Continued)

Worldwide Smart Card Activity
(Year-to-Date)

Type	Known Participants	Country	Year Began
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
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	

(Continued)

Table 4 (Continued)

Worldwide Smart Card Activity
(Year-to-Date)

Type	Known Participants	Country	Year Began
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 MicroCard Technologies	Canada	1985
Peanut/Tobacco Buying Point Automation	U.S. Dept. of Agriculture MicroCard Technologies	United States	1985
Credit/Debit Cards	VISA International Toshiba Smart Card International General Instruments	United States	1987
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	

(Continued)

Table 4 (Continued)

Worldwide Smart Card Activity
(Year-to-Date)

Type	Known Participants	Country	Year Began
Biometrics Security	Identix MicroCard 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
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

(Continued)

Table 4 (Continued)

Worldwide Smart Card Activity
(Year-to-Date)

Type	Known Participants	Country	Year Began
Health Care	Primary Prevention Program Personal HealthCard Systems, Inc. MicroCard Technologies	United States	1986
Cashless Shopping/ Personnel ID	U.S. Marine Corps MicroCard Technologies	United States	1988
"SmartShopper Card"	MicroCard Technologies	United States	1988
Security Interface	Dial-Guard MicroCard Technologies	United States	1988
Card Terminals	Amphenol	United States	1988
Job Placement	State of Michigan Applied Systems Institute	United States	1988
Travellers	Thomas Cook Group Ltd. SmartCard International	United States	1988
Insurance/Health	Blue Cross Blue Shield	United States	1987
Insurance/Health	Connecticut Mutual Smart Card International	United States	1988
Health	Affiliated Health Care	United States	1988
Security	CoderCard DEC	United States	1988
Debit Cards	State of Pennsylvania/ Welfare Department MTech	United States	1988
Electronic Banking	Barclays Bank Bull	United States	1988

(Continued)

Table 4 (Continued)

Worldwide Smart Card Activity
(Year-to-Date)

Type	Known Participants	Country	Year Began
Multipurpose	Valvo	West Germany	1988
Medical	GEC	England	1987

Source: Dataquest
March 1989

Many European countries, including England, Switzerland, Norway, The Netherlands, Germany, and Italy have some smart card development and application activity. In France, financial and telecommunications applications have proven very successful. Major point-of-sale (POS) and pay phone programs have been successfully put into effect. The financial smart card programs were set up to reduce check clearing and communications costs associated with the heavy use of checks that is pervasive in France. The pay phone program has cut down on vandalism, fraud, and the need to collect coins from millions of phone booths. Today, more than 20 million smart cards are in use in France for making telephone calls. The following three types of cards are involved in these programs:

- A prepaid card containing 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

To date, financial and telecommunications applications have been the primary driving force in the Western European 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 up to speed, acting as a second source to meet Bull's international smart card commitments. This facility will eventually produce cards primarily for the U.S. market.

MicroCard is another company that isn't waiting for further tests or final standards. MicroCard now supplies smart cards to the marine corps base on Parris Island, South Carolina. Instead of being paid in cash, recruits are issued 64K smart cards containing the recruit's name, social security number, platoon number, card issue date, initial spending balance, and a personal identification number selected by the recruit. In the general consumer area, MicroCard has introduced the Smart Shopper Card. The card holds user checking account numbers, retail credit numbers, and MasterCard and VISA numbers, allowing the user to select the account from which he wants to pay.

FORECAST

Dataquest estimates that today there are approximately 40 million smart cards in use worldwide. Most smart card unit demand comes from Western Europe, primarily France. More than half of the 40 million smart cards in use are in France; over 98 percent of which are for financial and telecommunications use. Primary semiconductor suppliers include Thomson, Motorola, and Philips. Still, U.S. market demand is steadily increasing. The acceptance of smart cards by the U.S. government and the market entrance of a major U.S. corporation, AT&T, will increase user confidence and acceptance of smart card technology. Also, with applications for smart cards still expanding, we expect continued industry growth. Over the next few years, Dataquest expects worldwide smart card use to increase by as much as 20 percent annually.

The Booz-Allen decision for VISA and MasterCard will set back smart bank card emergence in the United States until at least 1993. Dataquest sees a more likely date of 1995 for major acceptance of the use of the smart bank cards in the United States. This acceptance will bring large scale production volume (into the hundreds of millions). Current activity leads us to believe that in the near term (2-4 years), 40 percent of all cards issued will be for government and telecommunications applications, 34 percent in financial applications, 14 percent in medical applications, 5 percent in manufacturing, and 7 percent in other varied applications.

DATAQUEST CONCLUSIONS

Overall, Dataquest is encouraged by smart card activity and sees 1989 as a year of continued market opportunities and growth. Opportunities exist for many types of IC manufacturers due to market needs in both large-scale, high-volume applications and in niche applications. Those wishing to become market participants should be positioning themselves now, as the surge in demand expected to accompany general market acceptance is likely to be staggering.

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

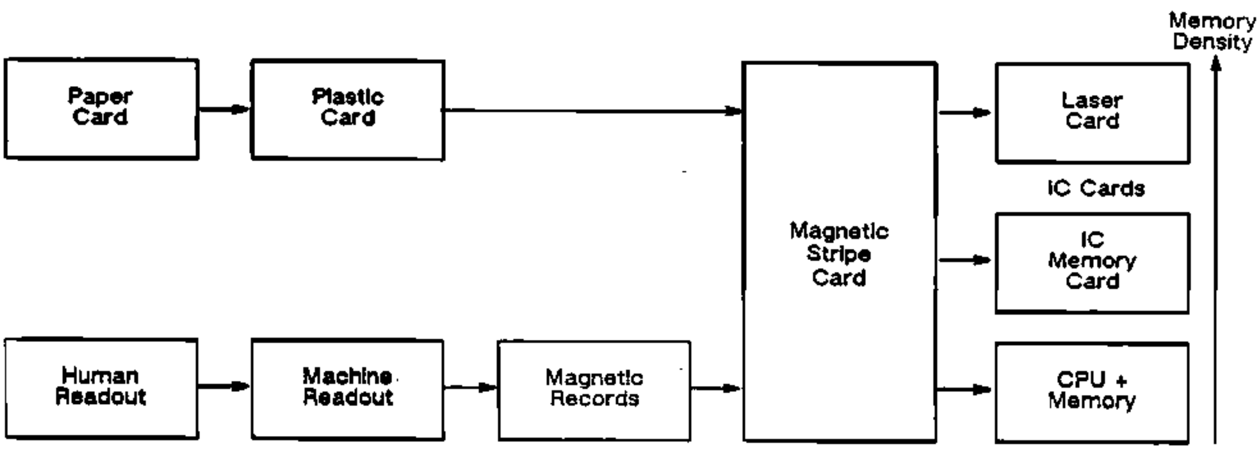
In October 1985, a report on the IC card was published as a result of a joint study conducted by the Groupement Carte Bleue, Bank of America, The Royal Bank of Canada, and VISA International. This study compared smart card technology to mag stripe technology and assessed how smart cards would influence 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

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

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.

<u>The VISA Approach</u>

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

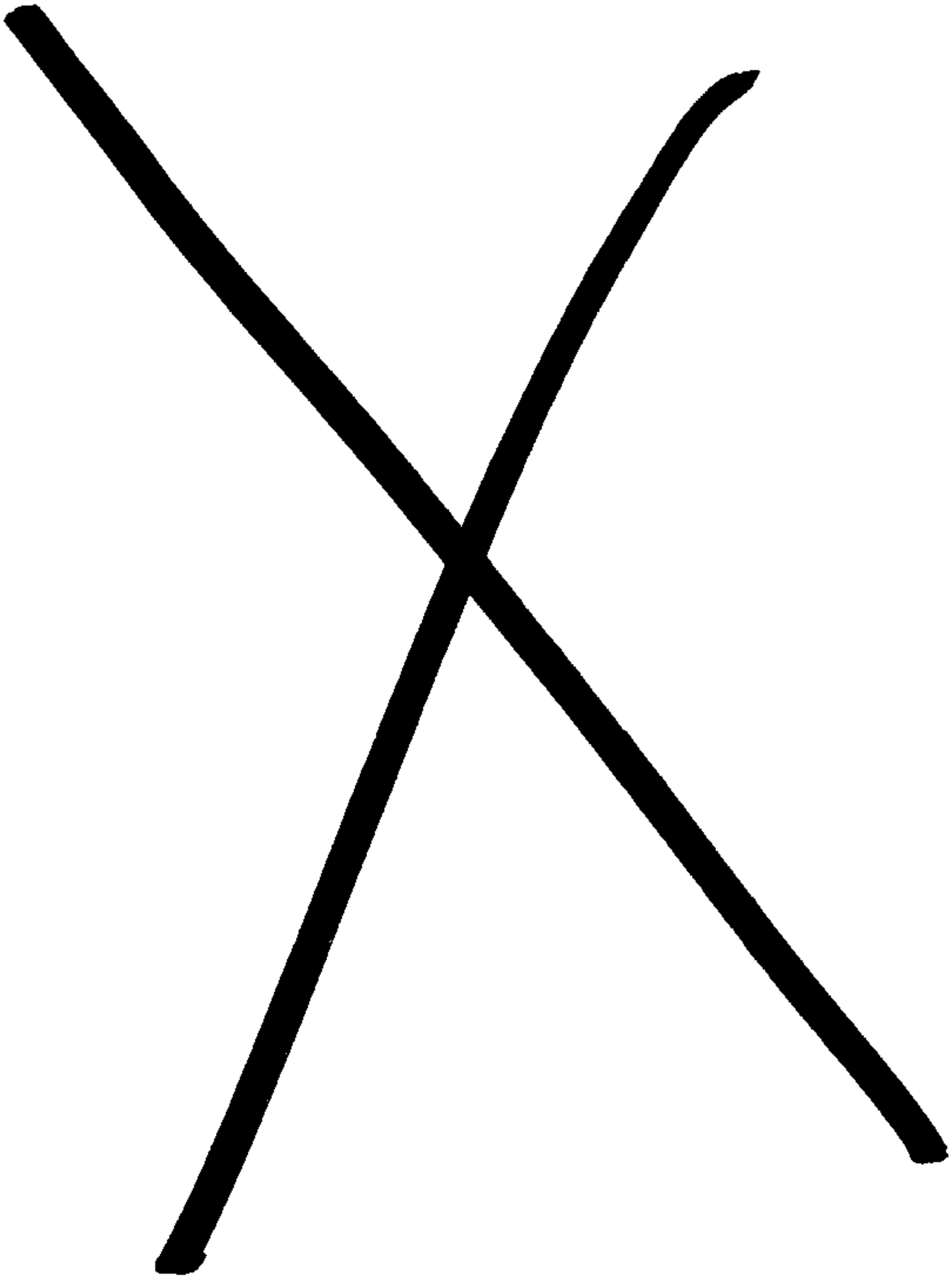
Source: Smart Card Reports
Dataquest
January 1987

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.



Communications

The following is a list of material in this section:

- Semiconductor Consumption Communications
- ➡ Trends In Telecommunications

NOTE: The arrow symbol indicates the latest document(s) correct location behind this subject tab.

Semiconductor Consumption—Communications

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Table 1

Forecast North American Electronic Equipment Production Communications (Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR (%) 1989-1990	CAGR (%) 1989-1994
Factory Revenue	27,483	29,915	32,239	34,459	36,861	39,244	42,865	7.8	7.5

Source: Dataquest (July 1990)

Table 2

Forecast North American Merchant Semiconductor Revenue Communications (Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR (%) 1989-1990	CAGR (%) 1989-1994
Total Semiconductor	2,251	2,476	2,335	2,654	3,100	3,780	4,010	(5.7)	10.1
Total IC	1,956	2,173	2,011	2,296	2,679	3,308	3,499	(7.5)	10.0
Bipolar Digital	97	66	50	45	39	34	25	(25.3)	(18.0)
Bipolar Memory	10	11	8	7	6	5	4	(22.4)	(16.7)
Bipolar Logic	86	56	41	37	33	29	20	(25.9)	(18.3)
MOS	1,436	1,631	1,459	1,645	1,960	2,470	2,544	(10.6)	9.3
MOS Memory	587	771	586	661	795	1,012	1,035	(24.0)	6.1
MOS Micro	352	335	335	366	416	536	560	0.1	10.8
MOS Logic	498	526	538	618	749	921	948	2.3	12.5
Analog	423	475	502	606	680	804	931	5.7	14.4
Discrete	233	240	259	287	345	388	418	8.1	11.8
Opto	62	63	64	71	76	84	92	2.2	7.9

Source: Dataquest (July 1990)

Table 3

**Forecast North American Merchant Semiconductor Revenue
Communications
(Input/Output Ratios, Percentage)**

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	8.2	8.3	7.2	7.7	8.4	9.6	9.4
Total IC	7.1	7.3	6.2	6.7	7.3	8.4	8.2
Bipolar Digital	0.4	0.2	0.2	0.1	0.1	0.1	0.1
Bipolar Memory	0	0	0	0	0	0	0
Bipolar Logic	0.3	0.2	0.1	0.1	0.1	0.1	0
MOS	5.2	5.5	4.5	4.8	5.3	6.3	5.9
MOS Memory	2.1	2.6	1.8	1.9	2.2	2.6	2.4
MOS Micro	1.3	1.1	1.0	1.1	1.1	1.4	1.3
MOS Logic	1.8	1.8	1.7	1.8	2.0	2.3	2.2
Analog	1.5	1.6	1.6	1.8	1.8	2.0	2.2
Discrete	0.8	0.8	0.8	0.8	0.9	1.0	1.0
Opto	0.2	0.2	0.2	0.2	0.2	0.2	0.2

Source: Dataquest (July 1990)

Table 4

**Forecast North American Electronic Equipment Production
Communications
(Annual Percentage Growth)**

	1989	1990	1991	1992	1993	1994
Factory Revenue	8.8	7.8	6.9	7.0	6.5	9.2

Source: Dataquest (July 1990)

Table 5

Forecast North American Merchant Semiconductor Revenue Communications (Annual Percentage Growth)

	1989	1990	1991	1992	1993	1994
Total Semiconductor	10.0	(5.7)	13.7	16.8	21.9	6.1
Total IC	11.1	(7.5)	14.2	16.7	23.5	5.8
Bipolar Digital	(31.3)	(25.3)	(10.1)	(12.6)	(12.8)	(27.6)
Bipolar Memory	3.9	(22.4)	(12.0)	(17.8)	(16.7)	(14.0)
Bipolar Logic	(35.5)	(25.9)	(9.7)	(11.5)	(12.1)	(30.0)
MOS	13.6	(10.6)	12.7	19.1	26.0	3.0
MOS Memory	31.4	(24.0)	12.8	20.3	27.3	2.3
MOS Micro	(4.8)	0.1	9.3	13.7	28.9	4.5
MOS Logic	5.6	2.3	14.9	21.2	23.0	2.9
Analog	12.3	5.7	20.7	12.2	18.2	15.8
Discrete	3.0	8.1	10.6	20.2	12.5	7.8
Opto	1.6	2.2	10.2	7.0	10.5	9.5

Source: Dataquest (July 1990)

Table 6

Forecast North American Merchant Semiconductor Revenue Communications (Percentage of Total Communications)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total IC	86.9	87.8	86.1	86.5	86.4	87.5	87.3
Bipolar Digital	4.3	2.7	2.1	1.7	1.3	0.9	0.6
Bipolar Memory	0.5	0.4	0.4	0.3	0.2	0.1	0.1
Bipolar Logic	3.8	2.2	1.8	1.4	1.1	0.8	0.5
MOS	63.8	65.9	62.5	62.0	63.2	65.3	63.4
MOS Memory	26.1	31.1	25.1	24.9	25.6	26.8	25.8
MOS Micro	15.6	13.5	14.3	13.8	13.4	14.2	14.0
MOS Logic	22.1	21.2	23.0	23.3	24.2	24.4	23.6
Analog	18.8	19.2	21.5	22.8	21.9	21.3	23.2
Discrete	10.4	9.7	11.1	10.8	11.1	10.3	10.4
Opto	2.8	2.5	2.8	2.7	2.5	2.2	2.3

Source: Dataquest (July 1990)

Table 7

Forecast North American Electronic Equipment Production
Customer Premise
(Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR (%) 1989-1990	CAGR (%) 1989-1994
Factory Revenue	11,046	12,517	13,866	15,102	16,116	17,137	19,530	10.8	9.3

Source: Dataquest (July 1990)

Table 8

Forecast North American Merchant Semiconductor Revenue
Customer Premise
(Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR (%) 1989-1990	CAGR (%) 1989-1994
Total Semiconductor	1,243	1,377	1,310	1,503	1,770	2,186	2,340	(4.8)	11.2
Total IC	1,103	1,231	1,153	1,326	1,560	1,947	2,079	(6.4)	11.0
Bipolar Digital	45	30	23	21	18	16	12	(25.0)	(17.5)
Bipolar Memory	3	3	2	2	2	1	1	(21.1)	(15.2)
Bipolar Logic	42	27	21	19	17	15	10	(25.3)	(17.7)
MOS	824	936	848	962	1,153	1,469	1,527	(9.4)	10.3
MOS Memory	323	428	328	373	452	579	597	(23.4)	6.9
MOS Micro	251	240	242	266	304	394	414	0.7	11.5
MOS Logic	250	268	278	324	397	495	516	3.7	14.0
Analog	234	265	283	344	388	463	540	6.5	15.3
Discrete	116	121	132	148	179	204	222	9.3	13.0
Opto	24	25	26	29	31	35	39	3.8	9.5

Source: Dataquest (July 1990)

Table 9

Forecast North American Merchant Semiconductor Revenue
Customer Premise
(Input/Output Ratios, Percentage)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	11.3	11.0	9.5	9.9	11.0	12.8	12.0
Total IC	10.0	9.8	8.3	8.8	9.7	11.4	10.6
Bipolar Digital	0.4	0.2	0.2	0.1	0.1	0.1	0.1
Bipolar Memory	0	0	0	0	0	0	0
Bipolar Logic	0.4	0.2	0.1	0.1	0.1	0.1	0.1
MOS	7.5	7.5	6.1	6.4	7.2	8.6	7.8
MOS Memory	2.9	3.4	2.4	2.5	2.8	3.4	3.1
MOS Micro	2.3	1.9	1.7	1.8	1.9	2.3	2.1
MOS Logic	2.3	2.1	2.0	2.1	2.5	2.9	2.6
Analog	2.1	2.1	2.0	2.3	2.4	2.7	2.8
Discrete	1.0	1.0	1.0	1.0	1.1	1.2	1.1
Opto	0.2	0.2	0.2	0.2	0.2	0.2	0.2

Source: Dataquest (July 1990)

Table 10

Forecast North American Electronic Equipment Production
Customer Premise
(Annual Percentage Growth)

	1989	1990	1991	1992	1993	1994
Factory Revenue	13.3	10.8	8.9	6.7	6.3	14.0

Source: Dataquest (July 1990)

Table 11

Forecast North American Merchant Semiconductor Revenue
Customer Premise
(Annual Percentage Growth)

	1989	1990	1991	1992	1993	1994
Total Semiconductor	10.8	(4.8)	14.7	17.8	23.5	7.0
Total IC	11.6	(6.4)	15.0	17.6	24.9	6.7
Bipolar Digital	(32.7)	(25.0)	(9.2)	(11.4)	(11.9)	(28.1)
Bipolar Memory	5.8	(21.1)	(10.5)	(16.4)	(15.2)	(12.5)
Bipolar Logic	(35.0)	(25.3)	(9.1)	(10.9)	(11.5)	(29.5)
MOS	13.6	(9.4)	13.5	19.8	27.4	4.0
MOS Memory	32.4	(23.4)	13.7	21.2	28.3	3.0
MOS Micro	(4.2)	0.7	9.9	14.3	29.7	5.1
MOS Logic	7.1	3.7	16.4	22.8	24.6	4.2
Analog	13.2	6.5	21.6	13.1	19.1	16.6
Discrete	4.2	9.3	11.9	21.5	13.7	8.9
Opto	3.2	3.8	11.9	8.6	12.2	11.1

Source: Dataquest (July 1990)

Table 12

Forecast North American Merchant Semiconductor Revenue
Customer Premise
(Percentage of Communications)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	55.2	55.6	56.1	56.6	57.1	57.8	58.4
Total IC	56.4	56.7	57.3	57.8	58.2	58.9	59.4
Bipolar Digital	46.4	45.5	45.7	46.1	46.7	47.2	47.0
Bipolar Memory	25.0	25.5	25.9	26.4	26.8	27.3	27.7
Bipolar Logic	49.0	49.3	49.7	50.0	50.3	50.7	51.0
MOS	57.4	57.4	58.1	58.5	58.8	59.5	60.0
MOS Memory	55.1	55.5	55.9	56.4	56.8	57.2	57.7
MOS Micro	71.3	71.7	72.2	72.6	73.1	73.5	73.9
MOS Logic	50.3	51.0	51.7	52.4	53.1	53.7	54.4
Analog	55.4	55.8	56.3	56.7	57.1	57.6	58.0
Discrete	49.8	50.3	50.9	51.4	52.0	52.6	53.1
Opto	38.5	39.1	39.7	40.3	40.9	41.5	42.1

Source: Dataquest (July 1990)

Table 13

Forecast North American Merchant Semiconductor Revenue Customer Premise (Percentage of Total Customer Premise)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total IC	88.8	89.4	88.0	88.3	88.1	89.1	88.8
Bipolar Digital	3.6	2.2	1.7	1.4	1.0	0.7	0.5
Bipolar Memory	0.2	0.2	0.2	0.1	0.1	0.1	0.1
Bipolar Logic	3.4	2.0	1.6	1.2	0.9	0.7	0.4
MOS	66.3	68.0	64.7	64.0	65.1	67.2	65.3
MOS Memory	26.0	31.1	25.0	24.8	25.5	26.5	25.5
MOS Micro	20.2	17.4	18.5	17.7	17.2	18.0	17.7
MOS Logic	20.1	19.5	21.2	21.5	22.4	22.6	22.1
Analog	18.8	19.3	21.6	22.9	21.9	21.2	23.1
Discrete	9.3	8.8	10.1	9.8	10.1	9.3	9.5
Opto	1.9	1.8	1.9	1.9	1.8	1.6	1.7

Source: Dataquest (July 1990)

Table 14

Forecast North American Electronic Equipment Production Public Telecommunications (Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR (%) 1989-1990	CAGR (%) 1989-1994
Factory Revenue	6,887	7,175	7,590	8,019	8,870	9,666	10,328	5.8	7.6

Source: Dataquest (July 1990)

Table 15

Forecast North American Merchant Semiconductor Revenue
Public Telecommunications
(Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR (%) 1989-1990	CAGR (%) 1989-1994
Total Semiconductor	437	479	447	503	581	696	728	(6.5))	8.7
Total IC	367	408	373	421	487	592	618	(8.6)	8.7
Bipolar Digital	14	10	7	7	6	5	3	(26.1)	(19.1)
Bipolar Memory	3	3	2	2	1	1	1	(23.9)	(18.3)
Bipolar Logic	12	7	5	5	4	4	3	(26.9)	(19.4)
MOS	272	308	272	304	359	445	451	(11.7)	8.0
MOS Memory	113	147	110	123	147	185	187	(24.8)	4.9
MOS Micro	43	41	40	43	48	60	62	(1.8)	8.8
MOS Logic	115	120	121	138	165	200	203	1.0	11.0
Analog	81	90	93	111	123	143	163	4.1	12.6
Discrete	50	51	55	60	71	78	83	6.6	10.2
Opto	20	20	20	22	23	25	27	0.9	6.4

Source: Dataquest (July 1990)

Table 16

Forecast North American Merchant Semiconductor Revenue
Public Telecommunications
(Input/Output Ratios, Percentage)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	6.4	6.7	5.9	6.3	6.5	7.2	7.0
Total IC	5.3	5.7	4.9	5.3	5.5	6.1	6.0
Bipolar Digital	0.2	0.1	0.1	0.1	0.1	0	0
Bipolar Memory	0	0	0	0	0	0	0
Bipolar Logic	0.2	0.1	0.1	0.1	0	0	0
MOS	3.9	4.3	3.6	3.8	4.0	4.6	4.4
MOS Memory	1.6	2.0	1.5	1.5	1.7	1.9	1.8
MOS Micro	0.6	0.6	0.5	0.5	0.5	0.6	0.6
MOS Logic	1.7	1.7	1.6	1.7	1.9	2.1	2.0
Analog	1.2	1.3	1.2	1.4	1.4	1.5	1.6
Discrete	0.7	0.7	0.7	0.7	0.8	0.8	0.8
Opto	0.3	0.3	0.3	0.3	0.3	0.3	0.3

Source: Dataquest (July 1990)

Table 17

Forecast North American Electronic Equipment Production
Public Telecommunications
(Annual Percentage Growth)

	1989	1990	1991	1992	1993	1994
Factory Revenue	4.2	5.8	5.7	10.6	9.0	6.8

Source: Dataquest (July 1990)

Table 18

Forecast North American Merchant Semiconductor Revenue
Public Telecommunications
(Annual Percentage Growth)

	1989	1990	1991	1992	1993	1994
Total Semiconductor	9.4	(6.5)	12.4	15.6	19.8	4.6
Total IC	11.0	(8.6)	13.1	15.7	21.6	4.3
Bipolar Digital	(29.5)	(26.1)	(11.7)	(14.5)	(14.6)	(27.4)
Bipolar Memory	2.0	(23.9)	(13.7)	(19.4)	(18.3)	(15.7)
Bipolar Logic	(36.4)	(26.9)	(11.0)	(12.8)	(13.4)	(31.0)
MOS	13.2	(11.7)	11.7	18.2	23.9	1.5
MOS Memory	30.0	(24.8)	11.6	19.0	25.9	1.1
MOS Micro	(6.6)	(1.8)	7.3	11.6	26.5	2.5
MOS Logic	4.3	1.0	13.4	19.6	21.3	1.5
Analog	10.6	4.1	18.8	10.5	16.4	14.0
Discrete	1.6	6.6	9.1	18.6	10.9	6.3
Opto	0.3	0.9	8.8	5.6	9.0	8.0

Source: Dataquest (July 1990)

Table 19

Forecast North American Merchant Semiconductor Revenue Public Telecommunications (Percentage of Communications)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	19.4	19.3	19.2	18.9	18.7	18.4	18.2
Total IC	18.8	18.8	18.5	18.4	18.2	17.9	17.6
Bipolar Digital	14.8	15.2	15.0	14.8	14.4	14.1	14.2
Bipolar Memory	25.0	24.5	24.1	23.6	23.2	22.7	22.3
Bipolar Logic	13.6	13.4	13.2	13.0	12.9	12.7	12.5
MOS	18.9	18.9	18.6	18.5	18.3	18.0	17.7
MOS Memory	19.3	19.1	18.9	18.7	18.4	18.2	18.0
MOS Micro	12.3	12.1	11.9	11.7	11.4	11.2	11.0
MOS Logic	23.2	22.9	22.6	22.3	22.0	21.7	21.4
Analog	19.2	18.9	18.6	18.3	18.0	17.8	17.5
Discrete	21.6	21.3	21.1	20.8	20.5	20.2	19.9
Opto	32.1	31.6	31.2	30.8	30.4	30.0	29.5

Source: Dataquest (July 1990)

Table 20

Forecast North American Merchant Semiconductor Revenue Public Telecommunications (Percentage of Total Public Telecommunications)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total IC	83.9	85.1	83.3	83.8	83.9	85.1	84.8
Bipolar Digital	3.3	2.1	1.7	1.3	1.0	0.7	0.5
Bipolar Memory	0.6	0.5	0.4	0.3	0.2	0.2	0.1
Bipolar Logic	2.7	1.6	1.2	1.0	0.7	0.5	0.3
MOS	62.1	64.3	60.7	60.4	61.8	63.9	62.0
MOS Memory	25.8	30.7	24.7	24.5	25.2	26.5	25.7
MOS Micro	9.9	8.5	8.9	8.5	8.2	8.7	8.5
MOS Logic	26.3	25.1	27.1	27.4	28.3	28.7	27.9
Analog	18.6	18.8	20.9	22.1	21.1	20.5	22.4
Discrete	11.5	10.7	12.2	11.9	12.2	11.3	11.4
Opto	4.5	4.2	4.5	4.3	4.0	3.6	3.7

Source: Dataquest (July 1990)

Table 21

Forecast North American Electronic Equipment Production
Mobile Communications Equipment
(Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR (%) 1989-1990	CAGR (%) 1989-1994
Factory Revenue	5,985	6,418	6,748	7,083	7,400	7,746	8,092	5.1	4.7

Source: Dataquest (July 1990)

Table 22

Forecast North American Merchant Semiconductor Revenue
Mobile Communications Equipment
(Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR (%) 1989-1990	CAGR (%) 1989-1994
Total Semiconductor	351	380	351	393	451	538	562	(7.5)	8.2
Total IC	296	324	293	329	377	456	476	(9.7)	8.0
Bipolar Digital	23	15	11	10	9	8	5	(25.8)	(18.5)
Bipolar Memory	2	2	2	1	1	1	1	(22.9)	(17.2)
Bipolar Logic	21	13	10	9	8	7	5	(26.3)	(18.8)
MOS	204	232	201	223	261	323	326	(13.4)	7.1
MOS Memory	94	122	91	101	120	150	151	(25.2)	4.4
MOS Micro	37	35	34	36	40	51	52	(2.1)	8.5
MOS Logic	73	76	76	85	101	122	123	0.4	10.3
Analog	69	77	81	96	107	126	144	4.7	13.3
Discrete	43	44	46	50	60	66	70	6.4	10.0
Opto	12	12	12	13	14	15	17	1.4	6.9

Source: Dataquest (July 1990)

Table 23

Forecast North American Merchant Semiconductor Revenue
Mobile Communications Equipment
(Input/Output Ratios, Percentage)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	5.9	5.9	5.2	5.6	6.1	6.9	7.0
Total IC	4.9	5.1	4.3	4.6	5.1	5.9	5.9
Bipolar Digital	0.4	0.2	0.2	0.1	0.1	0.1	0.1
Bipolar Memory	0	0	0	0	0	0	0
Bipolar Logic	0.3	0.2	0.1	0.1	0.1	0.1	0.1
MOS	3.4	3.6	3.0	3.1	3.5	4.2	4.0
MOS Memory	1.6	1.9	1.4	1.4	1.6	1.9	1.9
MOS Micro	0.6	0.5	0.5	0.5	0.5	0.7	0.6
MOS Logic	1.2	1.2	1.1	1.2	1.4	1.6	1.5
Analog	1.2	1.2	1.2	1.4	1.4	1.6	1.8
Discrete	0.7	0.7	0.7	0.7	0.8	0.9	0.9
Opto	0.2	0.2	0.2	0.2	0.2	0.2	0.2

Source: Dataquest (July 1990)

Table 24

Forecast North American Electronic Equipment Production
Mobile Communications Equipment
(Annual Percentage Growth)

	1989	1990	1991	1992	1993	1994
Factory Revenue	7.2	5.1	5.0	4.5	4.7	4.5

Source: Dataquest (July 1990)

Table 25

Forecast North American Merchant Semiconductor Revenue Mobile Communications Equipment (Annual Percentage Growth)

	1989	1990	1991	1992	1993	1994
Total Semiconductor	8.2	(7.5)	11.9	14.8	19.2	4.6
Total IC	9.5	(9.7)	12.5	14.6	20.9	4.2
Bipolar Digital	(32.5)	(25.8)	(10.5)	(12.9)	(13.2)	(28.5)
Bipolar Memory	3.3	(22.9)	(12.6)	(18.3)	(17.2)	(14.6)
Bipolar Logic	(35.8)	(26.3)	(10.2)	(12.0)	(12.6)	(30.4)
MOS	13.6	(13.4)	10.9	17.4	23.6	1.0
MOS Memory	29.3	(25.2)	11.0	18.4	25.3	0.6
MOS Micro	(6.9)	(2.1)	6.9	11.2	26.1	2.2
MOS Logic	3.6	0.4	12.6	18.8	20.6	0.9
Analog	11.3	4.7	19.6	11.2	17.1	14.7
Discrete	1.4	6.4	8.9	18.3	10.7	6.1
Opto	0.8	1.4	9.3	6.1	9.6	8.5

Source: Dataquest (July 1990)

Table 26

Forecast North American Merchant Semiconductor Revenue Mobile Communications Equipment (Percentage of Communications)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	15.6	15.3	15.0	14.8	14.6	14.2	14.0
Total IC	15.1	14.9	14.6	14.3	14.1	13.8	13.6
Bipolar Digital	23.5	23.1	22.9	22.8	22.7	22.6	22.3
Bipolar Memory	18.8	18.6	18.5	18.4	18.3	18.2	18.1
Bipolar Logic	24.1	23.9	23.8	23.7	23.5	23.4	23.3
MOS	14.2	14.2	13.8	13.5	13.3	13.1	12.8
MOS Memory	16.1	15.8	15.6	15.3	15.1	14.8	14.6
MOS Micro	10.5	10.3	10.1	9.9	9.7	9.5	9.2
MOS Logic	14.6	14.4	14.1	13.8	13.5	13.3	13.0
Analog	16.4	16.2	16.1	15.9	15.8	15.6	15.5
Discrete	18.4	18.1	17.9	17.6	17.3	17.0	16.7
Opto	19.2	19.1	18.9	18.8	18.6	18.4	18.3

Source: Dataquest (July 1990)

Table 27

Forecast North American Merchant Semiconductor Revenue
Mobile Communications Equipment
(Percentage of Total Mobile Communications)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total IC	84.4	85.4	83.3	83.8	83.6	84.8	84.6
Bipolar Digital	6.5	4.0	3.2	2.6	2.0	1.4	1.0
Bipolar Memory	0.6	0.5	0.4	0.3	0.2	0.2	0.1
Bipolar Logic	5.9	3.5	2.8	2.2	1.7	1.3	0.8
MOS	58.2	61.0	57.1	56.6	57.9	60.1	58.0
MOS Memory	26.8	32.1	25.9	25.7	26.5	27.9	26.8
MOS Micro	10.6	9.1	9.6	9.2	8.9	9.4	9.2
MOS Logic	20.8	19.9	21.6	21.7	22.5	22.7	21.9
Analog	19.7	20.3	23.0	24.5	23.8	23.4	25.6
Discrete	12.2	11.5	13.2	12.8	13.2	12.3	12.5
Opto	3.4	3.2	3.5	3.4	3.1	2.9	3.0

Source: Dataquest (July 1990)

Table 28

Forecast North American Electronic Equipment Production
Broadcast and Studio
(Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR (%) 1989-1990	CAGR (%) 1989-1994
Factory Revenue	1,965	2,145	2,315	2,465	2,615	2,765	2,915	7.9	6.3

Source: Dataquest (July 1990)

Table 29

Forecast North American Merchant Semiconductor Revenue
Broadcast and Studio
(Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR (%) 1989-1990	CAGR (%) 1989-1994
Total Semiconductor	109	118	109	121	139	166	173	(7.6)	8.0
Total IC	94	103	93	104	120	145	150	(9.5)	7.9
Bipolar Digital	8	6	4	4	3	3	2	(24.9)	(18.0)
Bipolar Memory	2	2	2	1	1	1	1	(22.9)	(17.2)
Bipolar Logic	6	4	3	2	2	2	1	(26.1)	(18.5)
MOS	68	76	67	75	88	109	110	(12.1)	7.6
MOS Memory	28	37	28	31	37	46	47	(24.8)	4.9
MOS Micro	10	9	9	10	11	14	15	(1.5)	9.1
MOS Logic	29	30	30	34	40	48	49	0.1	10.0
Analog	19	21	22	26	28	33	38	4.2	12.8
Discrete	12	12	12	14	16	18	19	6.3	9.9
Opto	3	3	3	3	4	4	4	0.1	5.6

Source: Dataquest (July 1990)

Table 30

Forecast North American Merchant Semiconductor Revenue
Broadcast and Studio
(Input/Output Ratios, Percentage)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	5.5	5.5	4.7	4.9	5.3	6.0	5.9
Total IC	4.8	4.8	4.0	4.2	4.6	5.2	5.1
Bipolar Digital	0.4	0.3	0.2	0.2	0.1	0.1	0.1
Bipolar Memory	0.1	0.1	0.1	0.1	0	0	0
Bipolar Logic	0.3	0.2	0.1	0.1	0.1	0.1	0
MOS	3.4	3.6	2.9	3.0	3.4	3.9	3.8
MOS Memory	1.4	1.7	1.2	1.3	1.4	1.7	1.6
MOS Micro	0.5	0.4	0.4	0.4	0.4	0.5	0.5
MOS Logic	1.5	1.4	1.3	1.4	1.5	1.8	1.7
Analog	1.0	1.0	0.9	1.0	1.1	1.2	1.3
Discrete	0.6	0.5	0.5	0.6	0.6	0.6	0.6
Opto	0.2	0.1	0.1	0.1	0.1	0.1	0.1

Source: Dataquest (July 1990)

Table 31

Forecast North American Electronic Equipment Production
Broadcast and Studio
(Annual Percentage Growth)

	1989	1990	1991	1992	1993	1994
Factory Revenue	9.2	7.9	6.5	6.1	5.7	5.4

Source: Dataquest (July 1990)

Table 32

Forecast North American Merchant Semiconductor Revenue
Broadcast and Studio
(Annual Percentage Growth)

	1989	1990	1991	1992	1993	1994
Total Semiconductor	8.3	(7.6)	11.6	15.0	19.3	3.9
Total IC	9.5	(9.5)	12.1	14.9	20.8	3.6
Bipolar Digital	(25.7)	(24.9)	(10.9)	(14.1)	(14.0)	(25.1)
Bipolar Memory	3.3	(22.9)	(12.6)	(18.3)	(17.2)	(14.6)
Bipolar Logic	(35.6)	(26.1)	(10.0)	(11.8)	(12.4)	(30.2)
MOS	13.0	(12.1)	11.4	17.8	23.4	1.1
MOS Memory	30.0	(24.8)	11.6	19.0	25.9	1.1
MOS Micro	(6.3)	(1.5)	7.5	11.9	26.8	2.8
MOS Logic	3.3	0.1	12.3	18.5	20.2	0.6
Analog	10.7	4.2	19.0	10.6	16.6	14.1
Discrete	1.4	6.3	8.8	18.2	10.6	6.0
Opto	(0.5)	0.1	7.9	4.8	8.1	7.1

Source: Dataquest (July 1990)

Table 33

Forecast North American Merchant Semiconductor Revenue
Broadcast and Studio
(Percentage of Communications)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	4.8	4.8	4.7	4.6	4.5	4.4	4.3
Total IC	4.8	4.7	4.6	4.5	4.5	4.4	4.3
Bipolar Digital	7.8	8.5	8.5	8.4	8.3	8.2	8.4
Bipolar Memory	18.8	18.6	18.5	18.4	18.3	18.2	18.1
Bipolar Logic	6.5	6.5	6.5	6.5	6.5	6.4	6.4
MOS	4.7	4.7	4.6	4.5	4.5	4.4	4.3
MOS Memory	4.8	4.8	4.7	4.7	4.6	4.6	4.5
MOS Micro	2.9	2.8	2.8	2.7	2.7	2.6	2.6
MOS Logic	5.9	5.7	5.6	5.5	5.4	5.3	5.1
Analog	4.4	4.4	4.3	4.2	4.2	4.1	4.1
Discrete	5.0	4.9	4.8	4.7	4.7	4.6	4.5
Opto	5.1	5.0	4.9	4.8	4.7	4.6	4.5

Source: Dataquest (July 1990)

Table 34

Forecast North American Merchant Semiconductor Revenue
Broadcast and Studio
(Percentage of Total Broadcast and Studio)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total IC	86.4	87.3	85.6	86.0	85.9	87.0	86.7
Bipolar Digital	7.0	4.8	3.9	3.1	2.3	1.7	1.2
Bipolar Memory	1.8	1.7	1.4	1.1	0.8	0.5	0.4
Bipolar Logic	5.2	3.1	2.5	2.0	1.5	1.1	0.8
MOS	62.2	64.9	61.8	61.7	63.2	65.4	63.6
MOS Memory	26.0	31.2	25.4	25.4	26.3	27.7	27.0
MOS Micro	9.3	8.0	8.6	8.2	8.0	8.5	8.4
MOS Logic	26.9	25.7	27.8	28.0	28.9	29.1	28.2
Analog	17.2	17.6	19.9	21.2	20.4	19.9	21.9
Discrete	10.7	10.0	11.5	11.2	11.5	10.7	10.9
Opto	2.9	2.7	2.9	2.8	2.6	2.3	2.4

Source: Dataquest (July 1990)

Table 35

Forecast North American Electronic Equipment Production
Other Telecom
(Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR (%) 1989-1990	CAGR (%) 1989-1994
Factory Revenue	1,600	1,660	1,720	1,790	1,860	1,930	2,000	3.6	3.8

Source: Dataquest (July 1990)

Table 36

Forecast North American Merchant Semiconductor Revenue
Other Telecom
(Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR (%) 1989-1990	CAGR (%) 1989-1994
Total Semiconductor	111	123	117	134	158	193	206	(5.0)	10.9
Total IC	96	107	99	114	135	167	177	(7.0)	10.7
Bipolar Digital	7	5	4	4	3	3	2	(24.5)	(17.4)
Bipolar Memory	1	1	1	1	1	1	1	(21.1)	(15.2)
Bipolar Logic	6	4	3	3	2	2	1	(25.8)	(18.2)
MOS	69	80	72	82	99	125	129	(9.8)	10.1
MOS Memory	28	38	29	33	40	52	54	(23.0)	7.4
MOS Micro	10	10	10	11	13	17	18	1.2	12.0
MOS Logic	30	32	33	37	45	56	57	2.3	12.5
Analog	20	22	24	29	33	40	47	7.1	15.9
Discrete	12	13	14	16	19	22	24	9.8	13.5
Opto	3	3	3	4	4	5	5	3.8	9.5

Source: Dataquest (July 1990)

Table 37

Forecast North American Merchant Semiconductor Revenue
Other Telecom
(Input/Output Ratios, Percentage)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	6.9	7.4	6.8	7.5	8.5	10.0	10.3
Total IC	6.0	6.4	5.8	6.4	7.2	8.6	8.9
Bipolar Digital	0.4	0.3	0.2	0.2	0.2	0.1	0.1
Bipolar Memory	0.1	0.1	0.1	0.1	0	0	0
Bipolar Logic	0.4	0.2	0.2	0.1	0.1	0.1	0.1
MOS	4.3	4.8	4.2	4.6	5.3	6.5	6.4
MOS Memory	1.8	2.3	1.7	1.8	2.2	2.7	2.7
MOS Micro	0.7	0.6	0.6	0.6	0.7	0.9	0.9
MOS Logic	1.9	1.9	1.9	2.1	2.4	2.9	2.9
Analog	1.2	1.3	1.4	1.6	1.8	2.1	2.3
Discrete	0.8	0.8	0.8	0.9	1.0	1.1	1.2
Opto	0.2	0.2	0.2	0.2	0.2	0.2	0.3

Source: Dataquest (July 1990)

Table 38

Forecast North American Electronic Equipment Production
Other Telecom
(Annual Percentage Growth)

	1989	1990	1991	1992	1993	1994
Factory Revenue	3.8	3.6	4.1	3.9	3.8	3.6

Source: Dataquest (July 1990)

Table 39

Forecast North American Merchant Semiconductor Revenue
Other Telecom
(Annual Percentage Growth)

	1989	1990	1991	1992	1993	1994
Total Semiconductor	10.8	(5.0)	14.6	18.0	22.4	6.8
Total IC	11.9	(7.0)	15.0	17.8	23.8	6.3
Bipolar Digital	(28.0)	(24.5)	(9.9)	(12.8)	(12.9)	(25.5)
Bipolar Memory	5.8	(21.1)	(10.5)	(16.4)	(15.2)	(12.5)
Bipolar Logic	(35.4)	(25.8)	(9.6)	(11.5)	(12.1)	(30.0)
MOS	15.5	(9.8)	14.0	20.6	26.3	3.5
MOS Memory	33.1	(23.0)	14.2	21.8	28.9	3.5
MOS Micro	(3.8)	1.2	10.4	14.9	30.3	5.6
MOS Logic	5.7	2.3	14.9	21.2	22.9	2.9
Analog	13.8	7.1	22.3	13.7	19.8	17.3
Discrete	4.6	9.8	12.4	22.0	14.2	9.4
Opto	3.2	3.8	11.9	8.6	12.2	11.1

Source: Dataquest (July 1990)

Table 40

Forecast North American Merchant Semiconductor Revenue
Other Telecom
(Percentage of Communications)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	4.9	5.0	5.0	5.0	5.1	5.1	5.1
Total IC	4.9	4.9	4.9	5.0	5.0	5.0	5.1
Bipolar Digital	7.4	7.8	7.8	7.9	7.8	7.8	8.1
Bipolar Memory	12.5	12.7	13.0	13.2	13.4	13.6	13.9
Bipolar Logic	6.8	6.8	6.8	6.8	6.8	6.8	6.8
MOS	4.8	4.9	4.9	5.0	5.0	5.0	5.1
MOS Memory	4.8	4.9	4.9	5.0	5.1	5.1	5.2
MOS Micro	3.0	3.0	3.1	3.1	3.1	3.2	3.2
MOS Logic	6.0	6.0	6.0	6.0	6.0	6.0	6.0
Analog	4.6	4.7	4.7	4.8	4.9	4.9	5.0
Discrete	5.2	5.3	5.4	5.5	5.5	5.6	5.7
Opto	5.1	5.2	5.3	5.4	5.4	5.5	5.6

Source: Dataquest (July 1990)

Table 41

Forecast North American Merchant Semiconductor Revenue
Other Telecom
(Percentage of Total Other Telecom)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total IC	86.2	87.0	85.1	85.4	85.3	86.3	85.9
Bipolar Digital	6.5	4.2	3.3	2.6	1.9	1.4	1.0
Bipolar Memory	1.2	1.1	0.9	0.7	0.5	0.4	0.3
Bipolar Logic	5.3	3.1	2.4	1.9	1.4	1.0	0.7
MOS	62.1	64.7	61.4	61.1	62.4	64.4	62.4
MOS Memory	25.5	30.6	24.8	24.7	25.5	26.9	26.0
MOS Micro	9.5	8.2	8.8	8.4	8.2	8.7	8.6
MOS Logic	27.2	25.9	27.9	27.9	28.7	28.8	27.7
Analog	17.6	18.1	20.4	21.8	21.0	20.5	22.5
Discrete	11.0	10.3	12.0	11.7	12.1	11.3	11.6
Opto	2.9	2.7	2.9	2.8	2.6	2.4	2.5

Source: Dataquest (July 1990)

Trends in Telecommunications

SUMMARY

This section highlights the consumption of telecommunication services and equipment in the United States. Services will be presented first and equipment will be presented second.

Dataquest's forecast of the US telecommunications market is presented in Table 1.

Major trends in this market include globalization of the supply base, continued deregulation to encourage competition and innovation, the growing acceptance of wireless communications products by business and the general public, and the implementation of Integrated Services Digital Network (ISDN) over the next 20 years.

Dataquest's Telecommunications Industry Service (TCIS) has shared its perspective with the Semiconductor Application Markets (SAM) service on many of the key areas in the telecommunications market.

Table 1

Telecommunications Forecast
(Millions of Dollars)

	1990	1991	1992	1993	1994	CAGR 1990-1994
Telecom	$164,944	$171,515	$179,192	$187,950	$195,790	4.4%
Services	$136,139	$140,345	$145,921	$152,111	$156,308	3.5%
Equipment	$28,805	$31,170	$33,271	$35,839	$39,482	8.2%

Source: Dataquest (August 1990)

SERVICES

Telephone companies have constructed a network of telecommunications equipment so that they can offer carrier services to subscribers. The demand for the equipment (and the components needed for the equipment) is derived ultimately from the demand for these services.

Telecommunications services include the following:

- Centrex services
- Local telephone services
- Long distance telephone services
- Public data networks

Centrex Services

Centrex is a generic name for a range of business communications services that provide PBX-like functions and features from a telephone company's central office facilities. The installed base of Centrex lines is 6.5 million units in 1990.

A Centrex line costs approximately $195 per year and the Centrex service typically consists of the following three elements:

- Local exchange access and switching (including long distance access)
- Intercom service
- Call-processing software feature packages

Dataquest's forecast of the US Centrex services market is presented in Table 2.

The top suppliers of Centrex services are the Regional Bell Operating Companies (RBOCs) (with a 95 percent share of the installed base) and the approximately 1,400 independent telephone companies (with the remaining 5 percent share).

The major trend in this market will be the conversion of Centrex lines to ISDN during the next ten years.

Local Telephone Services

Local telephone services include local plain old telephone service (POTS), access to long distance networks, connections from customer premises equipment to private lines, and tie lines between separate business locations of an organization. The installed base of local access lines is estimated at 137.9 million units in 1990.

Local telephone service today is the result of the breakup of AT&T in 1984 and FCC initiatives to deregulate portions of the industry. Pricing is under a rate structure that is controlled by state regulatory agencies applying general guidelines of the FCC.

Dataquest's forecast of the US local telephone services market is presented in Table 3.

Table 2

Centrex Services Forecast

	1990	1991	1992	1993	1994	CAGR 1990-1994
Units (K)	863	922	975	1,050	1,120	6.7%
ASP	NA	NA	NA	NA	NA	NA
Revenue (M)	$1,279	$1,325	$1,375	$1,436	$1,489	3.7%

NA = Not applicable
Source: Dataquest (August 1990)

Table 3

Local Telephone Services Forecast

	1990	1991	1992	1993	1994	CAGR 1990-1994
Units (K)	NA	NA	NA	NA	NA	NA
ASP	NA	NA	NA	NA	NA	NA
Revenue (M)	$81,400	$83,400	$85,800	$89,100	$91,900	2.9%

NA = Not applicable
Source: Dataquest (August 1990)

The top suppliers of local telephone services include the Regional Holding Companies (i.e., AT&T's former local telephone business) with an estimated 77 percent share of the installed base of local access lines. Approximately 1,400 independent telephone companies control the remaining 23 percent of the installed base.

The major trend in this market will be the conversion of the local access to ISDN over the next 20 years. In addition, other changes in both the technology and regulatory arenas should take place under the guidance of the federal courts.

Long Distance Telephone Services

Long distance telephone services are provided on an international and domestic (interstate and intrastate) basis between local telephone companies. The regulatory climate has created an open market environment in all areas of long distance telecommunications. Dataquest's forecast of the US long distance telephone services market is presented in Table 4.

The suppliers of long distance telephone services have the following market shares:

- AT&T—74 percent
- MCI—11 percent
- Sprint—7 percent
- Approximately 400 other suppliers—8 percent

Table 4

Long Distance Telephone Services Forecast

	1990	1991	1992	1993	1994	CAGR 1990-1994
Units (K)	NA	NA	NA	NA	NA	NA
ASP	NA	NA	NA	NA	NA	NA
Revenue (M)	$53,000	$55,100	$58,200	$61,000	$63,800	4.6%

NA = Not applicable
Source: Dataquest (August 1990)

The major trend in this market are the changes to the network needed to support ISDN. Most of the optical cables for the long distance network have been installed already.

Public Data Networks

Public data network services are data communications network services that are offered to the general public. Public data networks connect user terminals, computers, local and metropolitan networks, and other private networks to the network.

Dataquest's forecast of the US public data networks market is presented in Table 5.

The suppliers of public data networks have the following market shares:

- Telenet—46 percent
- Tymnet—39 percent
- Compuserve—4 percent
- Others—11 percent

By 1991, the Regional Holding Companies are expected to have a 12 to 15 percent market share in the public data network market.

The major trend in this market will be the incorporation of packet switching in the ISDN network over the next 20 years.

Table 5

Public Data Networks Forecast

	1990	1991	1992	1993	1994	CAGR 1990-1994
Units (K)	NA	NA	NA	NA	NA	NA
ASP	NA	NA	NA	NA	NA	NA
Revenue (M)	$490	$520	$546	$575	$608	5.7%

NA = Not applicable
Source: Dataquest (August 1990)

EQUIPMENT

The largest portion of the telecommunications equipment sold in the United States is located on the customer premises and consists of the following equipment types:

- Automatic call distributors
- Call accounting systems
- DSU/CSU
- Data network control systems
- Data PBX
- Facsimile equipment
- Front-end processors
- Key telephone systems
- LANs
- Modems
- PBX
- Statistical multiplexers
- T-1 multiplexers
- Telephone equipment
- Video teleconferencing systems
- Voice messaging systems

The remaining portion of the telecommunications equipment sold in the United States is in the category of public communications and consists of the following equipment types:

- Carrier equipment
- Cellular mobile radio
- Central office switching equipment
- Microwave radio equipment
- Multiplex equipment
- Private packet radio equipment
- Satellite earth station equipment

This equipment will be discussed in alphabetical order in the following subsections.

Automatic Call Distributors

Automatic call distributors (ACDs) are designed to help businesses answer large volumes of incoming calls by routing them to the operators on duty. Typical users of ACDs include catalog sales departments, insurance companies, credit card companies, utility companies, newspaper classified advertising departments, government agencies, and 911 emergency services departments.

The two major categories of ACDs include switch-based systems (e.g., systems integrated with PBXs) and systems designed to operate standalone. Smaller ACDs can handle up to 20 telephone operators and larger ACDs can handle more than 1,000.

Dataquest's forecast of the US ACD market is presented in Table 6.

The suppliers of ACDs have the following market shares:

- AT&T—20 percent
- Northern Telecom—20 percent
- IBM/ROLM—18 percent
- Others—42 percent

The major trends in this market include the emergence of central office ACD services, the incorporation of voice processing and telemarketing capabilities in ACDs, and the incorporation of ISDN.

Call Accounting Systems

Call accounting systems record the calling activity of a telephone system and generate MIS reports. Typical users of this equipment include hotels for billing guests and businesses for monitoring employee usage.

Passive call accounting systems process call accounting reports; active systems offer additional features such as least-cost routing and toll-call restrictions. Many call accounting systems are an integral part of a PBX.

Dataquest's forecast of the US call accounting system market is presented in Table 7.

Table 6

Automatic Call Distributors Forecast

	1990	1991	1992	1993	1994	CAGR 1990-1994
Units (K)	259.6	297.6	339.5	384.4	440.9	14.7%
ASP	$2,188	$2,172	$2,158	$2,150	$2,137	(0.6%)
Revenue (M)	$568.0	$646.2	$732.7	$826.4	$942.2	14.0%

Source: Dataquest (August 1990)

Table 7

Call Accounting Systems Forecast

	1990	1991	1992	1993	1994	CAGR 1990-1994
Units (K)	168.6	186.1	217.8	243.9	273.9	12.3%
ASP	$1,796	$1,717	$1,652	$1,574	$1,503	(4.5%)
Revenue (M)	$269.0	$285.0	$296.0	$309.0	$412.0	11.3%

Source: Dataquest (August 1990)

The suppliers of call accounting systems have the following market shares:

- Com Dev—5.9 percent
- Moscom—5.8 percent
- Summa Four—3.5 percent
- Telecom Research—3.3 percent
- Infortext Systems—2.8 percent
- Others—78.7 percent

The major trends in this market include the integration of call accounting systems in larger telemanagement systems and the shift to a microcomputer installed base.

Carrier Equipment

Carrier equipment provides transmission of a number of voice-frequency channels over a common cable. Purchasers of this equipment include both telephone companies and large users of telephone services seeking to bypass telephone company facilities.

The carrier system market consists of two segments: trunk carrier systems (transmission links between telephone company central offices) and subscriber carrier systems (transmission links between a subscriber premise and a central office). Lower-capacity transmission links can carry 24 voice-frequency channels (i.e., T-1); higher-capacity links can carry 96 channels (i.e., T-2); and future subscriber carrier capability is expected to reach 672 customer per fiber (i.e., T-3).

Dataquest's forecast of the US carrier equipment market is presented in Table 8.

The top suppliers of carrier equipment include the following:

- Alcatel
- AT&T
- Northern Telecom
- Rockwell

Table 8

Carrier Equipment Forecast

	1990	1991	1992	1993	1994	CAGR 1990-1994
Units (K)	NA	NA	NA	NA	NA	NA
ASP	NA	NA	NA	NA	NA	NA
Revenue (M)	$2,010	$2,200	$2,415	$2,664	$2,912	9.3%

NA = Not available
Source: Dataquest (August 1990)

The major trends in this market include the continued shift from analog to digital transmission facilities, the increased penetration of fiber optics, and Synchronous Optical Network (SONET), the standardization of offerings by 1995.

Cellular Mobile Radio

Cellular mobile radio allows a greater number of users to be accommodated on the radio-telephone frequency allocations. Typical users of this equipment include both consumers and business people who want to either make or receive telephone calls while in transit.

The three basic types of telephone instruments on the market include mobile units (3.0-watt output power) for use in automobiles, portable units (0.5-watt output power) for hand-held operation, and transportable units (3.0-watt output power, but bulkier than the hand-held units due to the battery pack required) for hand-held operation.

Dataquest's forecast of the US cellular mobile radio market is presented in Table 9.

The top suppliers of cellular mobile radios include the following:

- Matsushita
- Motorola
- NEC
- Novatel
- Oki

The major trends in this market include declining prices (e.g., rising demand) and the expected introduction of digital cellular radio in the early 1990s. Personal communications devices (e.g., "pocket telephones") are expected to be commonplace by the late 1990s, and these will be implemented using cellular technology.

Central Office Switching Equipment

Central office switching equipment interconnects local telephone lines and also connects these local telephone lines to long distance trunks. Purchasers of this equipment include telphone companies. Although central office switching equipment can be either analog or digital, all new installations have been digital only. Dataquest's forecast of the US central office switching equipment market is presented in Table 10.

Table 9

Cellular Mobile Radio Forecast

	1990	1991	1992	1993	1994	CAGR 1990-1994
Units (K)	1,870	2,110	2,950	3,850	4,800	26.6%
ASP	$630	$580	$530	$500	$520	(4.7%)
Revenue (M)	$1,178	$1,224	$1,564	1,925	$2,496	20.6%

Source: Dataquest (August 1990)

Table 10

Central Office Switching Equipment Forecast

	1990	1991	1992	1993	1994	CAGR 1990-1994
Units (K)	12,500	12,500	13,000	13,500	13,600	1.0%
ASP	$185	$190	$192	$195	$195	0
Revenue (M)	$2,313.0	$2,375.0	$2,496.0	$2,633.0	$2,652.0	3.5%

Source: Dataquest (August 1990)

The suppliers of central office switching equipment have the following market shares:

- AT&T—47 percent
- Northern Telecom—39 percent
- GTE—9 percent
- Others—5 percent

The major trend in this market will be the conversion to ISDN over the next 20 years.

DSU/CSU

Data service units (DSUs) and channel service units (CSUs) allow computers to communicate with each other over the digital facilities of the public telephone network. These equipments convert the user's datastream from the unipolar format used in digital computers to the bipolar format used in digital networks. Major industries using this service include banking, finance, manufacturing, government, wholesale and retail, transportation, utilities, and education.

The two major categories of DSU products are low-speed (2,400 bps, 4,800 bps, and 9,600 bps) and high-speed (19.2 Kbps and 56.0 Kbps). CSU products connect to a 1.544-Mbps DS-1 digital facility.

Dataquest's forecast of the US DSU/CSU market is presented in Table 11.

Table 11

DSU/CSU Forecast

	1990	1991	1992	1993	1994	CAGR 1990-1994
Units (K)	205.1	251.1	292.1	322.0	380.9	16.7%
ASP	$788	$751	$709	$699	$684	(3.5%)
Revenue (M)	$161.6	$188.7	$207.2	$225.2	$260.4	12.7%

Source: Dataquest (August 1990)

The suppliers of DSUs/CSUs have the following market shares:

- AT&T—23 percent
- Verilink—17 percent
- TPP—12 percent
- GDC—10 percent
- Datatel—10 percent
- Others—28 percent

The major trend in this market is the migration to board-level and chip-level products.

Data Network Control Systems

Data network control systems cover an assortment of equipment to ensure network availability, test network operations, and report on network performance.

The data network control system market is very fragmented because many of today's systems are specific to the type of equipment they control. General segments include protocol analyzers, network switches, matrix switches, modem network controllers, network management systems, and products that analyze network response time.

Dataquest's forecast of the data network control systems market is presented in Table 12.

The top suppliers of data network control systems include the following:

- Avant-Garde
- Bytex
- Codex
- Dynatech
- Hewlett-Packard

The major trends in this market include the incorporation of user friendliness (e.g., touch screens, icon displays) and the ability to support a multivendor environment.

Table 12

Data Network Control Systems Forecast

	1990	1991	1992	1993	1994	CAGR 1990-1994
Units (K)	NA	NA	NA	NA	NA	NA
ASP	NA	NA	NA	NA	NA	NA
Revenue (M)	$1,004.5	$1,252.2	$1,595.0	$1,976.0	$2,458.1	24.4%

NA = Not available
Source: Dataquest (August 1990)

Data PBX

Data PBXs are digital private branch exchange systems designed specifically for data communications networks. Typical users of this equipment include universities, financial institutions, government computer centers, manufacturing operations, and time-sharing services.

Data PBX units are designed so that line capacity can be expanded easily to fit growing data communication needs of the user organization. A data PBX does not provide any voice-switching capability.

Dataquest's forecast of the data PBX market is presented in Table 13.

The suppliers of data PBX equipment have the following market shares:

- Gandalf—31 percent
- Micom—31 percent
- Equinox—13 percent
- Sequel—10 percent
- Others—15 percent

The major trend in this market is the capability to handle a larger variety of data communications and protocols.

Facsimile Equipment

Facsimile equipment consists of machines capable of transmitting and receiving document images over the telephone lines.

Facsimile equipment is classified into the following four groups:

- Group 1—Transmits at four to six minutes per page (obsolete; all machines taken out of service)
- Group 2—Transmits at two to three minutes per page (obsolete; all machines being taken out of service)
- Group 3—Transmits at one minute per page (all fax machine sales currently fall into this category)

Table 13

Data PBX Forecast

	1990	1991	1992	1993	1994	CAGR 1990-1994
Units	850	800	750	685	640	(6.6%)
ASP	$90,941	$92,975	$94,400	$97,518	$99,844	2.4%
Revenue (M)	$77.3	$74.2	$70.8	$66.8	$63.9	(4.3%)

Source: Dataquest (August 1990)

- Group 4—Transmits at five seconds per page (ISDN interface; significant sales not expected before 1991)

Dataquest's forecast of the US facsimile equipment market is presented in Table 14.

The suppliers of facsimile equipment have the following market shares:

- Sharp—19 percent
- Ricoh—16 percent
- Canon—11 percent
- Pitney Bowes—7 percent
- Fujitsu—6 percent
- Others—41 percent

The major trends in this market include the introduction of ISDN-based Group 4 machines in the early 1990s and the location of manufacturing facilities in all regions of the world (e.g., 98 percent of the facsimile machines actually are built by Japanese companies and some of these are privately labeled for non-Japanese suppliers).

Front-End Processors

Front-end processors are themselves computers that link mainframe computers with data communications networks.

Front-end processors are commonly attached to mainframe and large business-unit computers manufactured by Amdahl, Control Data, Honeywell, IBM, National Advanced Systems, NCR, Tandem, and Unisys.

Dataquest's forecast of the US front-end processor market is presented in Table 15.

The suppliers of front-end processors have the following market shares:

- IBM—48 percent
- NCR Comten—7 percent
- Others—45 percent

The major trends in this market include the addition of enhanced network management capabilities and the ability to connect to a broader variety of data communications networks. Packet switching and ISDN are expected to have a negative impact on this market.

Table 14

Facsimile Equipment Forecast

	1990	1991	1992	1993	1994	CAGR 1990-1994
Units (K)	1,740.3	2,091.7	2,281.5	2,908.9	3,566.3	22.6%
ASP	$1,627	$1,357	$1,146	$974	$822	(15.6%)
Revenue (M)	$2,831.5	$2,838.4	$2,614.6	$2,833.3	$2,931.5	3.4%

Source: Dataquest (August 1990)

Table 15

Front-End Processors Forecast

	1990	1991	1992	1993	1994	CAGR 1990-1994
Units	5,900	6,300	6,800	7,200	7,740	7.5%
ASP (K)	$90	$87	$85	$83	$81	(2.8%)
Revenue (M)	$531	$548	$578	$598	$627	4.4%

Source: Dataquest (August 1990)

Key Telephone Systems

Key telephone systems are multiline business telephones that provide a shared access to outside central office lines by way of direct lines on the station sets. Typical users are small and medium-size businesses with less than 50 employees. (In contrast, PBX systems are characterized by pooled access to a group of central office lines, typically by dialing "9" from a station set. Centrex is a business communications service that provides PBX-like functions and features from telephone company central office switches. The total business-switching revenue is split among PBX at 45 percent, key telephone systems at 35 percent, and Centrex service at 20 percent.)

Standalone key telephone systems account for approximately 70 percent of the shipments and installed base. Adjunct key telephone systems are connected to either a PBX system or Centrex service rather than directly to the network.

Dataquest's forecast of the US key telephone systems market is presented in Table 16.

The suppliers of key telephone systems have the following market shares:

- AT&T—30 percent
- TIE/Communications—18 percent
- Executone—11 percent
- Toshiba—6 percent
- Inter-Tel—5 percent
- Others—30 percent

Table 16

Key Telephone Systems Forecast

	1990	1991	1992	1993	1994	CAGR 1990-1994
Units (K)	4,473.7	4,555.8	4,648.7	4,751.3	4,841.6	1.9%
ASP	$454	$431	$410	$389	$370	(5.0%)
Revenue (M)	$2,031.1	$1,963.5	$1,906.0	$1,848.3	$1,789.2	(3.2%)

Source: Dataquest (August 1990)

The major trend in this market is the replacement of electromechanical systems with electronic systems, spurred by the implementation of ISDN.

Local Area Networks (LANs)

A local area network (LAN) is a communications product able to connect three or more communications devices in a peer-to-peer relationship for the purpose of sharing information and resources. (This definition excludes point-to-point, PBX, and data PBX connections.) LANs are used principally for information sharing, database access, mainframe access, data exchange, and peripheral sharing.

The key characteristics that distinguish different types of LANs include signaling technique, access protocols, transmission media, and network topology. The Institute of Electrical and Electronic Engineers (IEEE) has formed eight IEEE-802 subcommittees to prepare LAN standards.

Dataquest's forecast of the US LAN market is presented in Table 17.

The suppliers of LANs have the following market shares:

- Digital Equipment—27 percent
- IBM—13 percent
- 3Com—10 percent
- Novell—9 percent
- Ungermann-Bass—6 percent
- Others—35 percent

The major trends in this market include connectivity, which will permit multiple interconnections between computing devices; innovation, which will develop lower cost implementations on metallic cables or faster networks on optical cables; and consolidation, which will reduce the number of suppliers through mergers and acquisitions.

Table 17

Local Area Network Forecast

	1990	1991	1992	1993	1994	CAGR 1990-1994
Units (K)	7,089	9,031	11,138	12,715	15,792	24.2%
ASP	$777	$749	$700	$687	$666	(3.1%)
Revenue (M)	$5,510.0	$6,760.0	$7,800.0	$8,730.0	$10,517.0	20.4%

Source: Dataquest (August 1990)

Microwave Radio Equipment

Microwave radio equipment is used to transmit communications signals point to point. Purchasers of this equipment include public common carriers and private industrial companies.

Complete microwave systems include the microwave antenna (dishes), transmitter/receiver systems, power supplies, related equipment (waveguides and channel banks), and optional repeaters. (Dataquest's database, however, deals only with the electrical portion of the system.) Microwave radio equipment is designed for either analog or digital signals.

Dataquest's forecast of the US microwave radio equipment market is presented in Table 18.

The suppliers of microwave radio equipment have the following market shares:

- AT&T—21 percent
- Rockwell/Collins—17 percent
- Harris/Farinon—14 percent
- NEC—10 percent
- Northern Telecom—9 percent
- Others—29 percent

The major trends in this market include the phasing out of analog equipment (which is being replaced by digital equipment), the increasing use of microwave equipment by private industry to bypass the local telephone utility, and the increasing use of fiber optics.

Modems

Modems allow digital data to be carried over voice-grade communications channels. Typical users of modems are people who must send or receive digital data to or from computers and other data processing equipment and who also select the telephone as the transmission channel of choice.

There are many types of modems based on data format transmitted and transmission speed. All modems support the Level 1 connectivity functions of the International Standards Organization (ISO) model for data communications architecture according to the Bell-equivalent and Consultative Committee on International Telephony and Telegraphy (CCITT) standards.

Table 18

Microwave Radio Equipment Forecast

	1990	1991	1992	1993	1994	CAGR 1990-1994
Units (K)	NA	NA	NA	NA	NA	NA
ASP	NA	NA	NA	NA	NA	NA
Revenue (M)	$547.0	$599.0	$667.0	$736.0	$807.0	9.6%

NA = Not available
Source: Dataquest (August 1990)

Dataquest's forecast of the US modem market is presented in Table 19.

The suppliers of modems have the following market shares:

- Codex (Motorola)—17 percent
- AT&T—12 percent
- Racal/Milgo—10 percent
- Hayes—7 percent
- UDS (Motorola)—7 percent
- Paradyne—6 percent
- Others—41 percent

The major trends in this market include the trend toward higher speeds, price reductions resulting from integrated VLSI modem chips, and the gradual replacement of modems by ISDN over the next two decades.

Multiplex Equipment

Multiplex equipment combines a number of voice-frequency message channels (i.e., telephone calls) into a single signal for transmission over a common medium (e.g., satellite, microwave radio, cable carrier, or fiber optics). Purchasers of this equipment include public common carriers and private industrial companies.

The multiplex equipment segments include analog (FDM), digital (TDM and PCM), and transmultiplexers, which allow analog and digital transmission links to be connected.

Dataquest's forecast of the US multiplex equipment market is presented in Table 20.

The top suppliers of multiplex equipment include the following:

- AT&T
- DSC
- Northern Telecom
- Rockwell
- Tellabs

Table 19

Modem Forecast

	1990	1991	1992	1993	1994	CAGR 1990-1994
Units (K)	3,068.0	3,388.5	3,640.5	3,832.0	4,153.9	8.4%
ASP	$340	$265	$201	$145	$110	(24.6%)
Revenue (M)	$1,044.1	$898.3	$731.5	$556.3	$456.2	(18.0%)

Source: Dataquest (August 1990)

Table 20

Multiplex Equipment Forecast

	1990	1991	1992	1993	1994	CAGR 1990-1994
Units (K)	NA	NA	NA	NA	NA	NA
ASP	NA	NA	NA	NA	NA	NA
Revenue (M)	$1,577.0	$1,653.0	$1,757.0	$1,998.0	$2,144.0	7.3%

NA = Not available
Source: Dataquest (August 1990)

The major trends in this market include the increasing popularity of digital systems (driven by the continued high use of fiber-optic transmission and the advent of ISDN) and the use of VLSI technology to reduce size and power requirements of the equipment.

PBX

A private branch exchange (PBX) is a customer-premise telephone system that connects the customer's office telephones to each other and to the outside public telephone network. Typical users of PBX equipment include organizations that want their own telephone system (e.g., industrial companies, government agencies, and large universities).

The PBX market is segmented by line size. Very small PBX systems have 1 to 40 lines; at the very large end of the spectrum are PBX systems with more than 1,000 lines. Various types of PBX end-user terminals range from standard single-line telephones to integrated voice/data workstations. Besides basic telephone service, PBXs now offer networking features, management control features, and advanced features such as automatic call distribution and voice messaging. PBX systems are modular in design so they can be expanded with additional channel cards.

Dataquest's forecast of the US PBX market is presented in Table 21.

Table 21

PBX Forecast

	1990	1991	1992	1993	1994	CAGR 1990-1994
Units (K)	5,112	5,343	5,604	5,884	6,049	2.8%
ASP	$689	$680	$673	$660	$651	(1.4%)
Revenue (M)	$3,522.0	$3,633.0	$3,771.0	$3,883.0	$3,938.0	2.8%

Source: Dataquest (August 1990)

The suppliers of PBXs have the following market shares:

- AT&T—26 percent
- Northern Telecom—16 percent
- Siemens/ROLM—15 percent
- Mitel—10 percent
- NEC—8 percent
- Others—25 percent

The major trends in this market include the continuing erosion in price per line, the addition of data and office automation features, new architectures that handle information in packet form, and the technical and feature changes caused by the implementation of ISDN.

Private Packet Data Networks

A private packet data network is a data communications system for geographically dispersed terminals that provides a lower-cost alternative to leased-lines or public packet network services when traffic is high. Typical users of private packet data networks include transaction processing (e.g., credit verifications), database inquiry, and any other datacomm application that transmits data in bursts.

Private packet data networks are the backbone of many large US corporations through the world. Equipment for a network can be supplied by any vendor whose product is certified to the X.25 international data transport standard. X.25 gateways allow private packet networks to internetwork with popular LANs. Products in this market include packet switches and packet assembler-disassemblers (PADs).

Dataquest's forecast of the US private packet data network market is presented in Table 22.

Table 22

Private Packet Data Networks Forecast

	1990	1991	1992	1993	1994	CAGR 1990-1994
Units (K)	NA	NA	NA	NA	NA	NA
ASP	NA	NA	NA	NA	NA	NA
Revenue (M)	$385.5	$425.0	$465.0	$505.0	$558.0	10.4%

NA = Not available
Source: Dataquest (August 1990)

The suppliers of private packet data networks have the following market shares:

- Northern Telecom—17 percent
- Telenet—12 percent
- BBN Communications—12 percent
- Tymnet—7 percent
- Telematics—6 percent
- Others—46 percent

The major trends in this market include the increasing use of gateways to link X.25 networks with other networks already in place, the use of Microcom Network Protocol (MNP) as an error-correction protocol, the use of X.PC for personal computer access to Tymnet networks, the appearance of board-level products for incorporation into multiplexers and personal computers, and the development of hybrid packet/ISDN switching systems.

Satellite Earth Station Equipment

Satellites are used for TV program distribution, international voice communications, low-speed data communications, video teleconferencing, and data broadcast. Only the low-speed data communications application is growing; all other segments have either reached saturation or are at a standstill.

Low-speed data communications via satellite are private full-solution communication networks. Typical applications for these networks include insurance policy and claims support, retail chain store sales and inventory, hotel and car rental reservations, on-line data processing services, automatic teller machines, oil field and pipeline data collection and monitoring, video training and announcements, and securities transactions.

Dataquest's forecast of the US satellite earth station equipment market is presented in Table 23.

Table 23

Satellite Earth Station Equipment Forecast

	1990	1991	1992	1993	1994	CAGR 1990-1994
Units (K)	NA	NA	NA	NA	NA	NA
ASP	NA	NA	NA	NA	NA	NA
Revenue (M)	$432.6	$542.2	$663.0	$804.5	$1,018.5	26.6%

NA = Not available
Source: Dataquest (August 1990)

The suppliers of satellite earth station equipment have the following market shares:

- Hughes Network Systems—51 percent
- Contel/ASC—16 percent
- GTE Spacenet—14 percent
- AT&T/Tridom—10 percent
- Scientific Atlanta—6 percent
- Others—3 percent

The major trends in this market include the shift from hardware to service provisions, competition from fiber optics, and plenty of satellite capacity. ISDN is expected to cause only a minor impact.

Statistical Multiplexers

Statistical multiplexers save data communications network costs by reducing the number of communications lines and related modems needed for local and remote communications. Users of statistical multiplexers include Fortune 5000 companies; colleges and universities; financial institutions; telephone and computer companies; multinational corporations; government; medical; and service bureaus.

Statistical multiplexers contain microprocessors and buffers to allocate dynamically the user's data into a high-speed composite data transmission link. Three market segments exist based on connections, features, and price: low end (2 to 6 lines), midrange (2 to 32 lines), and high end (48 plus lines).

Dataquest's forecast of the US statistical multiplexer market is presented in Table 24.

The suppliers of statistical multiplexers have the following market shares:

- Codex—16 percent
- Micom—15 percent
- Infotron—10 percent
- Timeplex—8 percent
- Others—51 percent

Table 24

Statistical Multiplexers Forecast

	1990	1991	1992	1993	1994	CAGR 1990-1994
Units (K)	65.6	67.2	68.1	67.0	68.1	1.6%
ASP	$2,577	$2,239	$1,918	$1,646	$1,425	(13.4%)
Revenue (M)	$169.1	$150.5	$130.6	$110.3	$97.0	(13.0%)

Source: Dataquest (August 1990)

The major trend in this market is the increased internetworking among vendor product offerings as user networks grow.

T-1 Multiplexers

T-1 is a point-to-point digital facility that carries 24 voice-frequency channels over a single communications line. Typical T-1 multiplex users include Fortune 2500 companies, colleges, universities, medical facilities, financial institutions, transportation companies, local telephone companies, multinational companies with off-shore locations, government agencies, service-focused companies, and any company that wants to communicate with intracompany premise locations (e.g., office parks and technology centers).

The North American T-1 standard allows the multiplexing of 24 64-Kbps channels over a single line at a combined rate of 1.544 Mbits per second. T-1 service can be provided by span lines, satellite, digital microwave, coaxial cable, and fiber optics.

Dataquest's forecast of the US T-1 multiplexer market is presented in Table 25.

The suppliers of T-1 multiplexers have the following market shares:

- Timeplex—25 percent
- Net—24 percent
- DCA/Cohesive—8 percent
- General DataComm—6 percent
- Others—37 percent

The major trends in this market include encryption, circuit and packet switching integration, LAN bridge applications, and the inclusion of enhanced network management and control functions to monitor high-speed link performance and quality.

Telephone Equipment

Telephone equipment is the single-line telephone sets used in the home or office and purchased from a retail outlet.

Dataquest's forecast of the US telephone equipment market is presented in Table 26.

Table 25

T-1 Multiplexers Forecast

	1990	1991	1992	1993	1994	CAGR 1990-1994
Units (K)	12.5	14.9	17.5	20.4	24.3	19.3%
ASP	$44,280	$42,081	$39,657	$36,765	$34,724	(5.9%)
Revenue (M)	$553.5	$627.0	$694.0	$750.0	$843.8	12.5%

Source: Dataquest (August 1990)

Table 26

Telephone Equipment Forecast

	1990	1991	1992	1993	1994	CAGR 1990-1994
Units (K)	27,600.0	29,400.0	31,400.0	33,500.0	35,678.0	6.5%
ASP	$62	$60	$59	$57	$56	(2.5%)
Revenue (M)	$1,703.0	$1,771.0	$1,848.0	$1,913.0	$1,988.0	3.9%

Source: Dataquest (August 1990)

The top suppliers of telephone equipment include the following:

- AT&T
- Panasonic
- Tandy

The major trends in this market include the continuation of consumer preference to purchase rather than lease telephone sets, the continuing reduction in telephone set prices, and the demand for electronic sets surpassing the demand for electromechanical sets to allow the implementation of more advanced features.

Video Teleconferencing Systems

Video teleconferencing systems allow the transmission of video images over communications channels. The decreasing cost of equipment and transmission facilities are increasing the viability of video conferencing.

Transmission speeds can be broadcast quality (45 Mbps), near full motion (768 Kbps to T-carrier 1.544 Mbps), and limited motion (56 Kbps). The compression standards used in digital-transmission systems are proprietary to the equipment manufacturer.

Dataquest's forecast of the video teleconferencing systems market is presented in Table 27.

Table 27

Video Teleconferencing Systems Forecast

	1990	1991	1992	1993	1994	CAGR 1990-1994
Units (K)	10.9	12.5	15.0	15.0	17.1	13.9%
ASP	$7,148	$8,730	$9,442	$9,384	$10,491	11.8%
Revenue (M)	$77.7	$109.1	$130.9	$141.0	$179.4	23.3%

Source: Dataquest (August 1990)

The top suppliers of video teleconferencing systems include the following:

- Compression Labs
- Mitsubishi
- PictureTel
- Stromberg-Carlson

Voice Messaging Systems

Voice messaging systems offer telephone users the conveniences of interactive messaging, telephone answering, caller routing, information providing, and transaction processing. Voice messaging systems can be used in any business environment that operates telecommunications equipment such as PBXs, key systems, Centrex, and message centers.

Voice messaging systems can be classified into three distinct product types: standalone systems, PBX-integrated systems, and board-level products. Basic technologies for voice processing products include voice store-and-forward (the ability to store digital speech and retrieve or manipulate it at a later time), voice recognition (the ability of a computer to recognize and accept voice as an input), and speech synthesis (computer-generated speech that uses fixed or variable vocabulary).

Dataquest's forecast of the US voice messaging systems market is presented in Table 28.

The suppliers of voice messaging systems have the following market shares:

- Octel—15 percent
- IBM—11 percent
- VMX—11 percent
- AT&T—11 percent
- Others—52 percent

The major trends in this market include a greater integration with PBX systems, the offering of voice mail services by telephone companies, and the move toward digital networking (e.g., X.25, T-1, and modems).

Table 28

Voice Messaging Systems Forecasts

	1990	1991	1992	1993	1994	CAGR 1990-1994
Units (K)	197.9	248.3	292.2	332.2	409.6	23.3%
ASP	$4,200	$3,900	$3,600	$3,300	$3,049	(7.6%)
Revenue (M)	$831.2	$968.4	$1,052.0	$1,106.4	$1,260.2	13.9%

Source: Dataquest (August 1990)

Trends in Telecommunications

SUMMARY

This section highlights the consumption of telecommunication services and equipment in the United States. Services will be presented first and equipment will be presented second.

Dataquest's forecast of the U.S. telecommunications market is presented in Table 1.

Table 1

Telecommunications Forecast
(Millions of Dollars)

	1989	1990	1991	1992	1993	CAGR 1989-1993
Telecom	$154,408	$159,614	$164,921	$171,478	$178,216	3.6%
Services	$128,182	$131,307	$134,952	$139,620	$143,371	2.8%
Equipment	$ 26,226	$ 28,307	$ 29,969	$ 31,858	$ 34,845	7.4%
Customer	$ 18,682	$ 20,327	$ 21,479	$ 22,548	$ 24,920	7.5%
Public	$ 7,544	$ 7,979	$ 8,490	$ 9,310	$ 9,925	7.1%

Source: Dataquest
October 1989

Major trends in this market include globalization of the supply base, continued deregulation to encourage competition and innovation, the growing acceptance of wireless communications products by business and the general public, and the implementation of Integrated Services Digital Network (ISDN) over the next 20 years.

Dataquest's Telecommunications Industry Service (TCIS) has shared its perspective with the Semiconductor Application Markets (SAM) service on many of the key areas in the telecommunications market.

SERVICES

Telephone companies have constructed a network of telecommunications equipment so that they can offer carrier services to subscribers. The demand for the equipment (and the components needed for the equipment) is derived ultimately from the demand for these services.

Telecommunications services include the following:

- Centrex services
- Local telephone services
- Long distance telephone services
- Public data networks

Centrex Services

Centrex is a generic name for a range of business communications services that provide PBX-like functions and features from a telephone company's central office facilities. The installed base of Centrex lines is 6.5 million units in 1989.

A Centrex line costs approximately $205 per year and the Centrex service typically consists of the following three elements:

- Local exchange access and switching (including long distance access)
- Intercom service
- Call-processing software feature packages

Dataquest's forecast of the U.S. Centrex services market is presented in Table 2.

Table 2

Centrex Services Forecast

	1989	1990	1991	1992	1993	CAGR 1989-1993
Units (K)	903	960	1,020	1,089	1,160	6.5%
ASP	N/A	N/A	N/A	N/A	N/A	N/A
Revenue (M)	$1,300	$1,316	$1,347	$1,393	$1,417	2.2%

N/A = Not Applicable

Source: Dataquest
October 1989

The top suppliers of Centrex services are the Regional Bell Operating Companies (RBOCs) (with a 95 percent share of the installed base) and the approximately 1,400 independent telephone companies (with the remaining 5 percent share).

The major trend in this market will be the conversion of Centrex lines to ISDN during the next 10 years.

Local Telephone Services

Local telephone services include local plain old telephone service (POTS), access to long distance networks, connections from customer premises equipment to private lines, and tie lines between separate business locations of an organization. The installed base of local access lines is estimated at 133.1 million units in 1989.

Local telephone service today is the result of the breakup of AT&T in 1984 and FCC initiatives to deregulate portions of the industry. Pricing is under a rate structure that is controlled by state regulatory agencies applying general guidelines of the FCC.

Dataquest's forecast of the U.S. local telephone services market is presented in Table 3.

Table 3

Local Telephone Services Forecast

	1989	1990	1991	1992	1993	CAGR 1989-1993
Units (K)	N/A	N/A	N/A	N/A	N/A	N/A
ASP	N/A	N/A	N/A	N/A	N/A	N/A
Revenue (M)	$81,600	$84,200	$86,900	$90,200	$93,100	3.4%

N/A = Not Applicable

Source: Dataquest
October 1989

The top suppliers of local telephone services include the Regional Holding Companies (i.e., AT&T's former local telephone business) with an estimated 77 percent share of the installed base of local access lines. Approximately 1,400 independent telephone companies control the remaining 23 percent of the installed base.

The major trend in this market will be the conversion of the local access to ISDN over the next 20 years. In addition, other changes in both the technology and regulatory arenas should take place under the guidance of the federal courts.

Long Distance Telephone Services

Long distance telephone services are provided on an international and domestic (interstate and intrastate) basis between local telephone companies. The regulatory climate has created an open market environment in all areas of long distance telecommunications. Dataquest's forecast of the U.S. long distance telephone services market is presented in Table 4.

Table 4

Long Distance Telephone Services Forecast

	1989	1990	1991	1992	1993	CAGR 1989-1993
Units (K)	N/A	N/A	N/A	N/A	N/A	N/A
ASP	N/A	N/A	N/A	N/A	N/A	N/A
Revenue (M)	$44,800	$45,300	$46,200	$47,500	$48,300	1.9%

N/A = Not Applicable

Source: Dataquest
October 1989

The suppliers of long distance telephone services have the following market shares:

- AT&T—80 percent
- MCI—9 percent
- Sprint—6 percent
- Approximately 400 other suppliers—5 percent

The major trend in this market are the changes to the network needed to support ISDN. Most of the optical cables for the long distance network have been installed already.

Public Data Networks

Public data network services are data communications network services that are offered to the general public. Public data networks connect user terminals, computers, local and metropolitan networks, and other private networks to the network.

Dataquest's forecast of the U.S. public data networks market is presented in Table 5.

Table 5

Public Data Networks Forecast

	1989	1990	1991	1992	1993	CAGR 1989-1993
Units (K)	N/A	N/A	N/A	N/A	N/A	N/A
ASP	N/A	N/A	N/A	N/A	N/A	N/A
Revenue (M)	$475	$498	$523	$545	$569	3.5%

N/A = Not Applicable

Source: Dataquest
October 1989

Trends in Telecommunications

The suppliers of public data networks have the following market shares:

- Telenet—48 percent market share
- Tymnet—40 percent
- Compuserve—4 percent
- Others—8 percent

By 1991, the Regional Holding Companies are expected to have a 12 to 15 percent market share in the public data network market.

The major trend in this market will be the incorporation of packet switching in the ISDN network over the next 20 years.

EQUIPMENT

The largest portion of the telecommunications equipment sold in the United States is located on the customer premises and consists of the following equipment types:

- Automatic call distributors
- Call accounting systems
- DSU/CSU
- Data network control systems
- Data PBX
- Facsimile equipment
- Front-end processors
- Integrated voice/data workstations
- Key telephone systems
- LANs
- Modems
- PBX
- Statistical multiplexers

- T-1 multiplexers
- Telephone equipment
- Video teleconferencing systems
- Voice messaging systems

The remaining portion of the telecommunications equipment sold in the United States is in the category of public communications and consists of the following equipment types:

- Carrier equipment
- Cellular mobile radio
- Central office switching equipment
- Microwave radio equipment
- Multiplex equipment
- Private packet radio equipment
- Satellite earth station equipment

This equipment will be discussed in alphabetical order in the following subsections.

Automatic Call Distributors

Automatic call distributors (ACDs) are designed to help businesses answer large volumes of incoming calls by routing them to the operators on duty. Typical users of ACDs include catalog sales departments, insurance companies, credit card companies, utility companies, newspaper classified advertising departments, government agencies, and 911 emergency services departments.

The two major categories of ACDs include switch-based systems (e.g., systems integrated with PBXs) and systems designed to operate standalone. Smaller ACDs can handle up to 20 telephone operators and larger ACDs can handle more than 1,000.

Dataquest's forecast of the U.S. ACD market is presented in Table 6.

Table 6

Automatic Call Distributors Forecast

	1989	1990	1991	1992	1993	CAGR 1989-1993
Units (K)	143.8	168.5	194.1	220.5	255.3	15.4%
ASP	$2,323	$2,160	$2,048	$1,982	$1,881	(5.1%)
Revenue (M)	$334.0	$364.0	$397.5	$437.0	$480.2	9.5%

Source: Dataquest
October 1989

The suppliers of ACDs have the following market shares:

- Northern Telecom—25 percent
- AT&T—13 percent
- Rockwell—12 percent
- Siemens/ROLM—12 percent
- Telecom Technologies—11 percent
- Others—27 percent

The major trends in this market include the emergence of central office ACD services, the incorporation of voice processing and telemarketing capabilities in ACDs, and the incorporation of ISDN.

Call Accounting Systems

Call accounting systems record the calling activity of a telephone system and generate MIS reports. Typical users of this equipment include hotels for billing guests and businesses for monitoring employee usage.

Passive call accounting systems process call accounting reports; active systems offer additional features such as least-cost routing and toll-call restrictions. Many call accounting systems are an integral part of a PBX.

Dataquest's forecast of the U.S. call accounting system market is presented in Table 7.

Table 7

Call Accounting Systems Forecast

	1989	1990	1991	1992	1993	CAGR 1989-1993
Units (K)	152.7	170.0	193.4	226.9	257.2	13.9%
ASP	$1,844	$1,769	$1,715	$1,611	$1,537	(4.5%)
Revenue (M)	$281.6	$300.7	$331.7	$365.5	$395.3	8.9%

Source: Dataquest
October 1989

The suppliers of call accounting systems have the following market shares:

- Moscom—4.7 percent
- Summa Four—4.6 percent
- Com Dev—4.3 percent
- Infortext Systems—3.6 percent
- Telecom Systems Management—3.1 percent
- Others—79.7 percent

The major trends in this market include the integration of call accounting systems in larger telemanagement systems and the shift to a microcomputer installed base.

Carrier Equipment

Carrier equipment provides transmission of a number of voice-frequency channels over a common cable. Purchasers of this equipment include both telephone companies and large users of telephone services seeking to bypass telephone company facilities.

The carrier system market consists of two segments: trunk carrier systems (transmission links between telephone company central offices) and subscriber carrier systems (transmission links between a subscriber premise and a central office). Lower-capacity transmission links can carry 24 voice-frequency channels (i.e., T-1); higher-capacity links can carry 96 channels (i.e., T-2); and future subscriber carrier capability is expected to reach 672 customer per fiber (i.e., T-3).

Dataquest's forecast of the U.S. carrier equipment market is presented in Table 8.

Table 8

Carrier Equipment Forecast

	1989	1990	1991	1992	1993	CAGR 1989-1993
Units (K)	N/A	N/A	N/A	N/A	N/A	N/A
ASP	N/A	N/A	N/A	N/A	N/A	N/A
Revenue (M)	$1,806	$1,970	$2,144	$2,390	$2,374	7.1%

N/A = Not Available

Source: Dataquest
October 1989

The top suppliers of carrier equipment include the following:

- Alcatel
- AT&T
- Northern Telecom
- Rockwell

The major trends in this market include the continued shift from analog to digital transmission facilities, the increased penetration of fiber optics, and Synchronous Optical Network (SONET), the standardization of offerings by 1995.

Cellular Mobile Radio

Cellular mobile radio allows a greater number of users to be accommodated on the radio-telephone frequency allocations. Typical users of this equipment include both consumers and business people who want to either make or receive telephone calls while in transit.

The three basic types of telephone instruments on the market include mobile units (3.0-watt output power) for use in automobiles, portable units (0.5-watt output power) for hand-held operation, and transportable units (3.0-watt output power, but bulkier than the hand-held units due to the battery pack required) for hand-held operation.

Dataquest's forecast of the U.S. cellular mobile radio market is presented in Table 9.

Table 9

Cellular Mobile Radio Forecast

	1989	1990	1991	1992	1993	CAGR 1989-1993
Units (K)	800.0	880.0	930.0	980.0	1,064.0	7.4%
ASP	$ 650	$ 580	$ 549	$ 520	$ 483	(7.2%)
Revenue (M)	$520.0	$510.4	$510.6	$509.6	$513.9	(0.3%)

Source: Dataquest
October 1989

The top suppliers of cellular mobile radios include the following:

- Matsushita
- Motorola
- NEC
- Novatel
- Oki

The major trends in this market include declining prices (e.g., rising demand) and the expected introduction of digital cellular radio in the early 1990s. Personal communications devices (e.g., "pocket telephones") are expected to be commonplace by the late 1990s, and these will be implemented using cellular technology.

Central Office Switching Equipment

Central office switching equipment interconnects local telephone lines and also connects these local telephone lines to long distance trunks. Purchasers of this equipment include telphone companies. Although central office switching equipment can be either analog or digital, all new installations have been digital only. Dataquest's forecast of the U.S. central office switching equipment market is presented in Table 10.

Table 10

Central Office Switching Equipment Forecast

	1989	1990	1991	1992	1993	CAGR 1989-1993
Units (K)	13,800.0	14,000.0	14,500.0	15,500.0	15,900.0	3.6%
ASP	$ 195	$ 200	$ 204	$ 205	$ 207	1.5%
Revenue (M)	$2,691.0	$2,800.0	$2,958.0	$3,177.5	$3,291.3	5.2%

Source: Dataquest
October 1989

The suppliers of central office switching equipment have the following market shares:

- AT&T—47 percent
- Northern Telecom—39 percent
- GTE—8 percent
- Others—6 percent

The major trend in this market will be the conversion to ISDN over the next 20 years.

DSU/CSU

Data service units (DSUs) and channel service units (CSUs) allow computers to communicate with each other over the digital facilities of the public telephone network. These equipments convert the user's datastream from the unipolar format used in digital computers to the bipolar format used in digital networks. Major industries using this service include banking, finance, manufacturing, government, wholesale and retail, transportation, utilities, and education.

The two major categories of DSU products are low-speed (2,400 bps, 4,800 bps, and 9,600 bps) and high-speed (19.2 Kbps and 56.0 Kbps). CSU products connect to a 1.544-Mbps DS-1 digital facility.

Dataquest's forecast of the U.S. DSU/CSU market is presented in Table 11.

Table 11

DSU/CSU Forecast

	1989	1990	1991	1992	1993	CAGR 1989-1993
Units (K)	169.1	208.1	240.9	278.1	333.1	18.5%
ASP	$ 807	$ 749	$ 738	$ 721	$ 703	(3.4%)
Revenue (M)	$136.4	$155.9	$177.7	$200.4	$234.3	14.5%

Source: Dataquest
October 1989

The suppliers of DSUs/CSUs have the following market shares:

- AT&T—26 percent
- Verilink—17 percent
- TPP—13 percent
- GDC—11 percent
- Datatel—10 percent
- Others—23 percent

The major trend in this market is the migration to board-level and chip-level products.

Data Network Control Systems

Data network control systems cover an assortment of equipment to ensure network availability, test network operations, and report on network performance.

The data network control system market is very fragmented because many of today's systems are specific to the type of equipment they control. General segments include protocol analyzers, network switches, matrix switches, modem network controllers, network management systems, and products that analyze network response time.

Dataquest's forecast of the data network control systems market is presented in Table 12.

Table 12

Data Network Control Systems Forecast

	1989	1990	1991	1992	1993	CAGR 1989-1993
Units (K)	N/A	N/A	N/A	N/A	N/A	N/A
ASP	N/A	N/A	N/A	N/A	N/A	N/A
Revenue (M)	$826.0	$1,004.5	$1,252.2	$1,595.0	$1,976.0	24.4%

N/A = Not Available

Source: Dataquest
October 1989

The top suppliers of data network control systems include the following:

- Avant-Garde
- Bytex
- Codex
- Dynatech
- Hewlett-Packard

The major trends in this market include the incorporation of user friendliness (e.g., touch screens, icon displays) and the ability to support a multivendor environment.

Data PBX

Data PBXs are digital private branch exchange systems designed specifically for data communications networks. Typical users of this equipment include universities, financial institutions, government computer centers, manufacturing operations, and time-sharing services.

Data PBX units are designed so that line capacity can be expanded easily to fit growing data communication needs of the user organization. A data PBX does not provide any voice-switching capability.

Dataquest's forecast of the data PBX market is presented in Table 13.

Table 13

Data PBX Forecast

	1989	1990	1991	1992	1993	CAGR 1989-1993
Units	800.0	775.0	750.0	700.0	670.0	(4.3%)
ASP	$97,875	$98,323	$99,200	$100,000	$101,045	0.8%
Revenue (M)	$ 78.3	$ 76.2	$ 74.4	$ 70.0	$ 67.7	(3.6%)

Source: Dataquest
October 1989

The suppliers of data PBX equipment have the following market shares:

- Micom—53 percent
- Equinox—14 percent
- Gandalf—12 percent
- Sequel—8 percent
- Infotron—6 percent
- Others—7 percent

The major trend in this market is the capability to handle a larger variety of data communications and protocols.

Facsimile Equipment

Facsimile equipment consists of machines capable of transmitting and receiving document images over the telephone lines.

Facsimile equipment is classified into the following four groups:

- Group 1—Transmits at four to six minutes per page (obsolete; all machines taken out of service)
- Group 2—Transmits at two to three minutes per page (obsolete; all machines being taken out of service)

- Group 3—Transmits at one minute per page (all fax machine sales currently fall into this category)
- Group 4—Transmits at five seconds per page (ISDN interface; significant sales not expected before 1991)

Dataquest's forecast of the U.S. facsimile equipment market is presented in Table 14.

Table 14

Facsimile Equipment Forecast

	1989	1990	1991	1992	1993	CAGR 1989-1993
Units (K)	1,287.8	1,740.3	2,091.7	2,281.5	2,908.9	22.6%
ASP	$ 1,921	$ 1,627	$ 1,357	$ 1,146	$ 974	(15.6%)
Revenue (M)	$2,473.9	$2,831.5	$2,838.4	$2,614.6	$2,833.3	3.4%

Source: Dataquest
October 1989

The suppliers of facsimile equipment have the following market shares:

- Sharp—19 percent
- Ricoh—16 percent
- Canon—11 percent
- Pitney-Bowes—7 percent
- Fujitsu—6 percent
- Others—41 percent

The major trends in this market include the introduction of ISDN-based Group 4 machines in the early 1990s and the location of manufacturing facilities in all regions of the world (e.g., 98 percent of the facsimile machines actually are built by Japanese companies and some of these are privately labeled for non-Japanese suppliers).

Front-End Processors

Front-end processors are themselves computers that link mainframe computers with data communications networks.

Front-end processors are commonly attached to mainframe and large business-unit computers manufactured by Amdahl, Control Data, Honeywell, IBM, National Advanced Systems, NCR, Tandem, and Unisys.

Dataquest's forecast of the U.S. front-end processor market is presented in Table 15.

Table 15

Front-End Processors Forecast

	1989	1990	1991	1992	1993	CAGR 1989-1993
Units	5,350.0	5,830.0	6,320.0	6,790.0	7,347.0	8.3%
ASP (K)	$ 93	$ 90	$ 87	$ 85	$ 82	(3.1%)
Revenue (M)	$ 497.6	$ 524.7	$ 549.8	$ 577.2	$ 602.5	4.9%

Source: Dataquest
October 1989

The suppliers of front-end processors have the following market shares:

- IBM—47 percent
- Unisys—16 percent
- Honeywell—9 percent
- Control Data—7 percent
- NCR Comten—6 percent
- Others—15 percent

The major trends in this market include the addition of enhanced network management capabilities and the ability to connect to a broader variety of data communications networks. Packet switching and ISDN are expected to have a negative impact on this market.

Integrated Voice/Data Workstations

Integrated voice/data workstations are products that integrate a telephone with either a terminal or a personal computer to produce a single workstation.

This market emerged from the "office of the future" concept as it developed originally in the late 1950s and early 1960s. The ISDN concept that was developed in the 1970s, however, has emerged as the way integrated voice and data actually will be implemented in a desktop environment.

Dataquest's forecast of the U.S. integrated voice/data workstation market is presented in Table 16.

Table 16

Integrated Voice/Data Workstations Forecast

	1989	1990	1991	1992	1993	CAGR 1989-1993
Units (K)	29.9	28.6	27.4	25.6	24.4	(5.0%)
ASP	$ 940	$ 874	$ 799	$ 730	$ 665	(8.3%)
Revenue (M)	$28.1	$25.0	$21.9	$18.7	$16.2	(12.8%)

Source: Dataquest
October 1989

The remaining six suppliers of integrated voice/data workstations have the following market shares:

- Northern Telecom—41 percent
- Siemens/ROLM—37 percent
- Davox—14 percent
- AT&T—3 percent
- Zaisan—3 percent
- NEC—2 percent

The major trend in this market is the replacement of integrated voice/data workstations with ISDN terminals. Dataquest will cease covering this particular market segment in the future and will focus our efforts on ISDN instead.

Key Telephone Systems

Key telephone systems are multiline business telephones that provide a shared access to outside central office lines by way of direct lines on the station sets. Typical users are small and medium-size businesses with less than 50 employees. (In contrast, PBX systems are characterized by pooled access to a group of central office lines, typically by dialing "9" from a station set. Centrex is a business communications service that provides PBX-like functions and features from telephone company central office switches. The total business-switching revenue is split among PBX at 45 percent, key telephone systems at 35 percent, and Centrex service at 20 percent.)

Standalone key telephone systems account for approximately 70 percent of the shipments and installed base. Adjunct key telephone systems are connected to either a PBX system or Centrex service, rather than directly to the network.

Dataquest's forecast of the U.S. key telephone systems market is presented in Table 17.

Table 17

Key Telephone Systems Forecast

	1989	1990	1991	1992	1993	CAGR 1989-1993
Units (K)	4,400.5	4,473.7	4,555.8	4,648.7	4,751.3	1.9%
ASP	$ 478	$ 454	$ 431	$ 410	$ 389	(5.0%)
Revenue (M)	$2,103.4	$2,031.1	$1,963.5	$1,906.0	$1,848.3	(3.2%)

Source: Dataquest
October 1989

The suppliers of key telephone systems have the following market shares:

- AT&T—30 percent
- TIE/Communications—18 percent
- Executone—11 percent
- Toshiba—6 percent
- Inter-Tel—5 percent
- Others—30 percent

Trends in Telecommunications

The major trend in this market is the replacement of electromechanical systems with electronic systems, spurred by the implementation of ISDN.

Local Area Networks (LANs)

A local area network (LAN) is a communications product able to connect three or more communications devices in a peer-to-peer relationship for the purpose of sharing information and resources. (This definition excludes point-to-point, PBX, and data PBX connections.) LANs are used principally for information sharing, database access, mainframe access, data exchange, and peripheral sharing.

The key characteristics that distinguish different types of LANs include signaling technique, access protocols, transmission media, and network topology. The Institute of Electrical and Electronic Engineers (IEEE) has formed eight IEEE-802 subcommittees to prepare LAN standards.

Dataquest's forecast of the U.S. LAN market is presented in Table 18.

Table 18

Local Area Network Forecast

	1989	1990	1991	1992	1993	CAGR 1989-1993
Units (K)	5,132.0	6,602.0	7,874.0	9,180.0	11,723.0	22.9%
ASP	$ 705	$ 663	$ 643	$ 627	$ 600	(4.0%)
Revenue (M)	$3,618.1	$4,377.1	$5,063.0	$5,755.9	$7,033.8	18.1%

Source: Dataquest
October 1989

The suppliers of LANs have the following market shares:

- Digital Equipment—21 percent
- 3Com—14 percent
- IBM—8 percent
- Ungermann-Bass—8 percent
- Apple—5 percent
- Others—44 percent

Trends in Telecommunications

The major trends in this market include connectivity, which will permit multiple interconnections between computing devices; innovation, which will develop lower cost implementations on metallic cables or faster networks on optical cables; and consolidation, which will reduce the number of suppliers through mergers and acquisitions.

Microwave Radio Equipment

Microwave radio equipment is used to transmit communications signals point to point. Purchasers of this equipment include public common carriers and private industrial companies.

Complete microwave systems include the microwave antenna (dishes), transmitter/receiver systems, power supplies, related equipment (waveguides and channel banks), and optional repeaters. (Dataquest's database, however, deals only with the electrical portion of the system.) Microwave radio equipment is designed for either analog or digital signals.

Dataquest's forecast of the U.S. microwave radio equipment market is presented in Table 19.

Table 19

Microwave Radio Equipment Forecast

	1989	1990	1991	1992	1993	CAGR 1989-1993
Units (K)	N/A	N/A	N/A	N/A	N/A	N/A
ASP	N/A	N/A	N/A	N/A	N/A	N/A
Revenue (M)	$482.0	$491.0	$505.0	$527.0	$554.0	3.5%

N/A = Not Available

Source: Dataquest
October 1989

The suppliers of microwave radio equipment have the following market shares:

- AT&T—22 percent
- Rockwell/Collins—16 percent
- Harris/Farinon—14 percent
- NEC—9 percent

- Northern Telecom—9 percent
- Others—30 percent

The major trends in this market include the phasing out of analog equipment (which is being replaced by digital equipment), the increasing use of microwave equipment by private industry to bypass the local telephone utility, and the increasing use of fiber optics.

Modems

Modems allow digital data to be carried over voice-grade communications channels. Typical users of modems are people who must send or receive digital data to or from computers and other data processing equipment and who also select the telephone as the transmission channel of choice.

There are many types of modems based on data format transmitted and transmission speed. All modems support the Level 1 connectivity functions of the International Standards Organization (ISO) model for data communications architecture according to the Bell-equivalent and Consultative Committee on International Telephony and Telegraphy (CCITT) standards.

Dataquest's forecast of the U.S. modem market is presented in Table 20.

Table 20

Modem Forecast

	1989	1990	1991	1992	1993	CAGR 1989-1993
Units (K)	2,779.0	3,150.9	3,510.1	3,824.2	4,283.1	11.4%
ASP	$ 446	$ 361	$ 288	$ 230	$ 187	(19.5%)
Revenue (M)	$1,238.2	$1,138.8	$1,009.7	$ 878.8	$ 801.5	(10.3%)

Source: Dataquest
October 1989

The suppliers of modems have the following market shares:

- Codex (Motorola)—19 percent
- AT&T—17 percent
- Racal/Milgo—11 percent

- Hayes—9 percent
- Paradyne—7 percent
- Others—37 percent

The major trends in this market include the trend toward higher speeds, price reductions resulting from integrated VLSI modem chips, and the gradual replacement of modems by ISDN over the next two decades.

Multiplex Equipment

Multiplex equipment combines a number of voice-frequency message channels (i.e., telephone calls) into a single signal for transmission over a common medium (e.g., satellite, microwave radio, cable carrier, or fiber optics). Purchasers of this equipment include public common carriers and private industrial companies.

The multiplex equipment segments include analog (FDM), digital (TDM and PCM), and transmultiplexers, which allow analog and digital transmission links to be connected.

Dataquest's forecast of the U.S. multiplex equipment market is presented in Table 21.

Table 21

Multiplex Equipment Forecast

	1989	1990	1991	1992	1993	CAGR 1989-1993
Units (K)	N/A	N/A	N/A	N/A	N/A	N/A
ASP	N/A	N/A	N/A	N/A	N/A	N/A
Revenue (M)	$1,507.0	$1,577.0	$1,653.0	$1,757.0	$1,998.0	7.3%

N/A = Not Available

Source: Dataquest
October 1989

The top suppliers of multiplex equipment include the following:

- AT&T
- DSC

- Northern Telecom
- Rockwell
- Tellabs

The major trends in this market include the increasing popularity of digital systems (driven by the continued high use of fiber-optic transmission and the advent of ISDN) and the use of VLSI technology to reduce size and power requirements of the equipment.

PBX

A private branch exchange (PBX) is a customer-premise telephone system that connects the customer's office telephones to each other and to the outside public telephone network. Typical users of PBX equipment include organizations that want their own telephone system (e.g., industrial companies, government agencies, and large universities).

The PBX market is segmented by line size. Very small PBX systems have 1 to 40 lines; at the very large end of the spectrum are PBX systems with more than 1,000 lines. Various types of PBX end-user terminals range from standard single-line telephones to integrated voice/data workstations. Besides basic telephone service, PBXs now offer networking features, management control features, and advanced features such as automatic call distribution and voice messaging. PBX systems are modular in design so they can be expanded with additional channel cards.

Dataquest's forecast of the U.S. PBX market is presented in Table 22.

Table 22

PBX Forecast

	1989	1990	1991	1992	1993	CAGR 1989-1993
Units (K)	5,645.0	5,811.0	6,003.0	6,239.0	6,439.0	3.3%
ASP	$ 697	$ 685	$ 676	$ 670	$ 660	(1.4%)
Revenue (M)	$3,934.6	$3,980.5	$4,058.0	$4,180.1	$4,249.7	1.9%

Source: Dataquest
October 1989

The suppliers of PBXs have the following market shares:

- AT&T—22 percent
- Siemens/ROLM—18 percent
- Northern Telecom—16 percent
- Mitel—10 percent
- NEC—9 percent
- Others—25 percent

The major trends in this market include the continuing erosion in price per line, the addition of data and office automation features, new architectures that handle information in packet form, and the technical and feature changes caused by the implementation of ISDN.

Private Packet Data Networks

A private packet data network is a data communications system for geographically dispersed terminals that provides a lower-cost alternative to leased-lines or public packet network services when traffic is high. Typical users of private packet data networks include transaction processing (e.g., credit verifications), database inquiry, and any other datacomm application that transmits data in bursts.

Private packet data networks are the backbone of many large U.S. corporations through the world. Equipment for a network can be supplied by any vendor whose product is certified to the X.25 international data transport standard. X.25 gateways allow private packet networks to internetwork with popular LANs. Products in this market include packet switches and packet assembler-disassemblers (PADs).

Dataquest's forecast of the U.S. private packet data network market is presented in Table 23.

Table 23

Private Packet Data Networks Forecast

	1989	1990	1991	1992	1993	CAGR 1989-1993
Units (K)	N/A	N/A	N/A	N/A	N/A	N/A
ASP	N/A	N/A	N/A	N/A	N/A	N/A
Revenue (M)	$344.5	$378.9	$418.9	$455.5	$503.2	9.9%

N/A = Not Available

Source: Dataquest
October 1989

The suppliers of private packet data networks have the following market shares:

- BBN Communications—31 percent
- Tymnet—11 percent
- Telenet—10 percent
- Northern Telecom—7 percent
- Telematics—6 percent
- Others—35 percent

The major trends in this market include the increasing use of gateways to link X.25 networks with other networks already in place, the use of Microcom Network Protocol (MNP) as an error-correction protocol, the use of X.PC for personal computer access to Tymnet networks, the appearance of board-level products for incorporation into multiplexers and personal computers, and the development of hybrid packet/ISDN switching systems.

Satellite Earth Station Equipment

Satellites are used for TV program distribution, international voice communications, low-speed data communications, video teleconferencing, and data broadcast. Only the low-speed data communications application is growing; all other segments have either reached saturation or are at a standstill.

Low-speed data communications via satellite are private full-solution communication networks. Typical applications for these networks include insurance policy and claims support, retail chain store sales and inventory, hotel and car rental reservations, on-line data processing services, automatic teller machines, oil field and pipeline data collection and monitoring, video training and announcements, and securities transactions.

Dataquest's forecast of the U.S. satellite earth station equipment market is presented in Table 24.

Table 24

Satellite Earth Station Equipment Forecast

	1989	1990	1991	1992	1993	CAGR 1989-1993
Units (K)	N/A	N/A	N/A	N/A	N/A	N/A
ASP	N/A	N/A	N/A	N/A	N/A	N/A
Revenue (M)	$193.3	$252.0	$300.6	$493.3	$690.1	37.5%

N/A = Not Available

Source: Dataquest
October 1989

The suppliers of satellite earth station equipment have the following market shares:

- Equitorial Contel ASC—35 percent
- Hughes M/A-Com—22 percent
- Tridom—12 percent
- GTE Spacenet—7 percent
- AT&T—5 percent
- Others—19 percent

The major trends in this market include the shift from hardware to service provisions, competition from fiber optics, and plenty of satellite capacity. ISDN is expected to cause only a minor impact.

Statistical Multiplexers

Statistical multiplexers save data communications network costs by reducing the number of communications lines and related modems needed for local and remote communications. Users of statistical multiplexers include Fortune 5000 companies; colleges and universities; financial institutions; telephone and computer companies; multinational corporations; government; medical; and service bureaus.

Statistical multiplexers contain microprocessors and buffers to allocate dynamically the user's data into a high-speed composite data transmission link. Three market segments exist based on connections, features, and price: low end (2 to 6 lines), midrange (2 to 32 lines), and high end (48 plus lines).

Dataquest's forecast of the U.S. statistical multiplexer market is presented in Table 25.

Table 25

Statistical Multiplexers Forecast

	1989	1990	1991	1992	1993	CAGR 1989-1993
Units (K)	76.1	80.3	83.6	90.4	95.3	5.8%
ASP	$3,168	$2,873	$2,644	$2,343	$2,050	(10.3%)
Revenue (M)	$241.1	$230.7	$221.0	$211.8	$195.4	(5.1%)

Source: Dataquest
October 1989

The suppliers of statistical multiplexers have the following market shares:

- Micom—15 percent
- Codex—15 percent
- Timeplex—8 percent
- Infotron—8 percent
- DCA—8 percent
- Others—46 percent

The major trend in this market is the increased internetworking among vendor product offerings as user networks grow.

T-1 Multiplexers

T-1 is a point-to-point digital facility that carries 24 voice-frequency channels over a single communications line. Typical T-1 multiplex users include Fortune 2500 companies, colleges, universities, medical facilities, financial institutions, transportation companies, local telephone companies, multinational companies with off-shore locations, government agencies, service-focused companies, and any company that wants to communicate with intracompany premise locations (e.g., office parks and technology centers).

The North American T-1 standard allows the multiplexing of 24 64-Kbps channels over a single line at a combined rate of 1.544 Mbits per second. T-1 service can be provided by span lines, satellite, digital microwave, coaxial cable, and fiber optics.

Dataquest's forecast of the U.S. T-1 multiplexer market is presented in Table 26.

Table 26

T-1 Multiplexers Forecast

	1989	1990	1991	1992	1993	CAGR 1989-1993
Units (K)	10.7	13.3	16.0	18.7	22.7	20.7%
ASP	$42,028	$44,338	$42,013	$39,540	$37,916	(2.5%)
Revenue (M)	$ 449.7	$ 589.7	$ 672.2	$ 739.4	$ 860.7	17.6%

Source: Dataquest
October 1989

The suppliers of T-1 multiplexers have the following market shares:

- Timeplex—32 percent
- Net—19 percent
- General DataComm—11 percent
- DCA/Cohesive—7 percent
- Datatel—6 percent
- Others—25 percent

The major trends in this market include encryption, circuit and packet switching integration, LAN bridge applications, and the inclusion of enhanced network management and control functions to monitor high-speed link performance and quality.

Telephone Equipment

Telephone equipment is the single-line telephone sets used in the home or office and purchased from a retail outlet.

Dataquest's forecast of the U.S. telephone equipment market is presented in Table 27.

Table 27

Telephone Equipment Forecast

	1989	1990	1991	1992	1993	CAGR 1989-1993
Units (K)	26,100.0	27,600.0	29,400.0	31,400.0	33,400.0	6.4%
ASP	$ 63	$ 62	$ 60	$ 59	$ 58	(2.0%)
Revenue (M)	$1,644.3	$1,711.2	$1,764.0	$1,852.6	$1,937.2	4.2%

Source: Dataquest
October 1989

The top suppliers of telephone equipment include the following:

- AT&T
- Panasonic
- Tandy

The major trends in this market include the continuation of consumer preference to purchase rather than lease telephone sets, the continuing reduction in telephone set prices, and the demand for electronic sets surpassing the demand for electromechanical sets to allow the implementation of more advanced features.

Video Teleconferencing Systems

Video teleconferencing systems allow the transmission of video images over communications channels. The decreasing cost of equipment and transmission facilities are increasing the viability of video conferencing.

Transmission speeds can be broadcast quality (45 Mbps), near full motion (768 Kbps to T-carrier 1.544 Mbps), and limited motion (56 Kbps). The compression standards used in digital-transmission systems are proprietary to the equipment manufacturer.

Dataquest's forecast of the video teleconferencing systems market is presented in Table 28.

Table 28

Video Teleconferencing Systems Forecast

	1989	1990	1991	1992	1993	CAGR 1989-1993
Units (K)	17.4	20.7	23.1	24.8	29.2	13.8%
ASP	$3,586	$4,217	$5,160	$5,681	$6,438	15.8%
Revenue (M)	$ 62.4	$ 87.3	$119.2	$140.9	$188.0	31.7%

Source: Dataquest
October 1989

The top suppliers of video teleconferencing systems include the following:

- Compression Labs
- Mitsubishi
- PictureTel
- Stromberg-Carlson

Voice Messaging Systems

Voice messaging systems offer telephone users the conveniences of interactive messaging, telephone answering, caller routing, information providing, and transaction processing. Voice messaging systems can be used in any business environment that operates telecommunications equipment such as PBXs, key systems, Centrex, and message centers.

Voice messaging systems can be classified into three distinct product types: standalone systems, PBX-integrated systems, and board-level products. Basic technologies for voice processing products include voice store-and-forward (the ability to store digital speech and retrieve or manipulate it at a later time), voice recognition (the ability of a computer to recognize and accept voice as an input), and speech synthesis (computer-generated speech that uses fixed or variable vocabulary).

Dataquest's forecast of the U.S. voice messaging systems market is presented in Table 29.

Table 29

Voice Messaging Systems Forecasts

	1989	1990	1991	1992	1993	CAGR 1989-1993
Units (K)	179.2	242.8	301.4	346.3	461.6	26.7%
ASP	$4,100	$3,700	$3,200	$ 2,900	$ 2,600	(10.8%)
Revenue (M)	$734.7	$898.4	$964.5	$1,004.3	$1,200.2	13.1%

Source: Dataquest
October 1989

The suppliers of voice messaging systems have the following market shares:

- IBM--20 percent
- Octel—12 percent
- VMX--10 percent
- AT&T--9 percent
- OPCOM--8 percent
- Others--41 percent

The major trends in this market include a greater integration with PBX systems, the offering of voice mail services by telephone companies, and the move toward digital networking (e.g., X.25, T-1, and modems).

Industrial

Industrial

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

Semiconductor Consumption—Industrial

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Index of Tables (Continued)

Table 1

Forecast North American Electronic Equipment Production Industrial (Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR (%) 1989-1990	CAGR (%) 1989-1994
Factory Revenue	43,624	46,899	49,989	54,742	59,199	63,514	68,230	6.6	7.8

Source: Dataquest (July 1990)

Table 2

Forecast North American Merchant Semiconductor Revenue Industrial (Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR (%) 1989-1990	CAGR (%) 1989-1994
Total Semiconductor	2,115	2,288	2,341	2,744	3,319	4,153	4,636	2.3	15.2
Total IC	1,403	1,587	1,623	1,982	2,457	3,227	3,677	2.3	18.3
Bipolar Digital	178	130	104	98	91	84	65	(19.8)	(12.9)
Bipolar Memory	20	20	16	13	11	9	7	(21.2)	(19.2)
Bipolar Logic	158	109	88	85	81	75	58	(19.5)	(11.9)
MOS	822	991	1,012	1,254	1,639	2,259	2,559	2.1	20.9
MOS Memory	236	330	267	322	412	560	610	(19.1)	13.1
MOS Micro	216	230	258	314	399	576	673	12.2	24.0
MOS Logic	370	431	487	618	827	1,124	1,276	13.0	24.2
Analog	403	466	507	630	727	884	1,053	8.8	17.7
Discrete	601	591	611	648	743	801	825	3.3	6.9
Opto	111	109	107	114	118	126	134	(2.2)	4.1

Source: Dataquest (July 1990)

Table 3

Forecast North American Merchant Semiconductor Revenue
Industrial
(Input/Output Ratios, Percentage)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	4.8	4.9	4.7	5.0	5.6	6.5	6.8
Total IC	3.2	3.4	3.2	3.6	4.2	5.1	5.4
Bipolar Digital	0.4	0.3	0.2	0.2	0.2	0.1	0.1
Bipolar Memory	0	0	0	0	0	0	0
Bipolar Logic	0.4	0.2	0.2	0.2	0.1	0.1	0.1
MOS	1.9	2.1	2.0	2.3	2.8	3.6	3.8
MOS Memory	0.5	0.7	0.5	0.6	0.7	0.9	0.9
MOS Micro	0.5	0.5	0.5	0.6	0.7	0.9	1.0
MOS Logic	0.8	0.9	1.0	1.1	1.4	1.8	1.9
Analog	0.9	1.0	1.0	1.2	1.2	1.4	1.5
Discrete	1.4	1.3	1.2	1.2	1.3	1.3	1.2
Opto	0.3	0.2	0.2	0.2	0.2	0.2	0.2

Source: Dataquest (July 1990)

Table 4

Forecast North America Electronic Equipment Production
Industrial
(Annual Percentage Growth)

	1989	1990	1991	1992	1993	1994
Factory Revenue	7.5	6.6	9.5	8.1	7.3	7.4

Source: Dataquest (July 1990)

Table 5

Forecast North America Merchant Semiconductor Revenue Industrial (Annual Percentage Growth)

	1989	1990	1991	1992	1993	1994
Total Semiconductor	8.2	2.3	17.2	20.9	25.2	11.6
Total IC	13.1	2.3	22.1	24.0	31.4	13.9
Bipolar Digital	(27.2)	(19.8)	(5.8)	(6.7)	(8.1)	(22.6)
Bipolar Memory	1.5	(21.2)	(18.8)	(17.7)	(15.9)	(22.2)
Bipolar Logic	(30.8)	(19.5)	(3.4)	(5.1)	(7.1)	(22.7)
MOS	20.6	2.1	23.9	30.7	37.9	13.3
MOS Memory	39.8	(19.1)	20.6	28.0	35.8	9.0
MOS Micro	6.5	12.2	21.7	27.1	44.2	16.9
MOS Logic	16.5	13.0	26.9	33.9	35.9	13.5
Analog	15.7	8.8	24.3	15.4	21.6	19.1
Discrete	(1.6)	3.3	6.1	14.7	7.7	3.1
Opto	(1.4)	(2.2)	6.5	3.8	6.1	6.8

Source: Dataquest (July 1990)

Table 6

North America Merchant Semiconductor Revenue Industrial (Percentage of Total Industrial)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total IC	66.3	69.4	69.3	72.2	74.0	77.7	79.3
Bipolar Digital	8.4	5.7	4.4	3.6	2.8	2.0	1.4
Bipolar Memory	0.9	0.9	0.7	0.5	0.3	0.2	0.2
Bipolar Logic	7.5	4.8	3.8	3.1	2.4	1.8	1.3
MOS	38.9	43.3	43.2	45.7	49.4	54.4	55.2
MOS Memory	11.2	14.4	11.4	11.7	12.4	13.5	13.2
MOS Micro	10.2	10.1	11.0	11.4	12.0	13.9	14.5
MOS Logic	17.5	18.8	20.8	22.5	24.9	27.1	27.5
Analog	19.1	20.4	21.7	23.0	21.9	21.3	22.7
Discrete	28.4	25.9	26.1	23.6	22.4	19.3	17.8
Opto	5.2	4.8	4.6	4.2	3.6	3.0	2.9

Source: Dataquest (July 1990)

Table 7

Forecast North American Electronic Equipment Production
Security/Energy Management
(Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR (%) 1989-1990	CAGR (%) 1989-1994
Factory Revenue	2,393	2,506	2,639	2,822	3,020	3,203	3,397	5.3	6.3

Source: Dataquest (July 1990)

Table 8

Forecast North American Merchant Semiconductor Revenue
Security/Energy Management
(Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR (%) 1989-1990	CAGR (%) 1989-1994
Total Semiconductor	134	148	157	189	232	297	341	5.7	18.1
Total IC	94	112	122	154	196	261	307	9.1	22.4
Bipolar Digital	0	0	0	0	0	0	0	NA	NA
Bipolar Memory	0	0	0	0	0	0	0	NA	NA
Bipolar Logic	0	0	0	0	0	0	0	NA	NA
MOS	52	64	70	90	122	171	199	9.3	25.5
MOS Memory	10	13	10	11	13	17	17	(23.5)	6.5
MOS Micro	8	10	12	15	21	32	40	21.0	32.9
MOS Logic	34	42	49	64	87	122	142	16.7	27.8
Analog	41	48	52	65	74	90	107	8.7	17.6
Discrete	37	34	32	31	33	33	31	(4.7)	(1.7)
Opto	3	3	3	3	3	3	3	(3.7)	2.6

Source: Dataquest (July 1990)
NA = Not applicable

Table 9

Forecast North American Merchant Semiconductor Revenue
Security/Energy Management
(Input/Output Ratios, Percentage)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	5.6	5.9	5.9	6.7	7.7	9.3	10.0
Total IC	3.9	4.5	4.6	5.5	6.5	8.2	9.0
Bipolar Digital	0	0	0	0	0	0	0
Bipolar Memory	0	0	0	0	0	0	0
Bipolar Logic	0	0	0	0	0	0	0
MOS	2.2	2.6	2.7	3.2	4.0	5.3	5.9
MOS Memory	0.4	0.5	0.4	0.4	0.4	0.5	0.5
MOS Micro	0.3	0.4	0.4	0.5	0.7	1.0	1.2
MOS Logic	1.4	1.7	1.8	2.3	2.9	3.8	4.2
Analog	1.7	1.9	2.0	2.3	2.5	2.8	3.2
Discrete	1.5	1.3	1.2	1.1	1.1	1.0	0.9
Opto	0.1	0.1	0.1	0.1	0.1	0.1	0.1

Source: Dataquest (July 1990)

Table 10

Forecast North American Electronic Equipment Production
Security/Energy Management
(Annual Percentage Growth)

	1989	1990	1991	1992	1993	1994
Factory Revenue	4.7	5.3	6.9	7.0	6.1	6.1

Source: Dataquest (July 1990)

Table 11

Forecast North American Merchant Semiconductor Revenue
Security/Energy Management
(Annual Percentage Growth)

	1989	1990	1991	1992	1993	1994
Total Semiconductor	10.8	5.7	20.3	23.0	28.1	14.7
Total IC	19.1	9.1	26.6	27.0	33.4	17.3
Bipolar Digital	NA	NA	NA	NA	NA	NA
Bipolar Memory	NA	NA	NA	NA	NA	NA
Bipolar Logic	NA	NA	NA	NA	NA	NA
MOS	21.9	9.3	28.5	35.3	40.7	16.4
MOS Memory	32.4	(23.5)	13.8	20.5	27.6	2.2
MOS Micro	15.2	21.0	30.9	36.3	54.1	24.5
MOS Logic	20.6	16.7	30.8	37.7	39.5	16.3
Analog	15.6	8.7	24.2	15.3	21.4	18.9
Discrete	(9.1)	(4.7)	(2.3)	5.5	(1.1)	(5.4)
Opto	(2.9)	(3.7)	4.9	2.2	4.5	5.1

NA = Not applicable
Source: Dataquest (July 1990)

Table 12

Forecast North American Merchant Semiconductor Revenue
Security/Energy Management
(Percentage of Industrial)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	6.3	6.5	6.7	6.9	7.0	7.2	7.4
Total IC	6.7	7.0	7.5	7.8	8.0	8.1	8.3
Bipolar Digital	0	0	0	0	0	0	0
Bipolar Memory	0	0	0	0	0	0	0
Bipolar Logic	0	0	0	0	0	0	0
MOS	6.4	6.5	6.9	7.2	7.4	7.6	7.8
MOS Memory	4.1	3.9	3.7	3.4	3.2	3.1	2.9
MOS Micro	3.9	4.2	4.5	4.9	5.2	5.6	5.9
MOS Logic	9.3	9.7	10.0	10.3	10.6	10.9	11.1
Analog	10.3	10.3	10.3	10.2	10.2	10.2	10.2
Discrete	6.2	5.7	5.2	4.8	4.4	4.1	3.7
Opto	2.9	2.8	2.8	2.7	2.7	2.6	2.6

Source: Dataquest (July 1990)

Table 13

Forecast North American Merchant Semiconductor Revenue
Security/Energy Management
(Percentage of Total Security/Energy Management)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total IC	70.0	75.3	77.7	81.8	84.4	87.9	89.9
Bipolar Digital	0	0	0	0	0	0	0
Bipolar Memory	0	0	0	0	0	0	0
Bipolar Logic	0	0	0	0	0	0	0
MOS	39.2	43.1	44.6	47.6	52.4	57.5	58.4
MOS Memory	7.2	8.6	6.2	5.9	5.8	5.7	5.1
MOS Micro	6.2	6.5	7.4	8.1	8.9	10.8	11.7
MOS Logic	25.7	28.0	30.9	33.6	37.7	41.0	41.6
Analog	30.9	32.2	33.1	34.2	32.0	30.4	31.5
Discrete	27.6	22.7	20.4	16.6	14.2	11.0	9.1
Opto	2.4	2.1	1.9	1.6	1.4	1.1	1.0

Source: Dataquest (July 1990)

Table 14

Forecast North American Electronic Equipment Production
Manufacturing Systems
(Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR (%) 1989-1990	CAGR (%) 1989-1994
Factory Revenue	15,200	16,286	16,965	18,538	20,106	21,484	22,976	4.2	7.1

Source: Dataquest (July 1990)

Table 15

Forecast North American Merchant Semiconductor Revenue
Manufacturing Systems
(Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR (%) 1989-1990	CAGR (%) 1989-1994
Total Semiconductor	838	882	894	1,040	1,268	1,615	1,809	1.4	15.4
Total IC	517	573	585	720	917	1,247	1,437	2.2	20.2
Bipolar Digital	118	84	66	60	54	48	36	(21.7)	(15.6)
Bipolar Memory	15	15	11	9	7	6	5	(22.3)	(20.5)
Bipolar Logic	103	69	54	51	47	42	31	(21.5)	(14.7)
MOS	315	392	415	531	715	1,021	1,192	5.9	24.9
MOS Memory	90	131	110	138	183	258	290	(15.9)	17.2
MOS Micro	111	120	137	169	216	313	366	13.8	24.9
MOS Logic	114	140	168	224	316	451	536	19.4	30.7
Analog	84	96	104	128	147	177	209	7.9	16.7
Discrete	264	253	254	261	291	303	302	0.4	3.6
Opto	57	56	55	59	61	65	69	(2.2)	4.1

Source: Dataquest (July 1990)

Table 16

Forecast North American Merchant Semiconductor Revenue
Manufacturing Systems
(Input/Output Ratios, Percentage)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	5.5	5.4	5.3	5.6	6.3	7.5	7.9
Total IC	3.4	3.5	3.4	3.9	4.6	5.8	6.3
Bipolar Digital	0.8	0.5	0.4	0.3	0.3	0.2	0.2
Bipolar Memory	0.1	0.1	0.1	0	0	0	0
Bipolar Logic	0.7	0.4	0.3	0.3	0.2	0.2	0.1
MOS	2.1	2.4	2.4	2.9	3.6	4.8	5.2
MOS Memory	0.6	0.8	0.7	0.7	0.9	1.2	1.3
MOS Micro	0.7	0.7	0.8	0.9	1.1	1.5	1.6
MOS Logic	0.7	0.9	1.0	1.2	1.6	2.1	2.3
Analog	0.6	0.6	0.6	0.7	0.7	0.8	0.9
Discrete	1.7	1.6	1.5	1.4	1.4	1.4	1.3
Opto	0.4	0.3	0.3	0.3	0.3	0.3	0.3

Source: Dataquest (July 1990)

Table 17

Forecast North American Electronic Equipment Production
Manufacturing Systems
(Annual Percentage Growth)

	1989	1990	1991	1992	1993	1994
Factory Revenue	7.1	4.2	9.3	8.5	6.9	6.9

Source: Dataquest (July 1990)

Table 18

Forecast North American Merchant Semiconductor Revenue
Manufacturing Systems
(Annual Percentage Growth)

	1989	1990	1991	1992	1993	1994
Total Semiconductor	5.3	1.4	16.3	22.0	27.3	12.0
Total IC	10.9	2.2	23.0	27.3	36.0	15.3
Bipolar Digital	(28.3)	(21.7)	(8.5)	(9.7)	(11.2)	(25.4)
Bipolar Memory	0.2	(22.3)	(20.0)	(19.0)	(17.3)	(23.6)
Bipolar Logic	(32.4)	(21.5)	(6.1)	(8.0)	(10.3)	(25.6)
MOS	24.4	5.9	28.0	34.7	42.8	16.7
MOS Memory	45.7	(15.9)	25.2	32.6	40.5	12.5
MOS Micro	8.3	13.8	23.1	28.2	44.9	17.0
MOS Logic	23.3	19.4	33.8	40.8	42.7	19.0
Analog	14.8	7.9	23.3	14.4	20.6	18.1
Discrete	(4.2)	0.4	3.0	11.2	4.3	(0.3)
Opto	(1.4)	(2.2)	6.5	3.8	6.1	6.8

Source: Dataquest (July 1990)

Table 19

Forecast North American Merchant Semiconductor Revenue Manufacturing Systems (Percentage of Industrial)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	39.6	38.6	38.2	37.9	38.2	38.9	39.0
Total IC	36.8	36.1	36.1	36.3	37.3	38.6	39.1
Bipolar Digital	66.0	65.0	63.5	61.6	59.6	57.6	55.5
Bipolar Memory	73.9	72.9	71.9	70.8	69.7	68.5	67.3
Bipolar Logic	65.0	63.5	61.9	60.2	58.3	56.3	54.1
MOS	38.3	39.6	41.0	42.4	43.7	45.2	46.6
MOS Memory	38.2	39.8	41.4	43.0	44.5	46.0	47.5
MOS Micro	51.5	52.3	53.1	53.7	54.1	54.4	54.4
MOS Logic	30.8	32.6	34.4	36.3	38.2	40.1	42.0
Analog	20.9	20.7	20.5	20.4	20.2	20.0	19.9
Discrete	43.9	42.7	41.5	40.3	39.1	37.9	36.6
Opto	51.6	51.6	51.6	51.7	51.7	51.6	51.6

Source: Dataquest (July 1990)

Table 20

Forecast North American Merchant Semiconductor Revenue Manufacturing Systems (Percentage of Total Manufacturing Systems)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total IC	61.7	64.9	65.4	69.2	72.3	77.2	79.5
Bipolar Digital	14.0	9.6	7.4	5.8	4.3	3.0	2.0
Bipolar Memory	1.8	1.7	1.3	0.9	0.6	0.4	0.3
Bipolar Logic	12.3	7.9	6.1	4.9	3.7	2.6	1.7
MOS	37.6	44.5	46.4	51.1	56.4	63.3	65.9
MOS Memory	10.8	14.9	12.4	13.3	14.5	16.0	16.0
MOS Micro	13.3	13.6	15.3	16.2	17.0	19.4	20.2
MOS Logic	13.6	15.9	18.7	21.6	24.9	27.9	29.0
Analog	10.0	10.9	11.6	12.3	11.6	11.0	11.6
Discrete	31.5	28.6	28.4	25.1	22.9	18.8	16.7
Opto	6.8	6.4	6.2	5.7	4.8	4.0	3.8

Source: Dataquest (July 1990)

Table 21

Forecast North American Electronic Equipment Production
Instrumentation
(Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR (%) 1989-1990	CAGR (%) 1989-1994
Factory Revenue	7,774	8,122	8,436	9,142	9,683	10,136	10,614	3.9	5.5

Source: Dataquest (July 1990)

Table 22

Forecast North American Merchant Semiconductor Revenue
Instrumentation
(Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR (%) 1989-1990	CAGR (%) 1989-1994
Total Semiconductor	328	359	364	423	510	631	692	1.5	14.0
Total IC	202	231	229	276	338	443	492	(0.6)	16.3
Bipolar Digital	20	16	15	16	17	17	15	(9.1)	(1.5)
Bipolar Memory	1	1	1	1	1	1	1	(13.3)	(11.2)
Bipolar Logic	19	15	14	15	16	17	14	(8.7)	(0.8)
MOS	145	170	165	196	246	330	360	(3.2)	16.2
MOS Memory	49	69	57	70	90	123	136	(17.9)	14.3
MOS Micro	61	61	65	74	88	118	129	5.6	15.9
MOS Logic	35	39	43	53	68	88	96	9.1	19.4
Analog	37	44	50	64	76	95	117	12.2	21.3
Discrete	109	110	118	129	152	168	178	6.6	10.0
Opto	18	17	17	18	19	20	22	(1.9)	4.5

Source: Dataquest (July 1990)

Table 23

Forecast North American Merchant Semiconductor Revenue
Instrumentation
(Input/Output Ratios, Percentage)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	4.2	4.4	4.3	4.6	5.3	6.2	6.5
Total IC	2.6	2.8	2.7	3.0	3.5	4.4	4.6
Bipolar Digital	0.3	0.2	0.2	0.2	0.2	0.2	0.1
Bipolar Memory	0	0	0	0	0	0	0
Bipolar Logic	0.2	0.2	0.2	0.2	0.2	0.2	0.1
MOS	1.9	2.1	2.0	2.1	2.5	3.3	3.4
MOS Memory	0.6	0.9	0.7	0.8	0.9	1.2	1.3
MOS Micro	0.8	0.8	0.8	0.8	0.9	1.2	1.2
MOS Logic	0.5	0.5	0.5	0.6	0.7	0.9	0.9
Analog	0.5	0.5	0.6	0.7	0.8	0.9	1.1
Discrete	1.4	1.4	1.4	1.4	1.6	1.7	1.7
Opto	0.2	0.2	0.2	0.2	0.2	0.2	0.2

Source: Dataquest (July 1990)

Table 24

Forecast North American Electronic Equipment Production
Instrumentation
(Annual Percentage Growth)

	1989	1990	1991	1992	1993	1994
Factory Revenue	4.5	3.9	8.4	5.9	4.7	4.7

Source: Dataquest (July 1990)

Table 25

Forecast North American Merchant Semiconductor Revenue Instrumentation (Annual Percentage Growth)

	1989	1990	1991	1992	1993	1994
Total Semiconductor	9.2	1.5	16.1	20.5	23.9	9.6
Total IC	14.1	(0.6)	20.3	22.7	30.7	11.1
Bipolar Digital	(19.4)	(9.1)	7.6	5.9	3.7	(13.6)
Bipolar Memory	11.8	(13.3)	(10.7)	(9.6)	(7.7)	(14.7)
Bipolar Logic	(21.4)	(8.7)	9.2	7.0	4.4	(13.5)
MOS	17.5	(3.2)	19.1	25.3	34.3	9.1
MOS Memory	42.2	(17.9)	22.2	29.4	37.1	9.8
MOS Micro	0.5	5.6	14.2	18.9	34.5	8.6
MOS Logic	12.7	9.1	22.2	28.6	30.3	8.7
Analog	19.3	12.2	28.1	18.9	25.3	22.7
Discrete	1.7	6.6	9.3	18.1	10.7	5.8
Opto	(1.1)	(1.9)	6.9	4.1	6.4	7.1

Source: Dataquest (July 1990)

Table 26

Forecast North American Merchant Semiconductor Revenue Instrumentation (Percentage of Industrial)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	15.5	15.7	15.6	15.4	15.4	15.2	14.9
Total IC	14.4	14.5	14.1	13.9	13.8	13.7	13.4
Bipolar Digital	11.3	12.5	14.2	16.2	18.4	20.8	23.2
Bipolar Memory	6.0	6.6	7.2	8.0	8.7	9.6	10.5
Bipolar Logic	12.0	13.6	15.5	17.5	19.7	22.1	24.7
MOS	17.6	17.2	16.3	15.6	15.0	14.6	14.1
MOS Memory	20.7	21.0	21.3	21.6	21.8	22.0	22.2
MOS Micro	28.3	26.7	25.1	23.6	22.1	20.6	19.1
MOS Logic	9.5	9.2	8.8	8.5	8.2	7.8	7.5
Analog	9.2	9.5	9.8	10.1	10.4	10.8	11.1
Discrete	18.1	18.7	19.3	19.9	20.5	21.0	21.6
Opto	15.8	15.9	15.9	16.0	16.0	16.1	16.1

Source: Dataquest (July 1990)

Table 27

Forecast North American Merchant Semiconductor Revenue Instrumentation (Percentage of Total Instrumentation)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total IC	61.6	64.4	63.0	65.2	66.4	70.1	71.1
Bipolar Digital	6.1	4.5	4.1	3.8	3.3	2.8	2.2
Bipolar Memory	0.4	0.4	0.3	0.2	0.2	0.1	0.1
Bipolar Logic	5.8	4.2	3.7	3.5	3.1	2.6	2.1
MOS	44.1	47.4	45.2	46.4	48.2	52.3	52.0
MOS Memory	14.8	19.3	15.6	16.4	17.7	19.6	19.6
MOS Micro	18.6	17.1	17.8	17.5	17.3	18.8	18.6
MOS Logic	10.7	11.0	11.8	12.4	13.3	14.0	13.8
Analog	11.3	12.4	13.7	15.1	14.9	15.1	16.9
Discrete	33.1	30.8	32.3	30.5	29.8	26.7	25.8
Opto	5.4	4.8	4.7	4.3	3.7	3.2	3.1

Source: Dataquest (July 1990)

Table 28

Forecast North American Electronic Equipment Production Medical Equipment (Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR (%) 1989-1990	CAGR (%) 1989-1994
Factory Revenue	5,785	6,117	6,485	6,896	7,171	7,530	7,916	6.0	5.3

Source: Dataquest (July 1990)

Table 29

Forecast North American Merchant Semiconductor Revenue
Medical Equipment
(Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR (%) 1989-1990	CAGR (%) 1989-1994
Total Semiconductor	305	341	351	415	501	623	697	3.0	15.4
Total IC	216	254	261	319	392	505	575	3.0	17.8
Bipolar Digital	0	0	0	0	0	0	0	NA	NA
Bipolar Memory	0	0	0	0	0	0	0	NA	NA
Bipolar Logic	0	0	0	0	0	0	0	NA	NA
MOS	132	157	156	189	243	325	362	(0.3)	18.2
MOS Memory	37	50	39	46	56	73	76	(22.0)	8.6
MOS Micro	10	13	17	24	35	58	78	30.9	43.7
MOS Logic	84	93	100	120	152	194	207	7.1	17.3
Analog	84	97	105	130	149	180	213	8.2	17.0
Discrete	77	76	79	85	97	105	108	3.9	7.2
Opto	11	11	11	12	12	13	14	(1.7)	4.7

NA = Not applicable
Source: Dataquest (July 1990)

Table 30

Forecast North American Merchant Semiconductor Revenue
Medical Equipment
(Input/Output Ratios, Percentage)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	5.3	5.6	5.4	6.0	7.0	8.3	8.8
Total IC	3.7	4.1	4.0	4.6	5.5	6.7	7.3
Bipolar Digital	0	0	0	0	0	0	0
Bipolar Memory	0	0	0	0	0	0	0
Bipolar Logic	0	0	0	0	0	0	0
MOS	2.3	2.6	2.4	2.7	3.4	4.3	4.6
MOS Memory	0.6	0.8	0.6	0.7	0.8	1.0	1.0
MOS Micro	0.2	0.2	0.3	0.3	0.5	0.8	1.0
MOS Logic	1.5	1.5	1.5	1.7	2.1	2.6	2.6
Analog	1.5	1.6	1.6	1.9	2.1	2.4	2.7
Discrete	1.3	1.2	1.2	1.2	1.4	1.4	1.4
Opto	0.2	0.2	0.2	0.2	0.2	0.2	0.2

Source: Dataquest (July 1990)

Table 31

Forecast North American Electronic Equipment Production
Medical Equipment
(Annual Percentage Growth)

	1989	1990	1991	1992	1993	1994
Factory Revenue	5.7	6.0	6.3	4.0	5.0	5.1

Source: Dataquest (July 1990)

Table 32

Forecast North American Merchant Semiconductor Revenue
Medical Equipment
(Annual Percentage Growth)

	1989	1990	1991	1992	1993	1994
Total Semiconductor	12.0	3.0	18.2	20.6	24.4	11.8
Total IC	17.3	3.0	22.3	22.7	29.1	13.7
Bipolar Digital	NA	NA	NA	NA	NA	NA
Bipolar Memory	NA	NA	NA	NA	NA	NA
Bipolar Logic	NA	NA	NA	NA	NA	NA
MOS	18.7	(0.3)	21.4	28.2	34.1	11.2
MOS Memory	35.1	(22.0)	16.0	22.9	30.2	4.3
MOS Micro	24.6	30.9	41.6	47.5	66.7	34.6
MOS Logic	10.7	7.1	20.1	26.4	28.0	6.8
Analog	15.1	8.2	23.6	14.7	20.9	18.4
Discrete	(0.9)	3.9	6.5	15.0	7.9	3.1
Opto	(0.9)	(1.7)	7.1	4.3	6.6	7.3

NA = Not applicable
Source: Dataquest (July 1990)

Table 33

Forecast North American Merchant Semiconductor Revenue
Medical Equipment
(Percentage of Industrial)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	14.4	14.9	15.0	15.1	15.1	15.0	15.0
Total IC	15.4	16.0	16.1	16.1	15.9	15.7	15.6
Bipolar Digital	0	0	0	0	0	0	0
Bipolar Memory	0	0	0	0	0	0	0
Bipolar Logic	0	0	0	0	0	0	0
MOS	16.0	15.8	15.4	15.1	14.8	14.4	14.1
MOS Memory	15.8	15.3	14.7	14.2	13.6	13.1	12.5
MOS Micro	4.7	5.5	6.5	7.5	8.7	10.1	11.6
MOS Logic	22.8	21.7	20.5	19.4	18.3	17.3	16.3
Analog	20.9	20.8	20.7	20.6	20.5	20.4	20.2
Discrete	12.8	12.9	13.0	13.1	13.1	13.1	13.1
Opto	10.1	10.2	10.2	10.3	10.3	10.4	10.5

Source: Dataquest (July 1990)

Table 34

Forecast North American Merchant Semiconductor Revenue
Medical Equipment
(Percentage of Total Medical Equipment)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total IC	71.0	74.3	74.3	76.8	78.1	81.1	82.5
Bipolar Digital	0	0	0	0	0	0	0
Bipolar Memory	0	0	0	0	0	0	0
Bipolar Logic	0	0	0	0	0	0	0
MOS	43.3	45.9	44.4	45.6	48.4	52.2	51.9
MOS Memory	12.3	14.8	11.2	11.0	11.2	11.7	10.9
MOS Micro	3.4	3.7	4.7	5.7	6.9	9.3	11.2
MOS Logic	27.7	27.4	28.5	28.9	30.3	31.2	29.8
Analog	27.7	28.5	29.9	31.2	29.7	28.9	30.6
Discrete	25.3	22.4	22.6	20.4	19.4	16.8	15.5
Opto	3.7	3.3	3.1	2.8	2.4	2.1	2.0

Source: Dataquest (July 1990)

Table 35

Forecast North American Electronic Equipment Production
Civil Aerospace
(Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR (%) 1989-1990	CAGR (%) 1989-1994
Factory Revenue	7,116	8,149	9,411	10,807	12,228	13,694	15,347	15.5	13.5

Source: Dataquest (July 1990)

Table 36

Forecast North American Merchant Semiconductor Revenue
Civil Aerospace
(Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR (%) 1989-1990	CAGR (%) 1989-1994
Total Semiconductor	241	255	253	292	342	417	453	(0.7)	12.2
Total IC	204	217	213	249	293	363	396	(1.6)	12.8
Bipolar Digital	40	29	23	22	20	18	14	(20.1)	(13.8)
Bipolar Memory	4	4	3	3	2	2	2	(19.8)	(17.9)
Bipolar Logic	36	25	20	19	18	16	12	(20.2)	(13.2)
MOS	98	115	113	134	168	222	239	(1.6)	15.9
MOS Memory	28	38	30	35	44	58	61	(21.1)	9.9
MOS Micro	25	26	28	33	40	54	60	7.8	18.4
MOS Logic	45	51	55	67	85	110	118	8.2	18.4
Analog	65	73	77	93	105	123	143	5.7	14.3
Discrete	31	31	33	35	41	45	48	5.6	8.9
Opto	7	7	7	7	8	8	9	0.1	6.6

Source: Dataquest (July 1990)

Table 37

Forecast North American Merchant Semiconductor Revenue
Civil Aerospace
(Input/Output Ratios, Percentage)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	3.4	3.1	2.7	2.7	2.8	3.0	2.9
Total IC	2.9	2.7	2.3	2.3	2.4	2.7	2.6
Bipolar Digital	0.6	0.4	0.2	0.2	0.2	0.1	0.1
Bipolar Memory	0.1	0.1	0	0	0	0	0
Bipolar Logic	0.5	0.3	0.2	0.2	0.1	0.1	0.1
MOS	1.4	1.4	1.2	1.2	1.4	1.6	1.6
MOS Memory	0.4	0.5	0.3	0.3	0.4	0.4	0.4
MOS Micro	0.4	0.3	0.3	0.3	0.3	0.4	0.4
MOS Logic	0.6	0.6	0.6	0.6	0.7	0.8	0.8
Analog	0.9	0.9	0.8	0.9	0.9	0.9	0.9
Discrete	0.4	0.4	0.3	0.3	0.3	0.3	0.3
Opto	0.1	0.1	0.1	0.1	0.1	0.1	0.1

Source: Dataquest (July 1990)

Table 38

Forecast North American Electronic Equipment Production
Civil Aerospace
(Annual Percentage Growth)

	1989	1990	1991	1992	1993	1994
Factory Revenue	14.5	15.5	14.8	13.1	12.0	12.1

Source: Dataquest (July 1990)

Table 39

Forecast North American Merchant Semiconductor Revenue
Civil Aerospace
(Annual Percentage Growth)

	1989	1990	1991	1992	1993	1994
Total Semiconductor	5.5	(0.7)	15.6	17.1	22.0	8.5
Total IC	6.4	(1.6)	16.9	17.5	24.1	9.0
Bipolar Digital	(27.8)	(20.1)	(6.4)	(7.7)	(9.4)	(24.0)
Bipolar Memory	3.4	(19.8)	(17.4)	(16.4)	(14.6)	(21.2)
Bipolar Logic	(31.3)	(20.2)	(4.5)	(6.5)	(8.7)	(24.3)
MOS	16.4	(1.6)	19.1	25.3	31.8	8.0
MOS Memory	36.6	(21.1)	17.4	24.4	31.7	5.5
MOS Micro	2.6	7.8	16.6	21.4	37.3	10.9
MOS Logic	11.7	8.2	21.2	27.6	29.2	7.8
Analog	12.4	5.7	20.7	12.1	18.1	15.6
Discrete	0.7	5.6	8.2	16.9	9.6	4.8
Opto	0.9	0.1	9.0	6.2	8.6	9.3

Source: Dataquest (July 1990)

Table 40

Forecast North American Merchant Semiconductor Revenue
Civil Aerospace
(Percentage of Industrial)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	11.4	11.1	10.8	10.6	10.3	10.0	9.8
Total IC	14.5	13.7	13.1	12.6	11.9	11.3	10.8
Bipolar Digital	22.7	22.5	22.4	22.2	22.0	21.7	21.3
Bipolar Memory	20.2	20.5	20.9	21.3	21.6	21.9	22.2
Bipolar Logic	23.0	22.8	22.6	22.4	22.0	21.6	21.2
MOS	12.0	11.6	11.2	10.7	10.3	9.8	9.4
MOS Memory	11.8	11.5	11.2	10.9	10.6	10.3	10.0
MOS Micro	11.7	11.3	10.8	10.4	9.9	9.4	8.9
MOS Logic	12.3	11.8	11.3	10.8	10.3	9.8	9.3
Analog	16.1	15.7	15.2	14.8	14.4	14.0	13.6
Discrete	5.1	5.2	5.4	5.5	5.6	5.7	5.8
Opto	5.9	6.1	6.2	6.3	6.5	6.6	6.8

Source: Dataquest (July 1990)

Table 41

Forecast North American Merchant Semiconductor Revenue
Civil Aerospace
(Percentage of Total Civil Aerospace)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total IC	84.5	85.2	84.4	85.4	85.6	87.1	87.5
Bipolar Digital	16.7	11.4	9.2	7.5	5.9	4.4	3.1
Bipolar Memory	1.7	1.6	1.3	0.9	0.7	0.5	0.3
Bipolar Logic	15.0	9.8	7.9	6.5	5.2	3.9	2.7
MOS	40.8	45.1	44.7	46.0	49.2	53.2	52.9
MOS Memory	11.5	14.9	11.9	12.1	12.8	13.8	13.4
MOS Micro	10.5	10.2	11.0	11.1	11.6	13.0	13.3
MOS Logic	18.8	20.0	21.7	22.8	24.8	26.3	26.2
Analog	26.9	28.7	30.6	31.9	30.6	29.6	31.5
Discrete	12.8	12.2	13.0	12.1	12.1	10.9	10.5
Opto	2.7	2.6	2.6	2.5	2.2	2.0	2.0

Source: Dataquest (July 1990)

Table 42

Forecast North American Electronic Equipment Production
Other Industrial
(Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR (%) 1989-1990	CAGR (%) 1989-1994
Factory Revenue	5,356	5,719	6,053	6,537	6,991	7,467	7,980	5.8	6.9

Source: Dataquest (July 1990)

Table 43

Forecast North American Merchant Semiconductor Revenue Other Industrial (Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR (%) 1989-1990	CAGR (%) 1989-1994
Total Semiconductor	269	303	321	385	465	569	645	6.2	16.3
Total IC	170	201	212	263	321	408	470	5.6	18.5
Bipolar Digital	0	0	0	0	0	0	0	NA	NA
Bipolar Memory	0	0	0	0	0	0	0	NA	NA
Bipolar Logic	0	0	0	0	0	0	0	NA	NA
MOS	79	94	93	113	145	190	206	(0.2)	17.1
MOS Memory	22	28	20	22	25	31	30	(27.2)	1.3
MOS Micro	0	0	0	0	0	0	0	NA	NA
MOS Logic	57	65	73	91	119	159	176	11.3	21.9
Analog	91	107	119	150	176	218	264	10.7	19.7
Discrete	84	87	95	107	129	146	158	9.2	12.6
Opto	15	15	14	15	15	16	17	(3.8)	2.4

NA = Not applicable
Source: Dataquest (July 1990)

Table 44

Forecast North American Merchant Semiconductor Revenue Other Industrial (Input/Output Ratios, Percentage)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	5.0	5.3	5.3	5.9	6.7	7.6	8.1
Total IC	3.2	3.5	3.5	4.0	4.6	5.5	5.9
Bipolar Digital	0	0	0	0	0	0	0
Bipolar Memory	0	0	0	0	0	0	0
Bipolar Logic	0	0	0	0	0	0	0
MOS	1.5	1.6	1.5	1.7	2.1	2.5	2.6
MOS Memory	0.3	0.3	0.2	0.2	0.2	0.2	0.2
MOS Micro	0	0	0	0	0	0	0
MOS Logic	0.8	0.8	0.8	0.8	1.0	1.2	1.1
Analog	1.3	1.3	1.3	1.4	1.4	1.6	1.7
Discrete	1.2	1.1	1.0	1.0	1.1	1.1	1.0
Opto	0.2	0.2	0.2	0.1	0.1	0.1	0.1

Source: Dataquest (July 1990)

Table 45

Forecast North American Electronic Equipment Production
Other Industrial
(Annual Percentage Growth)

	1989	1990	1991	1992	1993	1994
Factory Revenue	6.8	5.8	8.0	6.9	6.8	6.9

Source: Dataquest (July 1990)

Table 46

Forecast North American Merchant Semiconductor Revenue
Other Industrial
(Annual Percentage Growth)

	1989	1990	1991	1992	1993	1994
Total Semiconductor	12.4	6.2	19.6	20.9	22.5	13.2
Total IC	17.9	5.6	24.1	22.0	27.0	15.3
Bipolar Digital	NA	NA	NA	NA	NA	NA
Bipolar Memory	NA	NA	NA	NA	NA	NA
Bipolar Logic	NA	NA	NA	NA	NA	NA
MOS	18.1	(0.2)	21.2	28.1	31.0	8.7
MOS Memory	26.0	(27.2)	8.2	14.7	21.5	(2.7)
MOS Micro	NA	NA	NA	NA	NA	NA
MOS Logic	15.0	11.3	24.8	31.4	33.0	11.0
Analog	17.7	10.7	26.4	17.4	23.6	21.1
Discrete	4.1	9.2	11.9	20.9	13.3	8.3
Opto	(3.0)	(3.8)	4.8	2.1	4.3	5.0

NA = Not applicable
Source: Dataquest (July 1990)

Table 47

Forecast North American Merchant Semiconductor Revenue Other Industrial (Percentage of Industrial)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	12.7	13.2	13.7	14.0	14.0	13.7	13.9
Total IC	12.1	12.7	13.1	13.3	13.1	12.6	12.8
Bipolar Digital	0	0	0	0	0	0	0
Bipolar Memory	0	0	0	0	0	0	0
Bipolar Logic	0	0	0	0	0	0	0
MOS	9.6	9.4	9.2	9.0	8.8	8.4	8.1
MOS Memory	9.5	8.5	7.7	6.9	6.2	5.5	4.9
MOS Micro	0	0	0	0	0	0	0
MOS Logic	15.4	15.2	15.0	14.7	14.4	14.1	13.8
Analog	22.6	23.0	23.4	23.8	24.2	24.7	25.1
Discrete	13.9	14.7	15.6	16.4	17.3	18.2	19.2
Opto	13.7	13.4	13.2	13.0	12.8	12.6	12.4

Source: Dataquest (July 1990)

Table 48

Forecast North American Merchant Semiconductor Revenue Other Industrial (Percentage of Total Other Industrial)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total IC	63.3	66.3	66.0	68.4	69.1	71.6	72.9
Bipolar Digital	0	0	0	0	0	0	0
Bipolar Memory	0	0	0	0	0	0	0
Bipolar Logic	0	0	0	0	0	0	0
MOS	29.4	30.9	29.0	29.4	31.2	33.3	32.0
MOS Memory	8.3	9.3	6.4	5.8	5.5	5.4	4.7
MOS Micro	0	0	0	0	0	0	0
MOS Logic	21.1	21.6	22.7	23.7	25.7	27.9	27.4
Analog	33.8	35.4	36.9	39.0	37.9	38.3	40.9
Discrete	31.1	28.8	29.6	27.7	27.7	25.6	24.5
Opto	5.6	4.9	4.4	3.9	3.3	2.8	2.6

Source: Dataquest (July 1990)

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 manufacturing equipment covered within this section:

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

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

MANUFACTURING AUTOMATION OVERVIEW

Market Forecast and Issues

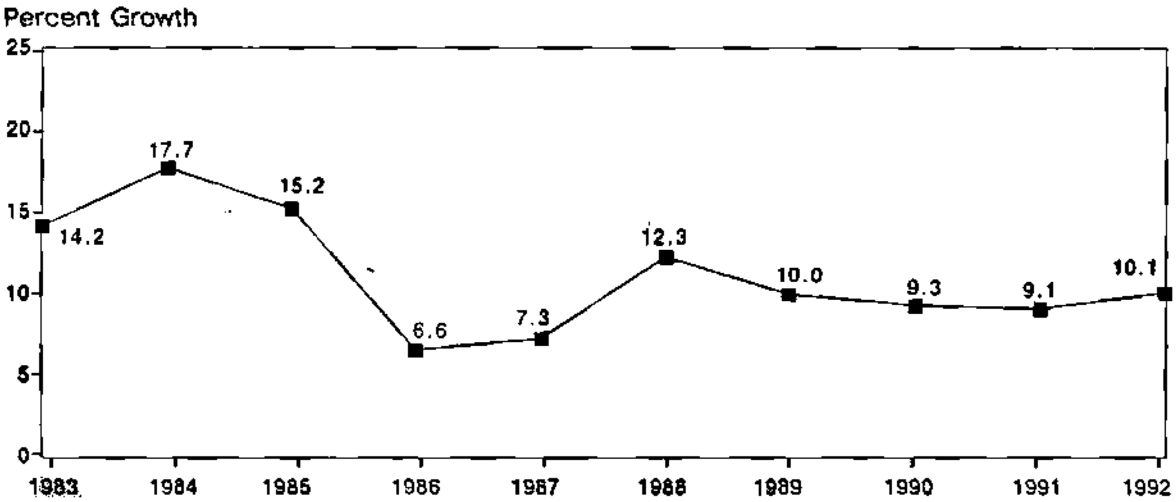
As illustrated in Figure 1, market growth should rise sharply through 1991. Manufacturing automation buyers have been slow to adopt new technology as a result of the following factors:

- 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

- 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

North American Manufacturing Automation Market
Estimated Annual Growth Rates in Factory Revenue
1983–1992



0004312-1

Source: Dataquest
July 1989

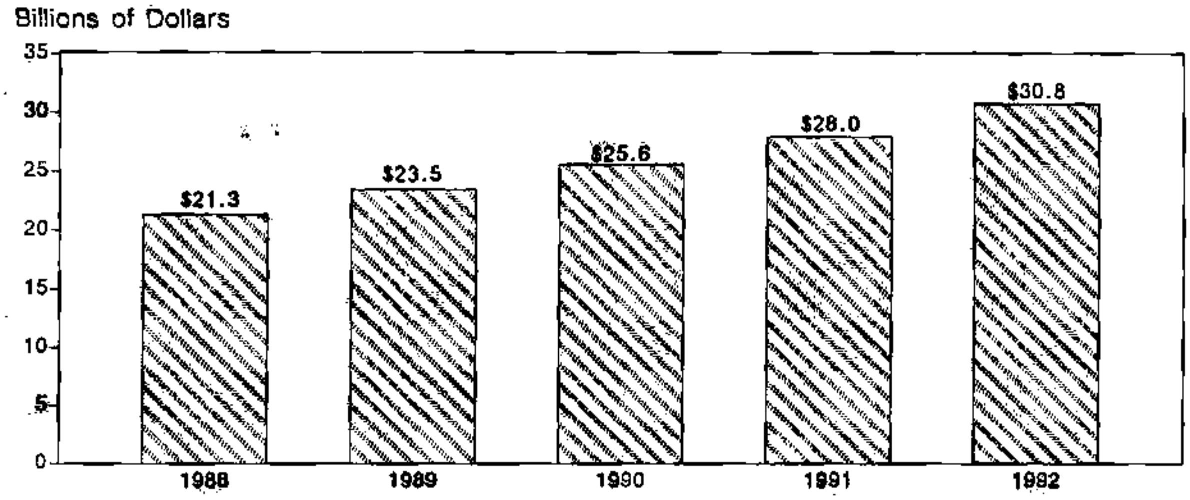
Dataquest believes that the U.S. manufacturing automation market will experience accelerated growth rates in factory revenue, as shown in Figure 2. The reasons for these increases are as follows:

- 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

- 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 2

North American Manufacturing Automation Market
Estimated Factory Revenue
1988–1992



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Source: Dataquest
July 1989

Top Ten Vendors

Table 1 lists the estimated 1987 manufacturing automation revenue for the top 10 North American vendors. Dataquest estimates that the total North American revenue for 1987 was $19.0 billion, excluding the CAD/CAE segment, which accounted for an additional $3.8 billion.

Table 1

Top 10 North American Manufacturing Automation Vendors by Estimated Factory Revenue 1987 (Millions of Dollars)

Vendor	Computers	Software	DC/ Networks	Manuf. Systems	Total Revenue	Market Share
IBM	$1,453	$ 301	$ 0	$ 7	$ 1,761	9.3%
Digital Equipment	1,065	0	15	0	1,080	5.7
Honeywell	38	10	0	690	738	3.9
Hewlett-Packard	261	20	1	254	536	2.8
Fisher Controls	0	0	0	525	525	2.8
Cincinnati Milacron	0	0	0	487	487	2.6
Unisys	453	14	0	0	467	2.5
Litton Industries	0	0	0	444	444	2.3
Cross & Trecker	0	0	0	336	336	1.8
Allen-Bradley	271	0	5	0	276	1.5
Other	807	1,341	472	9,744	12,364	65.0
Total	$4,348	$1,686	$493	$12,487	$19,014	100.0%
Segment Share	22.9%	8.8%	2.6%	65.7%	100.0%	

Source: Dataquest
July 1989

Trends in Manufacturing Automation

The following pages discuss the largest North American vendors in order according to their total automation share positions in 1987.

IBM Corporation

In terms of total North American manufacturing automation revenue, which includes hardware, software, networks and factory floor equipment, IBM continues to lead the market.

Digital Equipment Corporation

During 1987, Digital Equipment saw outstanding growth in revenue.

Many developments contributed to this growth, including the following:

- A product line that is compatible from the largest to smallest computer
- The slow start of factory LAN standards, which drove end users to seek vendors with total hardware compatibility

Honeywell, Inc.

Honeywell's strategic exit from the data processing industry has focused increased attention on the care businesses of process control systems and industrial automation developments for the discrete piece industries. For example, Honeywell's Process Control Division is one of the leaders in distributed process control systems.

Honeywell's North American market share position grew from 1.2 percent in 1986 to 3.9 percent in 1987, in part because of improved capital equipment investments by the chemical and petroleum industries. Honeywell has long been a leading supplier of control systems to these, and other, process industries.

Hewlett-Packard Company

Hewlett-Packard ranks fourth in North American revenue share position, with 1987 total sales of $537 million. Hewlett-Packard has one of the most diverse product lines of any North American supplier, with strengths in automatic test systems, computer hardware, and applications software packages.

HP has stressed a strategy of open architecture with its automation products.

Fisher Controls Division of Monsanto Corporation

In 1987, the Fisher Controls Division of Monsanto reported worldwide process control systems revenue of $750 million. Of that total, 70 percent, or $525 million, represented sales to North American end users, including the parent company.

The company's major automation revenue comes from the PRoVOX distributed control system. Fisher Controls has gained revenue in part by leveraging its long-standing dominant control valve market share.

Cincinnati Milacron Corporation

Revenue growth from the plastics machinery group of Cincinnati Milacron was responsible for most of the growth of 38.7 percent in 1987 over 1986. Revenue from the metalworking machine tool and the robotics group suffered from the depressed sales of these product segments in North America during 1987.

Unisys Corporation

Unisys has gained market share position during 1987, from 1.0 percent in 1986 to 2.5 percent. The Univac and Burroughs merger caused significant management changes and strategic redirection. One area that Unisys is stressing is the role of manufacturing, particularly with medium- to smaller-sized organizations. Plans for the establishment of automation centers in Detroit and Houston has resulted in increased automation revenue from the motor vehicle and areospace industries.

Litton Industries, Inc.

Litton's acquisitions of major suppliers of factory floor equipment—such as Lamb Technicon (programmable machine tools), automated material handling systems suppliers, and systems integration capabilities (Integrated Automation Systems, Inc.)—have resulted in Litton's becoming a powerful North American vendor. Dataquest expects continued growth as the domestic market for automated systems grows in 1988 and 1989.

Cross & Trecker Corporation

Cross & Trecker ranks ninth, with 1.8 percent market share in 1987, down somewhat from the 2.3 percent share it held in 1986. Its machine tool products and its CNC, DNC, and FMS products give the company a strong base for expanding into other manufacturing automation segments, such as material handling systems and robotics. The decline in 1987 was primarily a result of reductions in machine tool investments in the motor vehicle industry and the general North American vendor malaise in machine tool revenue in 1987 as foreign competition from Japan and West Germany in particular continue to plague domestic vendors.

Allen-Bradley Division of Rockwell International

Allen-Bradley, a division of Rockwell International, ranked tenth in 1987, down from its market share position in 1986. Its revenue is derived mainly from its leadership position in the PLC subsegment. The decline in 1987 revenue followed the down shifting of expenditure for PLCs in the motor vehicle market, particularly at General Motors, where Allen-Bradley had been strong in prior years.

Trends in Manufacturing Automation

Technology Trends

There are several evolving technologies that will affect 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 the following:

- 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)

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 as a result of advances in both graphic algorithms and semiconductor technology. Graphics can be an important tool in importing skilled characteristics to unskilled workers.

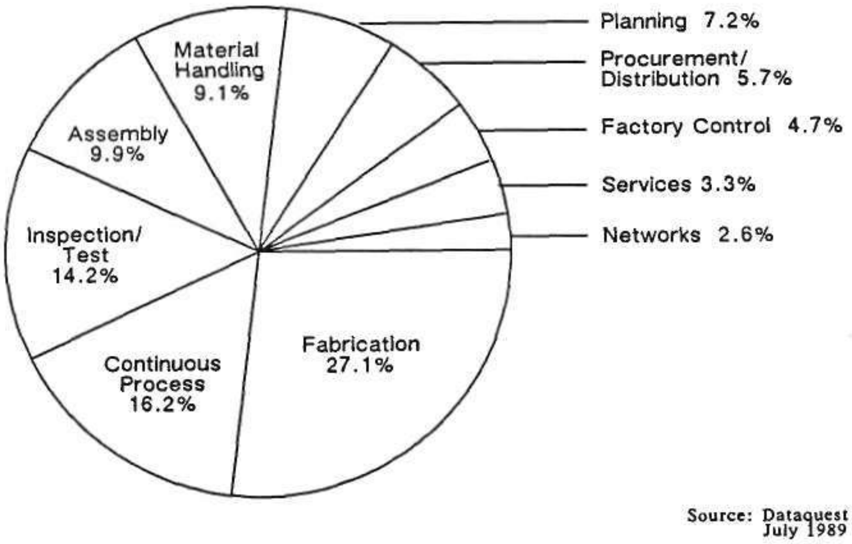
PCs are becoming as common on the factory floor as they are in the office. Both general-purpose PCs and specialty systems based on off-the-shelf microprocessor board components will be increasingly used at the cell and workstation level for applications in both operations and logistics. The 32-bit microcomputer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

This section presents Dataquest's forecast of North American manufacturing automation revenue by application.

As Figure 3 indicates, fabrication was the largest application segment in 1987, accounting for 27.2 percent of all revenue. This segment includes metalworking machine tools, special machinery (e.g., plastics), and semiconductor fabrication equipment.

Figure 3

North American Manufacturing Automation Applications by User Expenditures 1987



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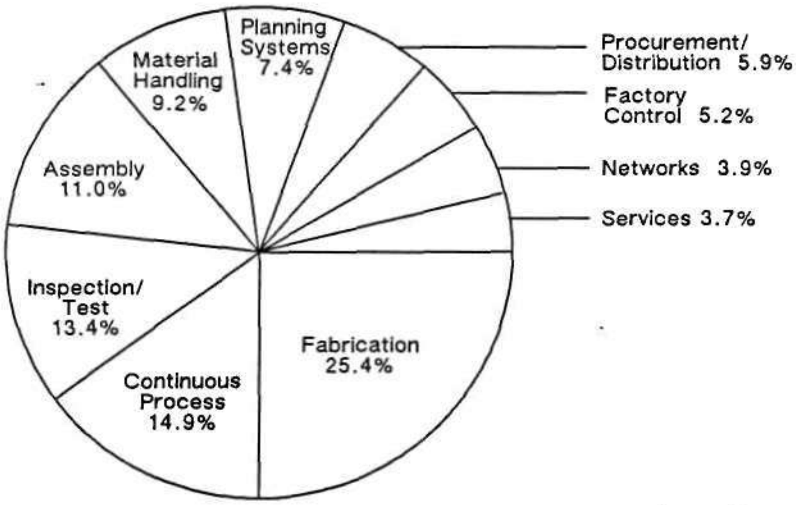
Source: Dataquest July 1989

Continuous process control systems and inspection/test systems were the other largest segments. These revenue reflect improvement in process industry investments in 1987 and the discrete piece industry emphasis on product quality improvement as a competitive necessity. Taken together, these three segments represent considerably more than half the North American market revenue.

Dataquest forecasts that, by 1992, fabrication, continuous process and inspection/test applications will remain the largest market revenue segments. However, their share of total revenue will have decreased from 57.6 percent in 1987 to 53.7 percent in 1992. Assembly automation and factory control systems will gain a larger share of the revenue, as shown in Figure 4.

Figure 4

North American Manufacturing Automation Applications by User Expenditures



0004312-4

Source: Dataquest July 1989

INDUSTRY SHARES

Table 2 shows Dataquests' revenue forecast by industry for 1988 to 1992. The electrical/electronics industry leads all other industry segments in growth, and will rank second only to the motor vehicle industry in absolute revenue by 1992.

Table 2

North American Manufacturing Automation
Revenue Forecast by Industry
1988-1992
(Millions of Dollars)

Industry	1988	1989	1990	1991	1992
Aerospace	$1,958	$1,967	$1,944	$2,037	$ 2,275
Motor Vehicle	$7,287	$8,137	$8,823	$9,220	$10,291
Fab. Prod./Machinery	$2,860	$3,154	$3,633	$3,747	$ 4,182
Electric/Electronic	$3,339	$3,861	$4,580	$5,450	$ 6,083
Other Dis. Piece	$1,230	$1,520	$1,785	$1,959	$ 2,087
Food/Beverage	$ 599	$ 676	$ 765	$ 875	$ 976
Chem./Petroleum	$2,560	$2,667	$2,711	$3,159	$ 3,526
Other Process	$1,507	$1,559	$1,616	$2,081	$ 2,423

Source: Dataquest
July 1989

For market forecasts, please refer to the Electronic Equipment Forecast section of the Semiconductor Application Markets (SAM) binder.

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.

Companies and Market Structure

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.

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

Technology Trends

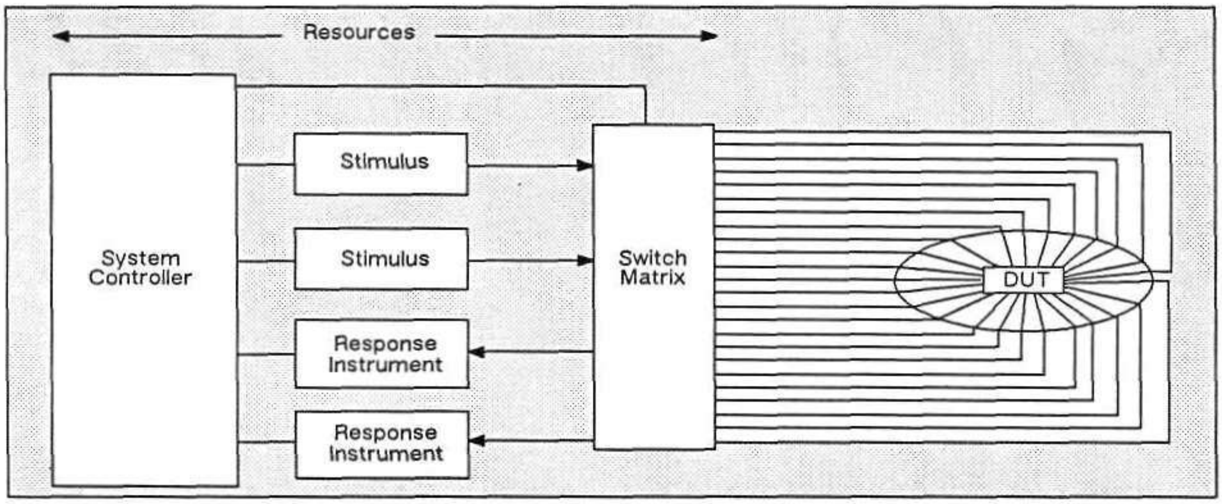
Trends in Device Testing

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 5. 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 5

IC Test: Shared-Resource Architecture



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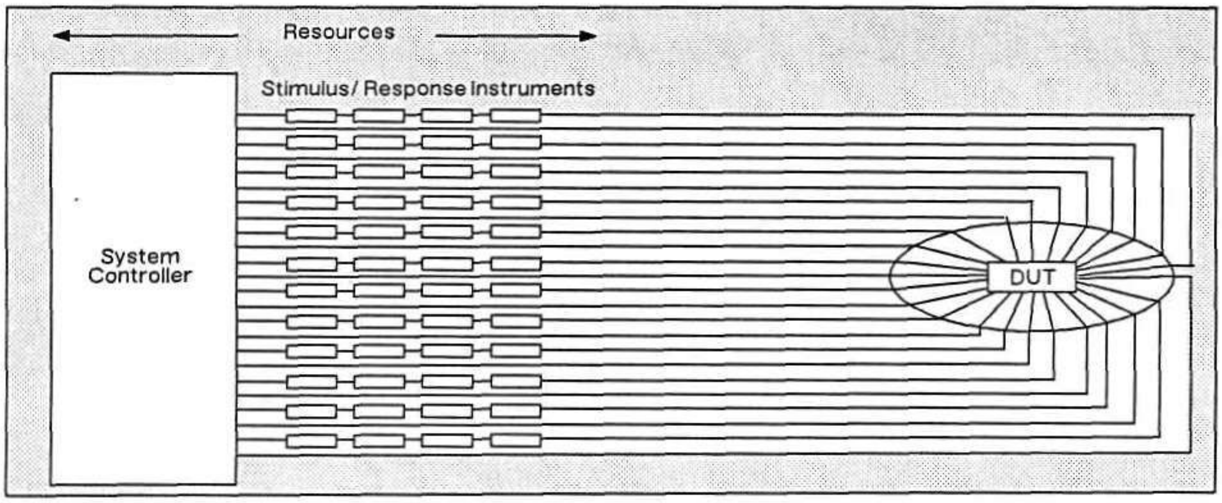
Source: Electronics Test August 1986

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 6. 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 6

IC Test: Tester-per-Pin Architecture



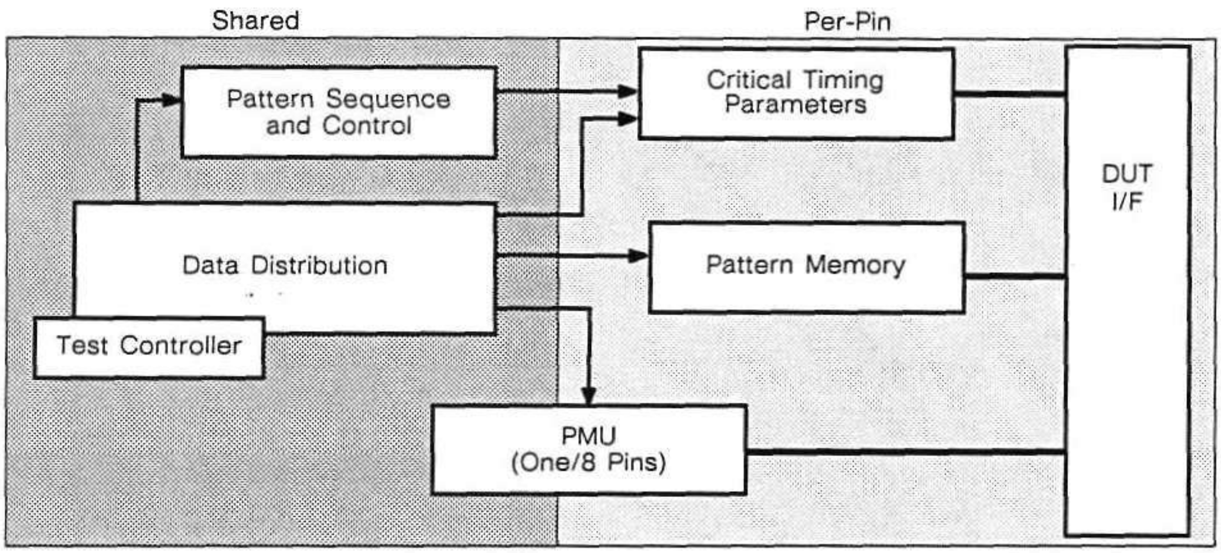
0004312-6

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 7. 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 7

IC Test: Mixed Architecture



0004312-7

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

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

Trends in Manufacturing Automation

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.

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.

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 approximately 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.

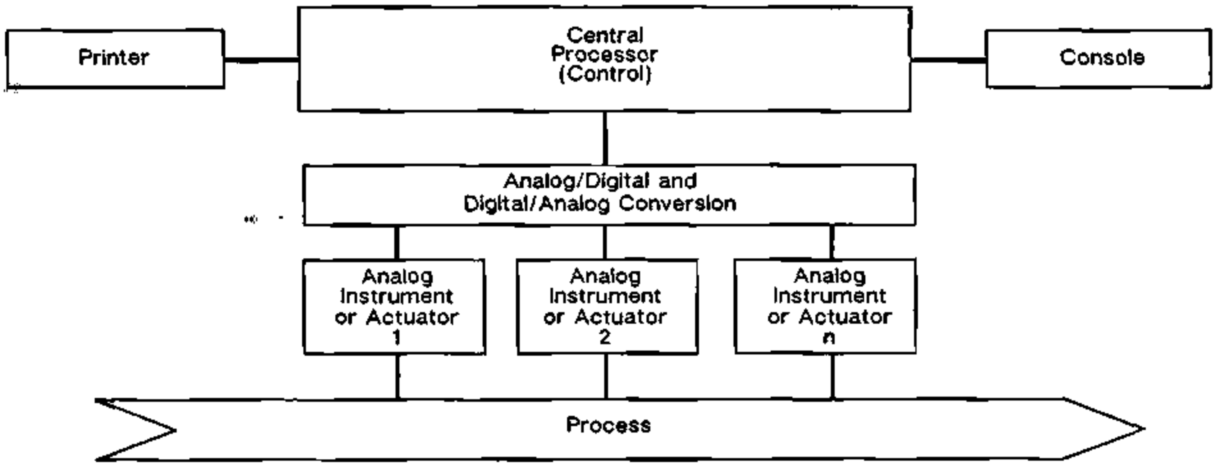
Characteristics of EPC

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 8 and 9 diagram the architecture of these two types of control systems.

Figure 8

Direct Digital Control



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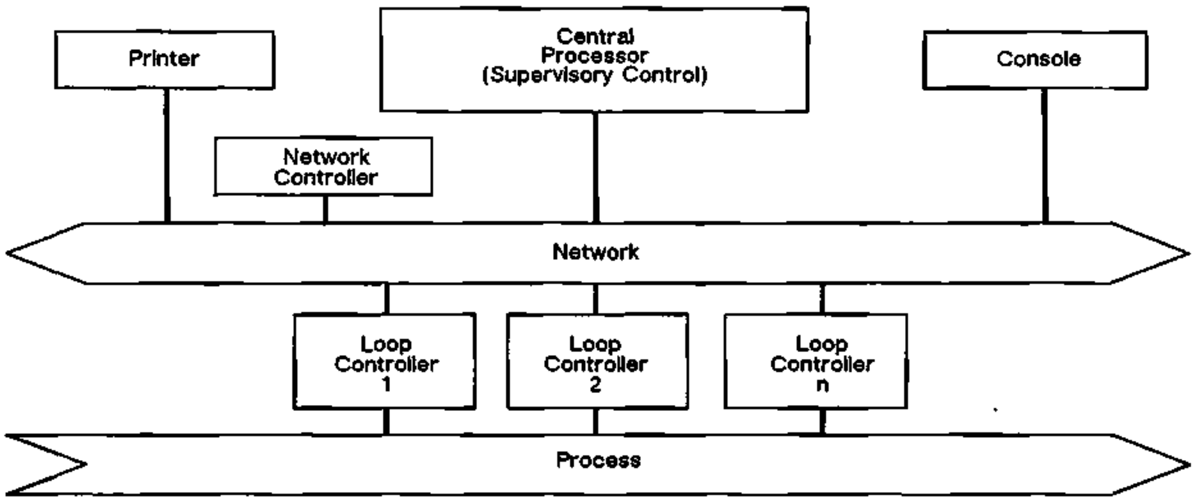
Source: Dataquest July 1989

Figure 9

Distributed Digital Control



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Source: Dataquest
July 1989

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 generally are 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.

Trends in Manufacturing Automation

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.

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 also may 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 more 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.

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 as follows:

- 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.

Trends in Manufacturing Automation

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

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 because of 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.

USER REQUIREMENTS

Dataquest recently conducted a survey of systems integration organizations in the United States to determine common user issues and desired vendor attributes. Table 3 lists the issues, ranked in order of response. The responses indicate that a major need exists for vendors to educate users about manufacturing automation in general, what is required to implement the systems, and how to develop specifications that properly define users' application requirements.

Table 4 lists the systems integrators' perceptions of desired vendor attributes. By far the greatest need is for vendor service and support. This attribute underscores the need for manufacturing automation vendors to provide additional field support beyond what has traditionally been needed in the computer industry. This conclusion is further emphasized by the second-highest desired vendor attribute of dependability and delivery assurance. Systems integrators are often contractually required to pay penalties if they do not meet their installation commitments. Of course, they depend upon the original vendors' deliveries if they expect to meet users' schedule requirements.

Table 3

North American Manufacturing Automation Market
User Issues
1988

Issue	Percent of Responses	Percent of Cases
Lack of Knowledge	19.0%	40.0%
Unable to Take Over System	13.4%	28.2%
Insufficient Specifications	10.6%	22.4%
Do Not Know Own Needs	8.9%	18.8%
Lack of Commitment/Cooperation	7.8%	16.5%
Unrealistic Expectations	6.7%	14.1%
Lack of Internal Communications	5.6%	11.8%
Price Limitations	5.0%	10.6%
Other	23.0%	48.2%

Source: Dataquest
July 1989

Table 4

North American Manufacturing Automation Market
Desired Vendor Attributes
1988

Attribute	Percent of Responses	Percent of Cases
Service and Support	27.6%	66.3%
Dependability and Delivery	12.7%	30.5%
Lowest Price	11.8%	28.4%
Technical Support	9.2%	22.1%
Involvement in Installation	5.3%	12.6%
Availability	4.8%	11.6%
Better Documentation	4.8%	11.6%
Local Representation	4.4%	10.5%
Responsiveness	3.9%	9.5%
Other	15.5%	28.9%

Source: Dataquest
July 1989

Trends in Medical Electronics

INTRODUCTION

The medical electronic equipment area continues to be of interest. It represents more than 15 percent of the industrial application market sector. With hundreds of equipment types and a multitude of manufacturers, the medical electronics field has been shrouded in confusion with respect to market analyses.

This section comprises Dataquest's analysis of some of the key issues in this rapidly changing market, which is approaching $5.5 billion in size. We have been able to identify a comprehensive equipment segmentation that will provide a perspective from which to look at the aggregate market and extrapolate issues that are of interest to semiconductor manufacturers. In addition, we have chosen certain types of equipment that have historically created "high visibility and high interest markets" at which we have taken a more in-depth look.

MARKET OVERVIEW

Any market analysis pertaining to electronic equipment tends to revolve around certain basic issues, such as buyer demand, capital investment trends, or technology development. Each has its dynamics that hold a market back or act as a catalyst to push a market forward. Often government-related factors peripherally affect a market, but do not fit into a typical frame of reference when discussing any particular market.

At other times, however, government-related factors have direct effects on a market. For example, in automotive electronics, government regulations regarding emission control requirements and increases in average estimates for miles per gallon were key forces affecting the competitiveness of domestic automobile manufacturers. Faced with opposing requirements, the manufacturers turned to solid-state electronics. Thus, when looking at automotive electronics and the automotive semiconductor market, it turns out that the federal government played a key role in positively affecting the market.

Similarly, in the medical electronic equipment market, fairly recent government legislation has played a major role in acting as a market force. In this case, however, federally mandated regulation has had an overall limiting effect, causing tremendous reevaluation in a discussion of most market dynamics.

Diagnosis-Related Groups (DRGs)

One of the most important developments affecting the medical electronics industry is Diagnosis-Related Groups (DRGs), an amendment to section 1886 of the Social Security Act. DRG legislation was passed by the federal government in the early 1980s in an attempt to curb historically runaway costs in federally subsidized medical and care programs. Being phased in over a three-year period that began October 1, 1983, the DRGs both limit and standardize the amount a hospital is reimbursed for treatment of Medicare patients who receive any one of 467 types of medical treatment.

The effects of the DRG reimbursement plan have varied across institutions. On one hand, hospitals may not be receiving full reimbursement for Medicare services if they have charged more than the standard reimbursement rate allowed for any given procedure listed in the DRGs. Conversely, hospitals are entitled to keep extra monies they receive if their services for any procedure costs less than the standard rate. This last measure was, of course, designed as an incentive for hospitals to cut their costs.

One positive effect of the PRG legislation is that it has caused certain types of medical care to be pushed outside of hospitals, where it can often be performed more cost effectively. An increasing number of clinics and diagnostic imaging centers, which are a function of this trend, have been emerging rapidly in the United States, providing a new market for many types of medical electronics. The downside of this new market is that these imaging centers cannot afford the high-priced systems hospitals had been purchasing in the past, causing manufacturers to reevaluate their product line strategies. Despite this, however, Dataquest believes that the DRGs' effects have been sweeping, and thus they have been detrimental to many emerging medical markets.

Table 1 reflects our current estimates for U.S. shipments of medical electronic equipment. Overall, forecast growth rates are modest; our total medical equipment estimate amounts to $5,577 million in 1987 and is forecast to grow at a 6.4 percent compound annual growth rate (CAGR) to $7,154 million in 1991. Within the aggregate, some equipment markets have generated quite a bit of interest, particularly those in the diagnostic imaging market sector. The following discussions cover each of these markets, beginning with pacemakers (in the therapeutic category) and followed by different types of diagnostic imaging equipment.

Table 1

ESTIMATED U.S. SHIPMENTS OF MEDICAL ELECTRONIC EQUIPMENT
(Millions of Dollars)

Equipment Type	1983	1984	1985	1986	1987
DIAGNOSTIC					
Auto. Blood Analyzer	$ 744	$ 724	$ 715	$ 787	$ 865
CAT Scanners	510	666	513	500	500
Digital Radiography	55	60	57	63	71
Electrocardiographs	72	118	96	98	106
Electroencephalographs	15	20	13	15	16
Nuclear Magnetic Resonance	69	81	155	420	505
Respiratory Analysis	16	17	15	15	16
Ultrasonic Scanners	376	294	187	211	232
X Ray	711	656	685	719	740
Other Diagnostic	291	254	263	276	280
Subtotal	$2,859	$2,890	$2,699	$3,104	$3,331
PATIENT-MONITORING	$ 659	$ 577	$ 640	$ 666	$ 699
PROSTHETIC					
Hearing Aids	$ 340	$ 363	$ 395	$ 419	$ 444
SURGICAL SUPPORT	$ 104	$ 130	$ 181	$ 217	$ 232
THERAPEUTIC					
Defibrillators	$ 86	$ 91	$ 104	$ 111	$ 117
Dialysis, Diathermy	73	65	71	74	78
Electrosurgical	64	81	80	79	83
Pacemakers	263	371	304	305	313
Ultrasonic Generators	18	32	27	25	27
Other Therapeutic	274	280	258	237	253
Subtotal	$ 778	$ 920	$ 844	$ 831	$ 871
Total Medical	$4,740	$4,880	$4,759	$5,237	$5,577

(Continued)

Table 1 (Continued)

ESTIMATED U.S. SHIPMENTS OF MEDICAL ELECTRONIC EQUIPMENT
(Millions of Dollars)

Equipment Type	1988	1989	1990	1991	CAGR 1987-1991
DIAGNOSTIC					
Auto. Blood Analyzer	$ 952	$1,047	$1,152	$1,267	10.0%
CAT Scanners	450	410	373	340	-9.2%
Digital Radiography	80	87	97	110	11.6%
Electrocardiographs	114	122	129	135	6.2%
Electroencephalographs	18	20	23	26	12.9%
Nuclear Magnetic Resonance	606	727	858	987	18.2%
Respiratory Analysis	16	16	17	18	3.0%
Ultrasonic Scanners	255	281	309	340	10.0%
X Ray	755	766	781	797	1.9%
Other Diagnostic	294	303	312	324	3.7%
Subtotal	$3,540	$3,779	$4,051	$4,344	6.9%
PATIENT-MONITORING	$ 741	$ 771	$ 817	$ 882	6.0%
PROSTHETIC					
Hearing Aids	$ 471	$ 500	$ 534	$ 570	6.4%
SURGICAL SUPPORT	$ 244	$ 249	$ 256	$ 271	4.0%
THERAPEUTIC					
Defibrillators	$ 126	$ 130	$ 135	$ 142	5.0%
Dialysis, Diathermy	85	87	89	92	4.2%
Electrosurgical	89	95	98	105	6.1%
Pacemakers	321	329	338	346	2.5%
Ultrasonic Generators	30	34	36	37	8.2%
Other Therapeutic	293	313	338	365	9.6%
Subtotal	$ 944	$ 988	$1,034	$1,087	5.7%
Total Medical	$5,940	$6,287	$6,692	$7,154	6.4%

Source: Dataquest
June 1987

Trends in Medical Electronics

IMPLANTABLE CARDIAC PACEMAKERS

The Market

The market for implantable cardiac pacemakers has grown from year to year largely due to technology upgrades for patients whose pacemakers became obsolete. During the first half of the 1980s, the pacemaker market grew at an estimated 21 percent CAGR, from approximately $258 million in 1981 to $376 million in 1983.

To date in 1987, however, industry leaders have noted a drop in implantable pacemaker sales. For several reasons, it is likely that a decline in market growth may last throughout the decade, with pacemakers experiencing as low as a 2 percent CAGR between 1987 and 1991.

Several factors are involved in the decline of the pacemaker market. Dataquest believes that the two most predominant factors having an impact on pacemakers have been Peer Review Organizations (PROs), which are another government attempt to control health care costs, and the DRGs.

The PROs' Effects

Peer Review Organizations, which began in October 1984, are state reviewing agencies that primarily are concerned with the medical necessity and quality of certain procedures and operations. The pacemaker market has been affected considerably by these agencies, which, after reviewing each pacemaker case separately, often rule that implantation is unnecessary. The result of this has been to reduce unit volume market growth in the United States. Early estimates of 1986 unit sales of implantable pacemakers into the United States are for approximately 105,000. This has caused more competition among the pacemaker manufacturers, who are now competing for fewer patients. Thus, ASPs have been declining. As a result, industry leaders expect some smaller manufacturers to drop out of the market over the next five years.

Price and cost cutting are all too often necessary to successfully compete in a tightening market. To reduce their own costs, pacemaker manufacturers have begun to produce less complicated pacemakers. Pacemakers that contain one instead of two ICs, for example, are becoming commonplace and have allowed some firms to reduce costs while still producing leading-edge technology. Pacemaker manufacturers cite increasing sophistication and integration of IC technology coupled with increasing price pressure in the semiconductor industry as the leading forces permitting this transition.

The DRGs' Effects

The DRGs have had a less drastic effect on the pacemaker market than have the PROs. We believe that this is due to the relatively low cost of the average pacemaker, which we believe is approximately $4,100. Pacemakers are affected by the standard treatment fee, however, so overall there has been increased hospital awareness about cost-effectively implementing the technology. DRGs have also had less of an effect on this market in comparison to other medical electronics. Measuring pacemaker necessity is relatively straightforward; the need for pacemakers is typically not as dispensable as many other types of sophisticated and more expensive medical equipment whose costs/benefits are not as easily justified under the DRGs.

Other Factors

Industry leaders commonly cite another interesting factor that is contributing to the forecast for slower growth in the pacemaker market--the American infatuation with exercise and nutrition that began emerging in the late 1970s and early 1980s. The medical community expects this fitness movement to have long-term effects on the pacemaker market, because of the associated reduction this lifestyle seems to have on heart disease.

A positive influence on the future of the pacemaker industry is the introduction of a completely new product, the implantable defibrillator. The implantable defibrillator treats a fast heartbeat and shocks a spasmatic heart back into its regular rhythm. This represents an untapped market for pacemaker manufacturers who, until now, produced devices that treated a slow-beating heart exclusively. At this time, one vendor has already received Food and Drug Administration approval to market an implantable defibrillator. This new product, coupled with the continuing increase of U.S. population over age 65, could override the moderating effects of the fitness movement and PROs on pacemaker sales. Overall, the issues are likely to meet somewhere in the middle, resulting in the slower market growth estimates of 2 to 3 percent CAGR from 1987 to 1991.

The Major Manufacturers

Major manufacturers in the pacemaker market include:

- Cardiac Pacemakers, Inc., St. Paul, Minnesota
- Cordis Corporation, Miami, Florida
- Intermedics, Inc., Freeport, Texas
- Medtronic, Inc., Minneapolis, Minnesota
- Pacesetter Systems, Inc., Sylmar, California

DIAGNOSTIC IMAGING EQUIPMENT

Dataquest believes that the diagnostic sector of the medical electronics industry will continue to be one of the most dynamic forces in the entire industry. Technological innovation and the development of new applications for some equipment types in the sector make it a constantly changing field. Well-known markets, such as CAT scanners, continue to face market pressure. Market estimates for diagnostic imaging equipment overall are somewhat low, with a 6.9 percent CAGR from $3,331 million in 1987 to $4,344 million in 1991.

CAT Scanners

As seen in Table 1, CAT (computerized axial tomography) scanners make up the third largest equipment sector within the diagnostic imaging market segment. The systems use X-ray technology to snapshot cross-sections of human organs such as the heart or brain, which typically are extremely difficult to analyze. The resulting X-ray images are composed into high-resolution graphic images, which are then used for analysis and diagnosis.

In the late 1970s, the CAT scanner market experienced a surge in growth because it was a miraculous new imaging device that medical experts had long needed and wanted. However, as early as 1983, the market for CAT scanners began to decline due to the maturing of the market itself, competition from other imaging systems, and, of course, the DRGs, which have had the heaviest effect on extremely expensive technologies like the CAT scanner.

The market for CAT scanners matured fairly quickly because of a typically low unit volume per institution. The current installed base has penetrated the majority of the market; most institutions that wanted, or could afford the investment, now own CAT scanners. At present, a large percentage of the CAT scanner market is the replacement market, with the average replacement taking place every five to six years. Because unit quantities are small, a five- to six-year time frame is inadequate to keep the market growing. One bright spot lies in the fact that CAT scanners are not destined to be an entirely replacement market. This has been fostered by the DRGs, which have spurred a small but continuing need for new scanners on the part of newly opened clinics and diagnostic centers. However, these clinics and diagnostic centers cannot afford the high-priced CAT scanners that large hospitals had purchased in the past. This situation is allowing overall CAT scanner unit sales to increase, while CAT scanner revenue is expected to decline 8 to 10 percent throughout the forecast period.

The Market

Dataquest expects the CAT scanner market to be flat in 1987 and to start declining in 1988. Overall, we believe that the market will decline about 9 percent per year from $465 million in 1985 to $285 million in 1991. We expect 1987 unit sales to be approximately 510 and believe that unit sales will decline between 2 and 3 percent per year. Prices of CAT scanners, which traditionally have ranged from $700,000 to $1.2 million, have been falling in anticipation of continued market pressure and competition; major manufacturers are citing prices as low as $700,000 for top-rated systems.

Competition with other types of imaging systems has had a negative effect on the CAT market. In 1983, a new imaging system, magnetic resonance (MR), was introduced. Though it is a different type of imager, with different capabilities and applications, it has proven to be a source of competition for the CAT since it is believed that certain CAT replacement decisions are being made with MR systems.

The Major Manufacturers

Major U.S. manufacturers include:

- General Electric Medical Systems, Milwaukee, Wisconsin
- Picker International, Highland Heights, Ohio

Major non-U.S. manufacturers include:

- Philips Medical Systems, Inc., Shelton, Connecticut
- Siemens, Iselin, New Jersey
- Toshiba Medical Systems, Tustin, California

Nuclear Magnetic Resonance

Nuclear magnetic resonance (MR) systems offer tremendous promise. The system, which emerged in 1983, offers tremendous potential as an imaging device because it has proven to be more successful than other diagnostic technologies in detecting certain types of tumors and neurological disorders. MR systems are able to detect early changes in metabolism that often occur before any noticeable changes in anatomy can be picked up by X rays.

Another major benefit of MR systems is that they do not rely on X-ray technology, which has been a long-time source of concern in the medical community. Thus, the systems are generally considered safer than other types of competitive technologies. Another promising aspect of the technology is its developers' continuing scientific interest and commitment to developing new applications that will allow the system to be used for a greater scope of diagnostic analyses.

The Market

Despite their strong potential, MR systems faced some barriers to early market entry and growth. In addition to their $1.3 to $2.2 million price tags, there are hidden costs associated with a purchase. Institutions often require special rooms to house the devices--rooms that have to be built because of the system's huge donut-shaped size, its 10-ton weight, its 10-foot height, and its 8-foot depth.

The MR system, which can produce a magnetic field 25,000 times stronger than that of the Earth, cannot be used on certain types of patients and thus will probably never entirely replace the CAT market. Patients dependent on life support, monitoring equipment, or emergency intervention with metal equipment cannot be brought near MRs. The system's use on pacemaker patients or on individuals with other forms of metal implantation is also prohibited.

Like other imaging technologies, the DRGs have also had an effect on the MR market, but to a lesser extent. Since MR technology is relatively new and offers so much potential, there is a greater willingness to make the investment in this technology compared with, and often instead of, its counterparts.

As mentioned earlier, because system applications are still being developed, and because its potential is still untapped, the expected MR market dynamics appear strong. Another encouraging factor is the downscaling currently undertaken by many manufacturers in an attempt to broaden the systems available market. These less-expensive systems are intended to capture the business of small clinics and institutions that cannot currently afford the MR systems' average selling price.

Overall, Dataquest believes that the market for this system will grow at an estimated 18.2 percent CAGR from $505 million in 1987 to $987 million in 1991. Unit sales for the system are estimated at 270 for 1986 and are expected to exceed 310 in 1987. Growth is expected to be more rapid throughout the remainder of the decade. At that time, the market is expected to level off due to market maturation and penetration.

The Major Manufacturers

Major U.S. manufacturers of magnetic resonance equipment include:

- Diasonics, Inc., Milpitas, California
- Fonar Corporation, Melville, New York
- General Electric Medical Systems, Milwaukee, Wisconsin
- Picker International, Highland Heights, Ohio

Major non-U.S. manufacturers include:

- Philips Medical Systems, Inc., Shelton, Connecticut
- Siemens, Iselin, New Jersey
- Technicare Corp., Solon, Ohio

X-Ray Equipment

Conventional medical X-ray equipment makes up approximately 34 percent of the medical imaging market. It is the largest and oldest medical imaging equipment market, and industry leaders expect it to remain the dominant imaging technology throughout the decade, though it may lose some market share due to competition with other emerging imaging technologies.

It is difficult to define the medical X-ray market because it comprises several different types of equipment, each of which has a different selling price and reacts differently to its own market dynamics and trends. Examples of specific types of X-ray equipment include basic radiographic, digital fluoroscopic, and cardiac X-ray.

The Market

Despite the difficulty of defining the complex medical X-ray market, projected overall growth estimates are for a 1.9 percent CAGR between 1987 and 1991. We believe that the market will be approximately $811 million in 1987, accounting for 10,000 to 12,000 units.

One major factor for this low growth rate is that the market's maturity now defines it as almost totally a replacement market. Virtually no medical institution can effectively operate without X-ray equipment, so the installed base, for the most part, has already been defined. The majority of new business comes from institutions needing to update or replace their equipment. A smaller portion of new business is also being generated by clinics and diagnostic imaging centers that are opening not only because of the DRGs but because of an overall effort by the public and private sector to reduce health care costs.

Several other factors have been important in the medical X-ray market, not the least of which is competition with other imaging technologies. Both the CAT scanner and the MR markets have reduced the market for X-ray equipment, which cannot provide the same type of analysis, or the quality of diagnostic functions, that either of its competing technologies are able to do. When forced to make a choice, many institutions with more than one X-ray system are choosing competitive technologies when replacement decisions arise.

Another issue affecting the market is the increasing "bad press" associated with X-ray technology. Physicians are increasingly reluctant to use the technology because of potentially harmful radiation exposure, and are recommending that X rays be given less frequently. Overall, industry participants believe that this is having a negative impact on the market.

A recent development in X-ray technology may assist in providing modest market growth. The introduction of digital radiography, a new computerized system that enhances and manipulates information obtained from conventional X-ray equipment, has helped focus new interest on the market. Dataquest estimates that digital radiography will grow from $71 million in 1987 to $110 million in 1991, an 11.6 percent CAGR. The cost of this system, which contains as much as 500 megabytes of memory, ranges between $250,000 and $1 million.

The Major Manufacturers

Major U.S. manufacturers of X-ray equipment include:

- ADAC Laboratories, Sunnyvale, California
- Andersen Group, Inc., Bloomfield, Connecticut
- Diasonics, Inc., Milpitas, California
- Picker International, Highland Heights, Ohio
- Raytheon Medical Systems, Lexington, Massachusetts
- Squibb Corporation, Princeton, New Jersey
- Xonics, Des Plaines, Illinois

Major non-U.S. manufacturers of X-ray equipment include:

- Philips Medical Systems, Inc., Shelton, Connecticut
- Siemens, Iselin, New Jersey
- Toshiba Medical Systems, Tustin, California

Diagnostic Ultrasound

The Market

The ultrasound imaging market is similar to the X-ray market in that there is a myriad of equipment types falling within the category, making it difficult to track and define. Despite the market complexity, there appears to be general consensus on overall market size and projections. Between 1987 and 1991 we expect a 10 percent CAGR, with sales estimates of $232 million in 1987 and $340 million in 1991. The 1987 unit sales projections are estimated at approximately 5,000 systems. Several factors make this segment very promising.

Ultrasound equipment does not appear to be in direct competition with other imaging technologies because it performs unique and different functions compared to its CAT, MR, and X-ray counterparts. The technology uses high-frequency sounds for imaging and diagnosis. One of the most popular applications for the technology, and to date its mainstay, has been obstetrics and pediatrics. According to the Electronics Industry Association (EIA), advancing technologies for this equipment are resulting in improved accuracy in detecting certain types of cancer, and in imaging such organs as the heart and kidney during particular types of operations.

Most institutions consider ultrasound technology indispensable, so the market has been fairly stable. Ultrasound systems change rapidly due to technological innovation and advancement. This, coupled with their lower cost, gives the systems shorter life expectancies of approximately three to five years before replacement. For these reasons, industry leaders have been pleasantly surprised to see that the DRGs have had little effect on the ultrasound market. However, pressure from foreign vendors has affected U.S. ultrasound vendors' sales.

Prices for ultrasound equipment vary depending on the number of transducers purchased with the system. Different transducers, which range between $5,000 and $8,000 in price, are needed to image different body parts. It is not unusual for an ultrasound system to have a large range of configurations. Nonetheless, system prices are much more affordable for hospitals, clinics, and even doctors' offices, which has made the market somewhat more resistant to the DRGs' effects.

The Major Manufacturers

Major U.S. manufacturers participating in the U.S. ultrasound market include:

- Advanced Tech Labs, Bellevue, Washington
- Biosound, Inc., Bloomfield, Connecticut
- Cooper Labs, Palo Alto, California
- Diasonics, Milpitas, California
- General Electric Medical Systems, Milwaukee, Wisconsin
- Picker International, Highland Heights, Ohio
- Hewlett-Packard Company, Palo Alto, California
- Honeywell, Minneapolis, Minnesota
- Johnson & Johnson, New Brunswick, New Jersey
- Squibb Corporation, Princeton, New Jersey

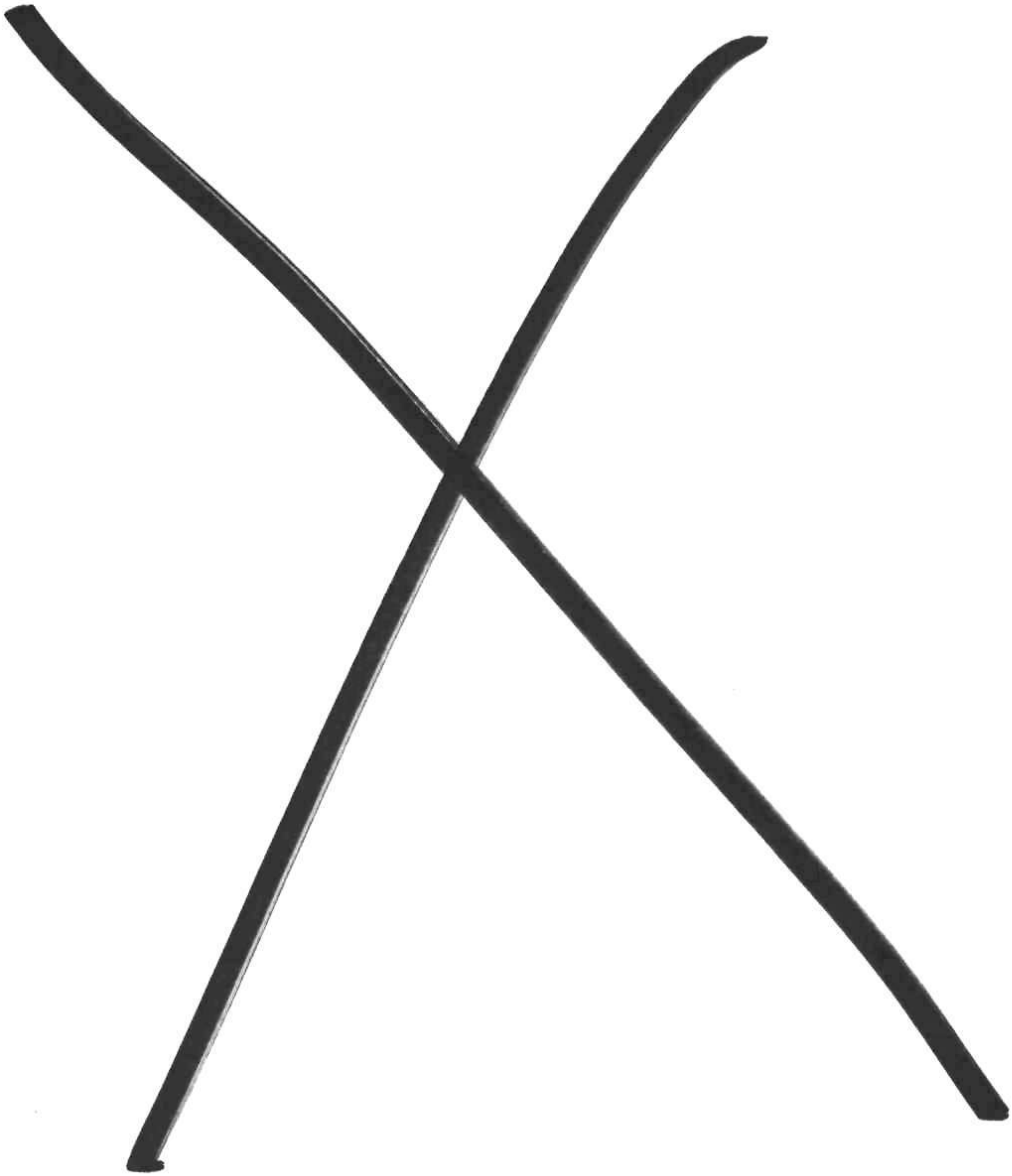
Major non-U.S. manufacturers participating in the U.S. ultrasound market include:

- Philips Ultrasound, Santa Ana, California
- Siemens, Iselin, New Jersey
- Toshiba Medical Systems, Tustin, California

DATAQUEST CONCLUSIONS

Traditional medicine is undergoing many dramatic changes, many of which are occurring in medical equipment and instrumentation. Changes in equipment have, of course, been allowed and continually fostered by semiconductor technology and computing power. The speed with which solid-state technology is incorporated by the medical field seems unending. Continual advances are being made in analytical capabilities, imaging, prosthetics, and artificial hearing, sight, and speech. According to the EIA, in the decade between 1975 and 1984, U.S. factory shipments of medical electronic equipment increased sevenfold. Overall, continued technological innovation is expected to provide the primary impetus to the market's future growth.

One market caveat, however, may continue to emerge; in keeping with the recent international trade imbalances facing so many other electronics markets, medical electronic equipment has also been affected. According to the EIA and the U.S. Industrial Outlook, U.S. exports of electromedical equipment increased by only a 4 percent annual rate from 1982 to 1985. Imports, however, rose at an average annual rate of 30 percent during the same period. Preliminary estimates for 1986 exports rose 9 percent, while imports increased 19 percent. While the numbers still reflect a U.S. surplus of approximately $14 million, the overall trend poses continual cause for concern, especially as many market segments are facing slower growth because of their market maturity alone. However, the recent weakening of the dollar against the Japanese yen and West German deutsche mark have begun to translate into increased exports for U.S. manufacturers. While new and fast-growing markets will continually emerge, no doubt fostered by advances in technology, we believe that competitive pressures must be taken into account when participating in this electronics marketplace.



Consumer

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

- Semiconductor Consumption Consumer
- Trends in Consumer Electronics

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Semiconductor Consumption—Consumer

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Table 1

Forecast North American Electronic Equipment Production Consumer (Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR (%) 1989-1990	CAGR (%) 1989-1994
Factory Revenue	19,970	20,457	20,986	21,598	22,239	22,789	23,372	2.6	2.7

Source: Dataquest (July 1990)

Table 2

Forecast North American Merchant Semiconductor Revenue Consumer (Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR (%) 1989-1990	CAGR (%) 1989-1994
Total Semiconductor	1,160	1,211	1,137	1,254	1,387	1,586	1,657	(6.1)	6.5
Total IC	911	963	881	980	1,073	1,246	1,304	(8.6)	6.2
Bipolar Digital	72	48	37	34	31	27	20	(24.4)	(16.2)
Bipolar Memory	4	4	3	2	2	1	1	(29.7)	(23.0)
Bipolar Logic	68	45	34	32	29	26	19	(23.9)	(15.7)
MOS	416	458	381	409	463	561	552	(16.9)	3.8
MOS Memory	206	259	188	203	234	286	280	(27.4)	1.6
MOS Micro	122	111	106	110	119	147	146	(4.3)	5.7
MOS Logic	89	89	87	95	110	129	126	(2.0)	7.2
Analog	423	457	463	537	579	658	732	1.4	9.9
Discrete	232	229	239	255	295	320	332	4.2	7.7
Opto	18	18	17	19	19	20	22	(7.1)	3.5

Source: Dataquest (July 1990)

Table 3

Forecast North American Merchant Semiconductor Revenue
Consumer
(Input/Output Ratios, Percentage)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	5.8	5.9	5.4	5.8	6.2	7.0	7.1
Total IC	4.6	4.7	4.2	4.5	4.8	5.5	5.6
Bipolar Digital	0.4	0.2	0.2	0.2	0.1	0.1	0.1
Bipolar Memory	0	0	0	0	0	0	0
Bipolar Logic	0.3	0.2	0.2	0.1	0.1	0.1	0.1
MOS	2.1	2.2	1.8	1.9	2.1	2.5	2.4
MOS Memory	1.0	1.3	0.9	0.9	1.1	1.3	1.2
MOS Micro	0.6	0.5	0.5	0.5	0.5	0.6	0.6
MOS Logic	0.4	0.4	0.4	0.4	0.5	0.6	0.5
Analog	2.1	2.2	2.2	2.5	2.6	2.9	3.1
Discrete	1.2	1.1	1.1	1.2	1.3	1.4	1.4
Opto	0.1	0.1	0.1	0.1	0.1	0.1	0.1

Source: Dataquest (July 1990)

Table 4

Forecast North American Electronic Equipment Production
Consumer
(Annual Percentage Change)

	1989	1990	1991	1992	1993	1994
Factory Revenue	2.4	2.6	2.9	3.0	2.5	2.6

Source: Dataquest (July 1990)

Table 5

Forecast North American Merchant Semiconductor Revenue
Consumer
(Annual Percentage Change)

	1989	1990	1991	1992	1993	1994
Total Semiconductor	4.4	(6.1)	10.3	10.6	14.4	4.5
Total IC	5.7	(8.6)	11.2	9.5	16.2	4.6
Bipolar Digital	(32.8)	(24.4)	(7.1)	(8.8)	(12.9)	(25.9)
Bipolar Memory	(7.5)	(29.7)	(23.1)	0	(50.0)	0
Bipolar Logic	(34.3)	(23.9)	(5.9)	(9.4)	(10.3)	(26.9)
MOS	10.1	(16.9)	7.2	13.3	21.3	(1.7)
MOS Memory	25.8	(27.4)	8.1	15.2	22.1	(2.0)
MOS Micro	(9.0)	(4.3)	4.0	8.0	23.4	(0.5)
MOS Logic	0	(2.0)	9.4	15.5	17.1	(2.2)
Analog	7.9	1.4	16.0	7.8	13.6	11.2
Discrete	(1.0)	4.2	6.7	15.7	8.5	3.7
Opto	4.6	(7.1)	11.8	0	5.3	8.5

Source: Dataquest (July 1990)

Table 6

Forecast North American Merchant Semiconductor Revenue
Consumer
(Percentage of Total Consumer)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total IC	78.5	79.6	77.5	78.1	77.4	78.6	78.7
Bipolar Digital	6.2	4.0	3.2	2.7	2.2	1.7	1.2
Bipolar Memory	0.3	0.3	0.2	0.2	0.1	0.1	0.1
Bipolar Logic	5.9	3.7	3.0	2.6	2.1	1.6	1.1
MOS	35.9	37.9	33.5	32.6	33.4	35.4	33.3
MOS Memory	17.7	21.4	16.5	16.2	16.9	18.0	16.9
MOS Micro	10.5	9.2	9.3	8.8	8.6	9.3	8.8
MOS Logic	7.7	7.3	7.7	7.6	7.9	8.1	7.6
Analog	36.5	37.7	40.7	42.8	41.7	41.5	44.2
Discrete	20.0	18.9	21.0	20.3	21.3	20.2	20.0
Opto	1.5	1.5	1.5	1.5	1.4	1.3	1.3

Source: Dataquest (July 1990)

Table 7

Forecast North American Electronic Equipment Production
Audio
(Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR (%) 1989-1990	CAGR (%) 1989-1994
Factory Revenue	279	285	292	299	306	311	318	2.5	2.2

Source: Dataquest (July 1990)

Table 8

Forecast North American Merchant Semiconductor Revenue
Audio
(Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR (%) 1989-1990	CAGR (%) 1989-1994
Total Semiconductor	15	15	15	16	18	20	21	(3.8)	7.2
Total IC	11	11	11	12	13	15	16	(6.2)	7.2
Bipolar Digital	1	0	0	0	0	0	0	(47.6)	(100.0)
Bipolar Memory	0	0	0	0	0	0	0	NM	NM
Bipolar Logic	1	0	0	0	0	0	0	(47.6)	(100.0)
MOS	4	4	4	4	4	5	5	(13.6)	4.3
MOS Memory	1	2	1	1	2	2	2	(27.6)	1.3
MOS Micro	2	1	1	1	2	2	2	(4.5)	5.5
MOS Logic	1	1	1	1	1	1	1	(1.7)	7.6
Analog	6	6	7	8	8	9	11	1.9	10.5
Discrete	4	4	4	4	5	5	5	3.8	7.2
Opto	0	0	0	0	0	0	0	(4.2)	6.7

NM = Not meaningful
Source: Dataquest (July 1990)

Table 9

Forecast North American Merchant Semiconductor Revenue Audio (Input/Output Ratios, Percentage)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	5.3	5.3	5.0	5.3	5.8	6.5	6.7
Total IC	3.9	3.9	3.6	3.9	4.2	4.8	5.0
Bipolar Digital	0.3	0.2	0.1	0	0	0	0
Bipolar Memory	0	0	0	0	0	0	0
Bipolar Logic	0.3	0.2	0.1	0	0	0	0
MOS	1.5	1.5	1.3	1.3	1.5	1.7	1.7
MOS Memory	0.5	0.6	0.4	0.5	0.5	0.6	0.6
MOS Micro	0.6	0.5	0.5	0.5	0.5	0.6	0.6
MOS Logic	0.4	0.3	0.3	0.4	0.4	0.5	0.4
Analog	2.1	2.3	2.2	2.6	2.7	3.0	3.3
Discrete	1.3	1.3	1.3	1.3	1.5	1.6	1.6
Opto	0.1	0.1	0.1	0.1	0.1	0.1	0.1

Source: Dataquest (July 1990)

Table 10

Forecast North American Electronic Equipment Production Audio (Annual Percentage Change)

	1989	1990	1991	1992	1993	1994
Factory Revenue	2.2	2.5	2.4	2.3	1.6	2.3

Source: Dataquest (July 1990)

Table 11

Forecast North American Merchant Semiconductor Revenue
Audio
(Annual Percentage Change)

	1989	1990	1991	1992	1993	1994
Total Semiconductor	1.6	(3.8)	10.0	10.6	13.9	6.1
Total IC	2.5	(6.2)	11.2	9.2	16.1	6.9
Bipolar Digital	(47.3)	(47.6)	(58.5)	(50.3)	(100.0)	NM
Bipolar Memory	NM	NM	NM	NM	NM	NM
Bipolar Logic	(47.3)	(47.6)	(58.5)	(50.3)	(100.0)	NM
MOS	5.3	(13.6)	6.8	12.5	21.1	(1.6)
MOS Memory	25.3	(27.6)	7.7	14.8	21.8	(2.3)
MOS Micro	(9.2)	(4.5)	3.8	7.8	23.2	(0.7)
MOS Logic	0.3	(1.7)	9.8	15.9	17.5	(1.9)
Analog	8.5	1.9	16.6	8.4	14.2	11.8
Discrete	(1.4)	3.8	6.2	15.2	8.0	3.2
Opto	7.8	(4.2)	15.2	3.1	8.5	11.9

NM = Not meaningful
Source: Dataquest (July 1990)

Table 12

Forecast North American Merchant Semiconductor Revenue
Audio
(Percentage of Consumer)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	1.3	1.2	1.3	1.3	1.3	1.3	1.3
Total IC	1.2	1.2	1.2	1.2	1.2	1.2	1.2
Bipolar Digital	1.3	1.0	0.7	0.3	0.2	0	0
Bipolar Memory	0	0	0	0	0	0	0
Bipolar Logic	1.4	1.1	0.8	0.3	0.2	0	0
MOS	1.0	0.9	1.0	1.0	1.0	1.0	1.0
MOS Memory	0.7	0.7	0.7	0.7	0.7	0.7	0.7
MOS Micro	1.4	1.4	1.3	1.3	1.3	1.3	1.3
MOS Logic	1.1	1.1	1.1	1.1	1.1	1.1	1.1
Analog	1.4	1.4	1.4	1.4	1.4	1.4	1.4
Discrete	1.6	1.6	1.6	1.6	1.6	1.6	1.6
Opto	1.3	1.3	1.4	1.4	1.4	1.5	1.5

Source: Dataquest (July 1990)

Table 13

Forecast North American Merchant Semiconductor Revenue Audio (Percentage of Total Audio)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total IC	73.6	74.3	72.4	73.2	72.3	73.7	74.3
Bipolar Digital	6.4	3.3	1.8	0.7	0.3	0	0
Bipolar Memory	0	0	0	0	0	0	0
Bipolar Logic	6.4	3.3	1.8	0.7	0.3	0	0
MOS	27.4	28.5	25.6	24.8	25.2	26.8	24.9
MOS Memory	9.7	12.0	9.0	8.8	9.2	9.8	9.0
MOS Micro	11.1	9.9	9.8	9.3	9.0	9.8	9.2
MOS Logic	6.6	6.6	6.7	6.7	7.0	7.2	6.7
Analog	39.8	42.5	45.0	47.7	46.8	46.9	49.4
Discrete	24.9	24.1	26.0	25.1	26.2	24.8	24.1
Opto	1.5	1.6	1.6	1.7	1.5	1.5	1.6

Source: Dataquest (July 1990)

Table 14

Forecast North American Electronic Equipment Production Video (Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR (%) 1989-1990	CAGR (%) 1989-1994
Factory Revenue	5,628	5,749	5,864	6,014	6,206	6,432	6,708	2.0	3.1

Source: Dataquest (July 1990)

Table 15

Forecast North American Merchant Semiconductor Revenue Video (Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR (%) 1989-1990	CAGR (%) 1989-1994
Total Semiconductor	346	359	340	374	415	472	494	(5.3)	6.6
Total IC	247	261	239	266	291	338	354	(8.5)	6.3
Bipolar Digital	19	12	9	8	7	6	4	(28.1)	(20.6)
Bipolar Memory	1	1	1	1	1	0	0	(32.0)	(25.2)
Bipolar Logic	18	11	8	7	6	5	4	(27.7)	(20.2)
MOS	110	121	101	109	123	150	148	(16.6)	4.1
MOS Memory	54	68	50	54	63	77	75	(27.1)	2.0
MOS Micro	32	29	28	29	32	39	39	(4.1)	6.0
MOS Logic	23	23	23	25	29	34	33	(1.8)	7.5
Analog	118	128	129	149	161	182	202	1.2	9.7
Discrete	90	89	93	100	115	125	130	4.2	7.7
Opto	8	8	8	8	8	9	10	(7.1)	3.5

Source: Dataquest (July 1990)

Table 16

Forecast North American Merchant Semiconductor Revenue Video (Input/Output Ratios, Percentage)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	6.1	6.2	5.8	6.2	6.7	7.3	7.4
Total IC	4.4	4.5	4.1	4.4	4.7	5.3	5.3
Bipolar Digital	0.3	0.2	0.2	0.1	0.1	0.1	0.1
Bipolar Memory	0	0	0	0	0	0	0
Bipolar Logic	0.3	0.2	0.1	0.1	0.1	0.1	0.1
MOS	1.9	2.1	1.7	1.8	2.0	2.3	2.2
MOS Memory	1.0	1.2	0.9	0.9	1.0	1.2	1.1
MOS Micro	0.6	0.5	0.5	0.5	0.5	0.6	0.6
MOS Logic	0.4	0.4	0.4	0.4	0.5	0.5	0.5
Analog	2.1	2.2	2.2	2.5	2.6	2.8	3.0
Discrete	1.6	1.6	1.6	1.7	1.9	1.9	1.9
Opto	0.1	0.1	0.1	0.1	0.1	0.1	0.1

Source: Dataquest (July 1990)

Table 17

Forecast North American Electronic Equipment Production
Video
(Annual Percentage Change)

	1989	1990	1991	1992	1993	1994
Factory Revenue	2.1	2.0	2.6	3.2	3.6	4.3

Source: Dataquest (July 1990)

Table 18

Forecast North American Merchant Semiconductor Revenue
Video
(Annual Percentage Change)

	1989	1990	1991	1992	1993	1994
Total Semiconductor	3.8	(5.3)	10.0	10.9	13.8	4.6
Total IC	5.5	(8.5)	11.3	9.4	16.2	4.8
Bipolar Digital	(35.7)	(28.1)	(11.9)	(13.4)	(18.3)	(29.7)
Bipolar Memory	(10.6)	(32.0)	(25.5)	(2.9)	(51.3)	(2.2)
Bipolar Logic	(37.5)	(27.7)	(10.6)	(14.3)	(15.2)	(31.1)
MOS	10.4	(16.6)	7.6	13.7	21.7	(1.4)
MOS Memory	26.2	(27.1)	8.5	15.6	22.6	(1.6)
MOS Micro	(8.8)	(4.1)	4.2	8.3	23.7	(0.3)
MOS Logic	0.2	(1.8)	9.6	15.8	17.3	(2.0)
Analog	7.7	1.2	15.7	7.6	13.4	11.0
Discrete	(0.9)	4.2	6.7	15.7	8.5	3.7
Opto	4.6	(7.1)	11.8	0	5.2	8.5

Source: Dataquest (July 1990)

Table 19

Forecast North American Merchant Semiconductor Revenue
Video
(Percentage of Consumer)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	29.8	29.6	29.9	29.8	29.9	29.7	29.8
Total IC	27.2	27.1	27.1	27.1	27.1	27.1	27.2
Bipolar Digital	26.9	25.7	24.5	23.2	22.0	20.7	19.6
Bipolar Memory	33.3	32.2	31.1	30.2	29.3	28.6	27.9
Bipolar Logic	26.5	25.2	23.9	22.8	21.5	20.4	19.2
MOS	26.3	26.4	26.5	26.6	26.7	26.8	26.8
MOS Memory	26.3	26.4	26.5	26.6	26.7	26.8	27.0
MOS Micro	26.5	26.6	26.6	26.7	26.8	26.8	26.9
MOS Logic	26.2	26.2	26.3	26.3	26.4	26.4	26.5
Analog	28.0	28.0	27.9	27.8	27.8	27.7	27.7
Discrete	39.0	39.0	39.0	39.0	39.0	39.0	39.0
Opto	44.3	44.3	44.3	44.2	44.2	44.2	44.2

Source: Dataquest (July 1990)

Table 20

Forecast North American Merchant Semiconductor Revenue
Video
(Percentage of Total Video)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total IC	71.6	72.8	70.3	71.1	70.2	71.7	71.8
Bipolar Digital	5.6	3.5	2.6	2.1	1.6	1.2	0.8
Bipolar Memory	0.4	0.3	0.2	0.2	0.1	0.1	0.1
Bipolar Logic	5.2	3.1	2.4	1.9	1.5	1.1	0.7
MOS	31.7	33.8	29.7	29.0	29.8	31.8	30.0
MOS Memory	15.7	19.1	14.7	14.5	15.1	16.3	15.3
MOS Micro	9.3	8.2	8.3	7.9	7.7	8.4	8.0
MOS Logic	6.7	6.5	6.7	6.7	7.0	7.2	6.8
Analog	34.3	35.6	38.0	40.0	38.8	38.6	41.0
Discrete	26.1	24.9	27.4	26.6	27.8	26.5	26.2
Opto	2.2	2.3	2.2	2.2	2.0	1.9	1.9

Source: Dataquest (July 1990)

Table 21

Forecast North American Electronic Equipment Production Personal Electronics (Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR (%) 1989-1990	CAGR (%) 1989-1994
Factory Revenue	241	239	240	241	239	239	239	0.4	0

Source: Dataquest (July 1990)

Table 22

Forecast North American Merchant Semiconductor Revenue Personal Electronics (Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR (%) 1989-1990	CAGR (%) 1989-1994
Total Semiconductor	12	12	11	12	12	14	14	(7.6)	4.4
Total IC	10	10	9	10	10	12	12	(9.0)	4.4
Bipolar Digital	1	0	0	0	0	0	0	(52.1)	(100.0)
Bipolar Memory	0	0	0	0	0	0	0	NM	NM
Bipolar Logic	1	0	0	0	0	0	0	(52.1)	(100.0)
MOS	4	4	3	4	4	5	4	(15.0)	2.7
MOS Memory	1	2	1	1	1	2	2	(29.3)	(1.1)
MOS Micro	2	1	1	1	1	2	2	(6.7)	3.0
MOS Logic	1	1	1	1	1	1	1	(1.4)	7.9
Analog	5	5	5	6	6	7	8	(1.1)	7.2
Discrete	2	2	2	2	2	2	2	1.7	5.0
Opto	0	0	0	0	0	0	0	(9.6)	0.7

NM = Not meaningful
Source: Dataquest (July 1990)

Table 23

Forecast North American Merchant Semiconductor Revenue
Personal Electronics
(Input/Output Ratios, Percentage)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	4.8	4.9	4.5	4.8	5.2	5.8	6.0
Total IC	4.0	4.1	3.7	4.0	4.3	4.8	5.0
Bipolar Digital	0.4	0.2	0.1	0	0	0	0
Bipolar Memory	0	0	0	0	0	0	0
Bipolar Logic	0.4	0.2	0.1	0	0	0	0
MOS	1.6	1.6	1.4	1.5	1.6	1.9	1.9
MOS Memory	0.6	0.7	0.5	0.5	0.6	0.7	0.7
MOS Micro	0.6	0.6	0.5	0.5	0.6	0.7	0.7
MOS Logic	0.4	0.4	0.4	0.4	0.5	0.6	0.6
Analog	2.1	2.2	2.2	2.5	2.6	2.9	3.2
Discrete	0.7	0.6	0.6	0.7	0.8	0.8	0.8
Opto	0.2	0.2	0.1	0.2	0.2	0.2	0.2

Source: Dataquest (July 1990)

Table 24

Forecast North American Electronic Equipment Production
Personal Electronics
(Annual Percentage Change)

	1989	1990	1991	1992	1993	1994
Factory Revenue	(0.8)	0.4	0.4	(0.8)	0	0

Source: Dataquest (July 1990)

Table 25

Forecast North American Merchant Semiconductor Revenue Personal Electronics (Annual Percentage Change)

	1989	1990	1991	1992	1993	1994
Total Semiconductor	(0.6)	(7.6)	8.0	7.2	12.0	3.5
Total IC	(0.2)	(9.0)	8.6	6.6	13.4	3.8
Bipolar Digital	(49.3)	(52.1)	(48.2)	(50.3)	(100.0)	NM
Bipolar Memory	NM	NM	NM	NM	NM	NM
Bipolar Logic	(49.3)	(52.1)	(48.2)	(50.3)	(100.0)	NM
MOS	3.5	(15.0)	5.1	10.8	19.1	(3.2)
MOS Memory	22.4	(29.3)	5.2	12.1	18.9	(4.6)
MOS Micro	(11.3)	(6.7)	1.4	5.3	20.3	(3.0)
MOS Logic	0.6	(1.4)	10.1	16.3	17.8	(1.6)
Analog	5.3	(1.1)	13.1	5.2	10.9	8.5
Discrete	(3.4)	1.7	4.1	12.9	5.8	1.1
Opto	1.8	(9.6)	8.8	(2.7)	2.5	5.6

NM = Not meaningful
Source: Dataquest (July 1990)

Table 26

Forecast North American Merchant Semiconductor Revenue Personal Electronics (Percentage of Consumer)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	1.0	1.0	0.9	0.9	0.9	0.9	0.9
Total IC	1.1	1.0	1.0	1.0	1.0	0.9	0.9
Bipolar Digital	1.2	0.9	0.6	0.3	0.2	0	0
Bipolar Memory	0	0	0	0	0	0	0
Bipolar Logic	1.3	1.0	0.6	0.3	0.2	0	0
MOS	0.9	0.9	0.9	0.9	0.8	0.8	0.8
MOS Memory	0.7	0.6	0.6	0.6	0.6	0.6	0.6
MOS Micro	1.3	1.2	1.2	1.2	1.1	1.1	1.1
MOS Logic	1.0	1.0	1.0	1.0	1.0	1.0	1.1
Analog	1.2	1.2	1.1	1.1	1.1	1.1	1.0
Discrete	0.7	0.7	0.6	0.6	0.6	0.6	0.6
Opto	2.1	2.1	2.0	2.0	1.9	1.9	1.8

Source: Dataquest (July 1990)

Table 27

Forecast North American Merchant Semiconductor Revenue
Personal Electronics
(Percentage of Total Personal Electronics)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total IC	83.3	83.6	82.4	82.9	82.4	83.5	83.7
Bipolar Digital	7.4	3.8	2.0	0.9	0.4	0	0
Bipolar Memory	0	0	0	0	0	0	0
Bipolar Logic	7.4	3.8	2.0	0.9	0.4	0	0
MOS	32.5	33.9	31.2	30.4	31.4	33.4	31.2
MOS Memory	11.6	14.3	10.9	10.7	11.2	11.8	10.9
MOS Micro	13.3	11.8	11.9	11.2	11.0	11.8	11.1
MOS Logic	7.7	7.8	8.3	8.5	9.2	9.7	9.2
Analog	43.4	45.9	49.2	51.6	50.6	50.1	52.5
Discrete	13.5	13.1	14.4	13.9	14.7	13.8	13.5
Opto	3.2	3.3	3.2	3.2	2.9	2.7	2.7

Source: Dataquest (July 1990)

Table 28

Forecast North American Electronic Equipment Production
Appliances
(Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR (%) 1989-1990	CAGR (%) 1989-1994
Factory Revenue	12,830	13,147	13,512	13,918	14,317	14,650	14,950	2.8	2.6

Source: Dataquest (July 1990)

Table 29

Forecast North American Merchant Semiconductor Revenue Appliances (Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR (%) 1989-1990	CAGR (%) 1989-1994
Total Semiconductor	715	749	700	773	854	980	1,023	(6.6)	6.4
Total IC	590	624	570	635	696	808	844	(8.6)	6.2
Bipolar Digital	46	32	25	24	22	20	15	(22.3)	(14.2)
Bipolar Memory	2	2	1	1	1	1	1	(28.0)	(20.7)
Bipolar Logic	44	30	23	22	21	19	14	(21.9)	(13.8)
MOS	274	301	250	267	302	366	359	(17.0)	3.6
MOS Memory	135	170	123	133	153	186	182	(27.5)	1.4
MOS Micro	79	72	69	72	77	95	95	(4.4)	5.6
MOS Logic	60	59	58	63	72	84	82	(2.5)	6.7
Analog	270	291	296	344	371	422	471	1.6	10.1
Discrete	118	117	122	130	151	163	169	4.3	7.7
Opto	7	8	7	8	8	9	9	(7.0)	3.6

Source: Dataquest (July 1990)

Table 30

Forecast North American Merchant Semiconductor Revenue Appliances (Input/Output Ratios, Percentage)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	5.6	5.7	5.2	5.6	6.0	6.7	6.8
Total IC	4.6	4.7	4.2	4.6	4.9	5.5	5.6
Bipolar Digital	0.4	0.2	0.2	0.2	0.2	0.1	0.1
Bipolar Memory	0	0	0	0	0	0	0
Bipolar Logic	0.3	0.2	0.2	0.2	0.1	0.1	0.1
MOS	2.1	2.3	1.8	1.9	2.1	2.5	2.4
MOS Memory	1.1	1.3	0.9	1.0	1.1	1.3	1.2
MOS Micro	0.6	0.5	0.5	0.5	0.5	0.7	0.6
MOS Logic	0.5	0.5	0.4	0.5	0.5	0.6	0.5
Analog	2.1	2.2	2.2	2.5	2.6	2.9	3.1
Discrete	0.9	0.9	0.9	0.9	1.1	1.1	1.1
Opto	0.1	0.1	0.1	0.1	0.1	0.1	0.1

Source: Dataquest (July 1990)

Table 31

Forecast North American Electronic Equipment Production
Appliances
(Annual Percentage Change)

	1989	1990	1991	1992	1993	1994
Factory Revenue	2.5	2.8	3.0	2.9	2.3	2.0

Source: Dataquest (July 1990)

Table 32

Forecast North American Merchant Semiconductor Revenue
Appliances
(Annual Percentage Change)

	1989	1990	1991	1992	1993	1994
Total Semiconductor	4.7	(6.6)	10.5	10.5	14.7	4.4
Total IC	5.8	(8.6)	11.3	9.6	16.2	4.5
Bipolar Digital	(31.4)	(22.3)	(4.4)	(7.0)	(10.4)	(24.8)
Bipolar Memory	(5.4)	(28.0)	(21.0)	2.9	(48.4)	3.6
Bipolar Logic	(32.5)	(21.9)	(3.4)	(7.5)	(8.4)	(25.7)
MOS	9.9	(17.0)	7.0	13.1	21.0	(1.9)
MOS Memory	25.5	(27.5)	7.9	15.0	21.9	(2.2)
MOS Micro	(9.1)	(4.4)	3.9	7.9	23.3	(0.6)
MOS Logic	(0.5)	(2.5)	8.9	15.0	16.5	(2.7)
Analog	8.1	1.6	16.2	8.0	13.8	11.4
Discrete	(0.9)	4.3	6.7	15.7	8.5	3.7
Opto	4.7	(7.0)	11.9	0.1	5.4	8.6

Source: Dataquest (July 1990)

Table 33

Forecast North American Merchant Semiconductor Revenue
Appliances
(Percentage of Consumer)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	61.7	61.9	61.6	61.7	61.6	61.8	61.7
Total IC	64.7	64.8	64.8	64.8	64.8	64.8	64.8
Bipolar Digital	64.2	65.5	67.4	69.3	70.7	72.7	73.8
Bipolar Memory	50.0	51.2	52.4	53.8	55.4	57.1	59.2
Bipolar Logic	65.0	66.7	68.5	70.3	71.8	73.3	74.6
MOS	65.9	65.7	65.6	65.5	65.3	65.2	65.0
MOS Memory	65.8	65.6	65.5	65.4	65.3	65.2	65.1
MOS Micro	65.1	65.1	65.0	65.0	64.9	64.9	64.8
MOS Logic	67.0	66.7	66.4	66.1	65.8	65.5	65.2
Analog	63.7	63.8	63.9	64.0	64.1	64.2	64.3
Discrete	51.0	51.0	51.0	51.0	51.0	51.1	51.1
Opto	42.6	42.6	42.6	42.7	42.7	42.8	42.8

Source: Dataquest (July 1990)

Table 34

Forecast North American Merchant Semiconductor Revenue
Appliances
(Percentage of Total Appliances)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total IC	82.5	83.4	81.5	82.1	81.4	82.5	82.5
Bipolar Digital	6.5	4.2	3.5	3.0	2.6	2.0	1.4
Bipolar Memory	0.3	0.3	0.2	0.1	0.1	0.1	0.1
Bipolar Logic	6.2	4.0	3.3	2.9	2.4	1.9	1.4
MOS	38.3	40.2	35.7	34.6	35.4	37.3	35.1
MOS Memory	18.9	22.7	17.6	17.2	17.9	19.0	17.8
MOS Micro	11.1	9.6	9.9	9.3	9.0	9.7	9.3
MOS Logic	8.3	7.9	8.3	8.1	8.5	8.6	8.0
Analog	37.7	38.9	42.3	44.5	43.5	43.1	46.0
Discrete	16.5	15.6	17.4	16.8	17.6	16.7	16.6
Opto	1.0	1.0	1.0	1.0	1.0	0.9	0.9

Source: Dataquest (July 1990)

Table 35

Forecast North American Electronic Equipment Production
Other Consumer
(Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR (%) 1989-1990	CAGR (%) 1989-1994
Factory Revenue	992	1,037	1,078	1,126	1,171	1,157	1,157	4.0	2.2

Source: Dataquest (July 1990)

Table 36

Forecast North American Merchant Semiconductor Revenue
Other Consumer
(Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR (%) 1989-1990	CAGR (%) 1989-1994
Total Semiconductor	73	77	72	79	88	101	105	(6.0)	6.5
Total IC	53	57	52	58	63	74	77	(9.2)	6.3
Bipolar Digital	5	3	3	2	2	2	1	(23.6)	(16.8)
Bipolar Memory	1	1	0	0	0	0	0	(30.6)	(26.9)
Bipolar Logic	4	3	2	2	2	2	1	(22.0)	(15.1)
MOS	25	28	23	25	29	35	35	(17.1)	4.7
MOS Memory	14	17	12	14	16	19	19	(27.0)	1.9
MOS Micro	7	6	6	6	7	9	8	(4.1)	5.8
MOS Logic	4	4	4	5	6	8	8	2.5	12.2
Analog	24	26	26	30	33	37	41	1.2	9.7
Discrete	18	18	19	20	23	25	26	4.2	7.7
Opto	2	2	2	2	2	2	2	(7.3)	3.2

Source: Dataquest (July 1990)

Table 37

Forecast North American Merchant Semiconductor Revenue
Other Consumer
(Input/Output Ratios, Percentage)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	7.4	7.4	6.7	7.0	7.5	8.7	9.1
Total IC	5.4	5.5	4.8	5.1	5.4	6.4	6.7
Bipolar Digital	0.5	0.3	0.2	0.2	0.2	0.2	0.1
Bipolar Memory	0.1	0.1	0	0	0	0	0
Bipolar Logic	0.4	0.3	0.2	0.2	0.2	0.1	0.1
MOS	2.5	2.7	2.1	2.2	2.5	3.0	3.0
MOS Memory	1.4	1.7	1.2	1.2	1.3	1.7	1.6
MOS Micro	0.7	0.6	0.6	0.6	0.6	0.7	0.7
MOS Logic	0.4	0.4	0.4	0.5	0.5	0.7	0.7
Analog	2.4	2.5	2.4	2.7	2.8	3.2	3.5
Discrete	1.8	1.7	1.7	1.8	2.0	2.1	2.2
Opto	0.2	0.2	0.2	0.2	0.2	0.2	0.2

Source: Dataquest (July 1990)

Table 38

Forecast North American Electronic Equipment Production
Other Consumer
(Annual Percentage Change)

	1989	1990	1991	1992	1993	1994
Factory Revenue	4.5	4.0	4.5	4.0	(1.2)	0

Source: Dataquest (July 1990)

Table 39

Forecast North American Merchant Semiconductor Revenue Other Consumer (Annual Percentage Change)

	1989	1990	1991	1992	1993	1994
Total Semiconductor	4.9	(6.0)	10.2	11.2	14.2	4.4
Total IC	7.0	(9.2)	11.4	10.1	16.6	4.5
Bipolar Digital	(28.8)	(23.6)	(7.7)	(8.1)	(16.5)	(26.5)
Bipolar Memory	(7.6)	(30.6)	(25.1)	(4.4)	(53.4)	(10.1)
Bipolar Logic	(32.3)	(22.0)	(4.1)	(8.7)	(10.4)	(27.9)
MOS	13.0	(17.1)	8.5	14.7	22.7	(0.7)
MOS Memory	26.5	(27.0)	8.5	15.5	22.4	(1.9)
MOS Micro	(8.7)	(4.1)	4.2	8.1	23.5	(0.5)
MOS Logic	5.3	2.5	14.5	20.9	22.5	2.3
Analog	7.7	1.2	15.7	7.6	13.4	11.0
Discrete	(0.9)	4.2	6.7	15.7	8.5	3.7
Opto	4.3	(7.3)	11.5	(0.3)	5.0	8.2

Source: Dataquest (July 1990)

Table 40

Forecast North American Merchant Semiconductor Revenue Other Consumer (Percentage of Consumer)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	6.3	6.3	6.3	6.3	6.4	6.3	6.3
Total IC	5.8	5.9	5.9	5.9	5.9	5.9	5.9
Bipolar Digital	6.4	6.8	6.9	6.8	6.9	6.6	6.6
Bipolar Memory	16.7	16.6	16.4	16.0	15.3	14.3	12.8
Bipolar Logic	5.8	6.0	6.2	6.3	6.3	6.3	6.2
MOS	5.9	6.1	6.1	6.1	6.2	6.3	6.3
MOS Memory	6.6	6.6	6.6	6.7	6.7	6.7	6.7
MOS Micro	5.8	5.8	5.8	5.8	5.8	5.8	5.8
MOS Logic	4.7	4.9	5.1	5.4	5.6	5.9	6.1
Analog	5.7	5.7	5.6	5.6	5.6	5.6	5.6
Discrete	7.7	7.7	7.7	7.7	7.7	7.7	7.7
Opto	9.8	9.8	9.7	9.7	9.7	9.7	9.6

Source: Dataquest (July 1990)

Table 41

Forecast North American Merchant Semiconductor Revenue
Other Consumer
(Percentage of Total Other Consumer)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total IC	73.1	74.5	71.9	72.7	72.0	73.4	73.5
Bipolar Digital	6.4	4.3	3.5	2.9	2.4	1.8	1.2
Bipolar Memory	0.9	0.8	0.6	0.4	0.3	0.1	0.1
Bipolar Logic	5.4	3.5	2.9	2.5	2.1	1.6	1.1
MOS	33.8	36.4	32.1	31.6	32.6	35.0	33.4
MOS Memory	18.6	22.4	17.4	17.1	17.8	19.1	17.9
MOS Micro	9.6	8.4	8.5	8.1	7.9	8.5	8.1
MOS Logic	5.7	5.7	6.2	6.4	7.0	7.5	7.4
Analog	32.9	33.7	36.3	38.2	36.9	36.6	38.9
Discrete	24.6	23.2	25.8	24.9	25.9	24.6	24.5
Opto	2.3	2.3	2.3	2.3	2.1	1.9	2.0

Source: Dataquest (July 1990)

Trends in Consumer Electronics

Table of Contents

This section presents statistics on the U.S. market for consumer electronics equipment. Dataquest analyzed government and industry information to prepare this section. Sources of data include the U.S. Department of Commerce (U.S. DOC), the Electronics Industry Association (EIA), and *Appliance* magazine.

WORLDWIDE INDUSTRY PERSPECTIVE

Consumer Electronics Overview

Consumer electronics is a worldwide industry that represents the ongoing evolution of electronics. Most of the scientific discoveries were made in Europe, most of the initial products were invented in North America, and most of the latest refinements are being made in the Far East (see Table 1). The next major development in consumer electronics will be the use of digital processing in the signal path.

The United States has contributed to the consumer electronics industry (see Table 2) by developing commercial applications for basic discoveries made in Europe and by developing the component technologies used in the equipment. Today's trade friction between the United States and the Far East began when the consumer electronics industry began relocating there in the 1960s.

Table 1

Megatrends in Consumer Electronics

Phase	Period	Concentration	Developments
Discovery	1700 to 1925	Europe	Electricity
			Magnetism
			Radio waves
			Amplification
			Feedback control
Invention	1850 to 1975	North America	Telephone
			Phonograph
			Radio
			Television
			Computer
Refinement	1950 to present	Far East	Solid state
			Miniaturization
			Advanced features
			Integration
			Digitization

Source: Dataquest
May 1990

Table 2

Twenty-Four Key U.S. Consumer Electronics Milestones

Year	Milestone
1876	Bell invents the telephone
1877	Edison invents the phonograph
1895	Marconi transmits radio waves (in Italy)
1906	DeForest invents the triode vacuum tube
1916	Armstrong invents the superheterodyne circuit
1920	Commercial radio broadcasts begin
1934	Federal Communications Commission (FCC) established
1939	Commercial TV broadcasts begin
1947	Bell Labs invents the transistor
1948	Cable TV service begins
1955	Fairchild and TI coinvent the integrated circuit (IC)
1966	ICs used in consumer electronics products
1968	FCC assumes jurisdiction over CATV systems
1970	Digital watches introduced
1971	Intel invents the microprocessor
	Electronic handheld calculators introduced
1975	Personal computer invented
1977	U.S. and Japan sign color TV Orderly Marketing Agreement
1979	U.S., Taiwan, and Korea agree on color TV export quotas
1980	Digital audio standard established
1982	Color TV export quota agreement expires
1983	Voice-synthesized and voice-activated products introduced
1984	Cellular radio service introduced
1988	Advanced TV (ATV) and high-definition TV (HDTV) proposed

Source: EIA
Dataquest
May 1990

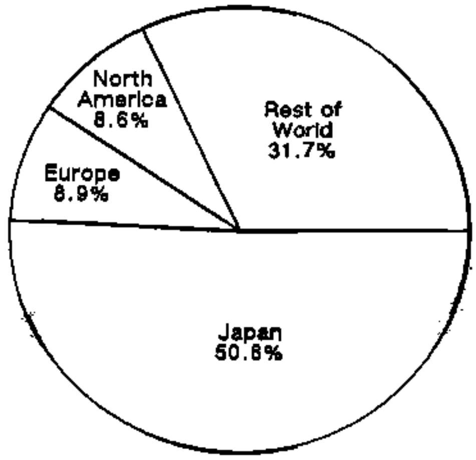
Regional Equipment Production

Approximately 80 percent of the consumer electronics equipment in the world is made in the Far East (see Figure 1 for an equipment production share based on semiconductor consumption percentages). Less than 10 percent is made in North America. Dataquest estimates that approximately 22 percent of the 1988 worldwide semiconductor shipments were to the consumer applications segment.

Much of the consumer electronics equipment consumed in the United States is imported either as finished goods or as assembled subsystems (see Table 3). Data from the U.S. DOC indicate that 64 percent of U.S. audio/video equipment consumption is imported, 18 percent of U.S. audio/video equipment production is exported, 17 percent of U.S. home appliance consumption is imported, and 10 percent of U.S. home appliance production is exported.

Figure 1

Estimated 1988 Consumer Semiconductor Consumption by Region



Total = $10,959 Million

0006820-1

Source: Dataquest May 1990

Table 3

1988 U.S. Consumer Electronics Trade Estimates (Millions Of Units)

Product	Consumption	Imports	Production	Exports
Audio Systems	4.7	4.9	0.4	0.6
Audio Tape Assemblies	41.7	43.1	0	1.4
Color TVs	20.9	8.2	14.1	1.4
Monochrome TVs	2.6	3.0	0	0.4
Radio Assemblies	49.8	36.9	14.9	2.0
VCRs	12.7	11.7	1.0	0

Source: EIA Dataquest May 1990

Of the 3,000 electronics companies in the United States, over 700 are involved with the manufacture of consumer electronics equipment. Over 25 of these companies have revenue in excess of $100 million per year from the production of consumer electronics equipment (see Table 4).

Table 4

Major Equipment Manufacturers with U.S. Facilities

Manufacturer	Consumer Electronics Production
Black & Decker	Appliances
Eastman Kodak	Personal electronics
Electrol	Appliances
Emerson Radio	Audio
Fuqua Industries	Appliances, personal electronics
General Electric	Appliances
Harmon International	Appliances
Hasbro	Personal electronics
Litton Industries	Appliances
Matsushita Electric	Appliances, video
Mattel	Personal electronics
Maytag	Appliances
North American Philips	Appliances, video
Peavey Electronics	Audio, personal electronics
Pioneer Electronics	Audio
Polaroid	Personal electronics
Raytheon	Appliances
Sanyo Electronics	Appliances, video
Sharp Electronics	Video
Sony Corp. of America	Video
Tandy	Audio, personal electronics
Thomson	Video
Toro	Appliances
Toshiba America	Appliances
Whirlpool	Appliances
Zenith Electronics	Video

Source: Dataquest
May 1990

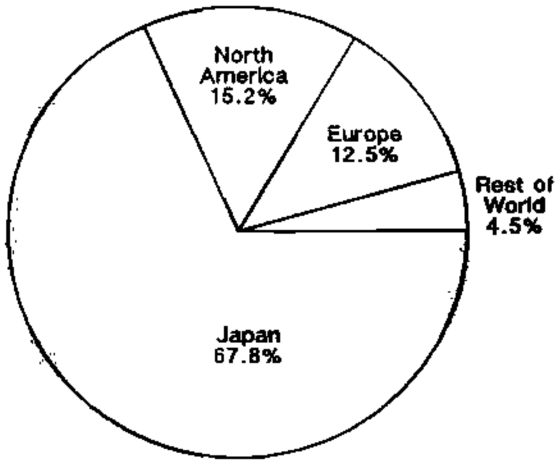
Regional Semiconductor Production

Approximately two-thirds of the semiconductors used in consumer electronics equipment are manufactured in Japan (see Figure 2).

The supplier base for semiconductors used in consumer electronics equipment is concentrated. Of the 125 major semiconductor manufacturers in the world, the top 10 suppliers of consumer semiconductors have a combined market share of nearly 70 percent (see Table 5).

Figure 2

Estimated 1988 Consumer Semiconductor Production by Region (Millions of Dollars)



Total = $10,959 Million

0006820-2

Source: Dataquest May 1990

Table 5

Estimated 1988 Worldwide Consumer Semiconductor Suppliers (Millions Of Dollars)

Company	Revenue	Percent
All Companies	10,959	100.0
Top 10 Companies	7,515	68.6
Matsushita	1,091	10.0
Toshiba	1,069	9.8
NEC	1,032	9.4
Hitachi	798	7.3
Mitsubishi	750	6.8
Philips-Signetics	710	6.5
Sanyo	698	6.4
Sharp	522	4.8
Sony	468	4.3
Motorola	377	3.4
Other Companies	3,444	32.4

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

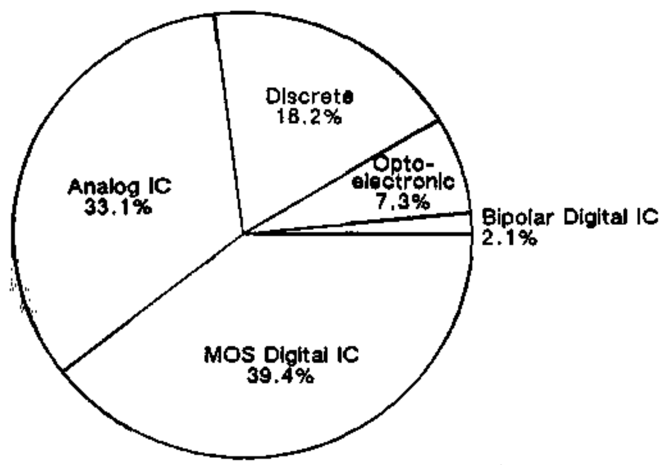
Source: Dataquest May 1990

Semiconductor Product Consumption

Nearly three-quarters of the semiconductor content value of consumer electronics equipment are either MOS digital or analog ICs (see Figure 3 and Table 6).

Figure 3

Estimated 1988 Worldwide Market For Consumer Semiconductors



Total = $10,959 Million

*Note: Segments may not add to 100% because of rounding.

0006820-3

Source: Dataquest May 1990

Table 6

Estimated 1988 Worldwide Market for Consumer Semiconductors (Millions of Dollars)

Semiconductor Product	Market	Share
Total Semiconductor	10,959	100.0
Integrated Circuit	8,170	74.6
Bipolar Digital	231	2.1
Memory	14	0.1
Logic	217	2.0
MOS Digital	4,316	39.4
Memory	1,164	10.6
Micro	1,378	12.6
Logic	1,774	16.2
Analog	3,623	33.1
Discrete	1,990	18.2
Optoelectronic	799	7.3

Source: Dataquest May 1990

U.S. EQUIPMENT CONSUMPTION

Consumption Overview

Approximately 85 percent of the population of the industrialized world live in the G7 countries (see Table 7) and residents of these countries have a standard of living that is high enough to be able to afford the "luxuries" of consumer electronics equipment. Using this criteria, the United States represents about one-third of the worldwide consumer electronics market.

Most consumer electronics equipment is purchased on the basis that it will be used by people living in the same household, which represents the unit of demand. There are an estimated 91 million households in the United States (see Table 7).

Much of the demand for consumer electronics equipment is based on new housing starts, especially for products such as home appliances. In the United States, new housing starts vary between 1 and 2 million units a year (see Figure 4), depending on economic conditions.

More than 70 percent of the consumer electronics equipment consumed in the United States are home appliances (see Figure 5 and Table 8). The remaining equipment is purchased and used primarily for entertainment. The U.S. consumer electronics equipment market is nearly $60 billion per year, which puts the world consumer electronics equipment market at the $200 billion level.

Table 7

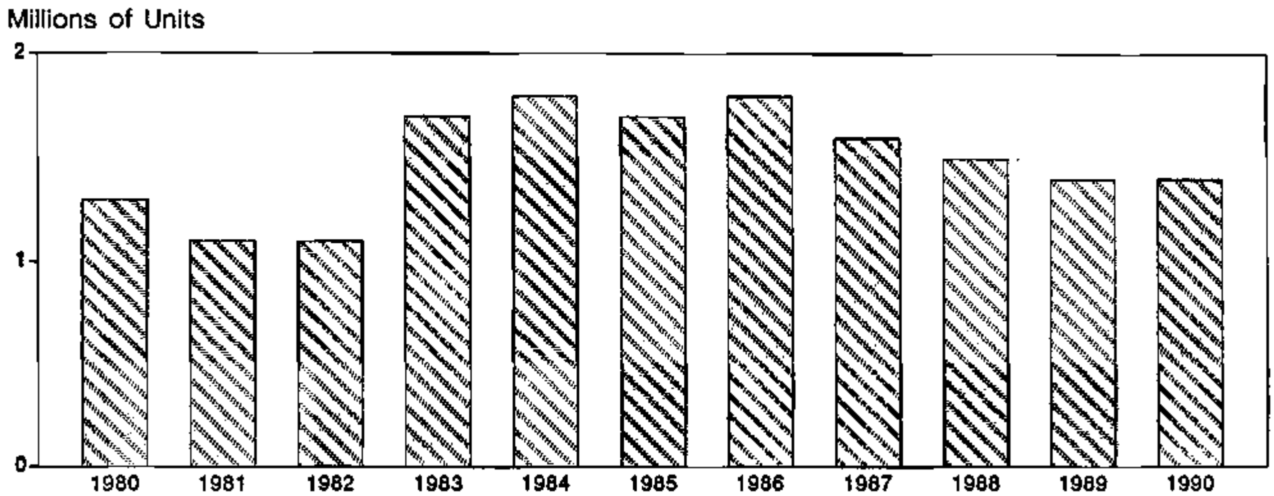
1988 Demographic Information for G7 Countries

Country	Population (Millions)	Households (Millions)	Per Capita Income
G7 Total	624	224	$17,700
Canada	26	9	$15,900
France	54	20	$13,500
Italy	57	19	$13,300
Japan	123	40	$23,500
United Kingdom	57	20	$11,100
United States	246	91	$18,900
West Germany	61	25	$15,600

Source: Government Statistics
Dataquest
May 1990

Figure 4

New Housing Starts in the United States (Millions Of Units)

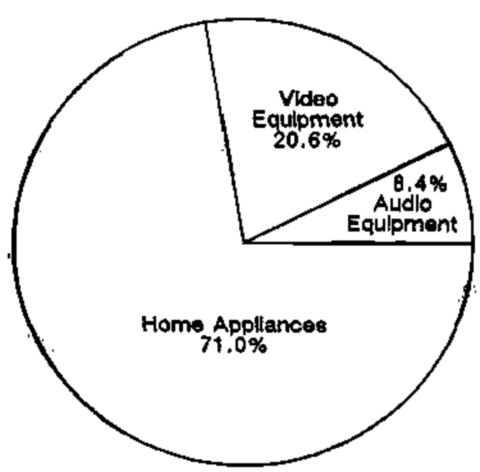


0006820-4

Source: U.S. Department of Commerce

Figure 5

Estimated 1988 U.S. Consumer Electronics Consumption



Total = $59.9 Billion

0006820-6

Source: Dataquest May 1990

Table 8

Estimated 1988 U.S. Consumer Electronics Consumption (Billions Of Dollars)

Consumer Electronic Equipment	Consumption	Share
Total Consumer Electronics	59.9	100.0
Appliances	42.5	71.0
Major Appliances	18.6	31.1
HVAC Equipment	16.6	27.7
Electric Housewares	3.5	5.8
Floor Care Appliances	1.6	2.7
Personal Care Appliances	1.5	2.5
Home Security Appliances	0.4	0.7
Water Systems and Pumps	0.3	0.5
Video Equipment	12.4	20.6
Color TV	6.6	11.0
VCR	3.1	5.2
Camcorder	2.0	3.3
Projection TV	0.5	0.8
Monochrome TV	0.2	0.3
Audio Equipment	5.0	8.4
Separate Audio Components	1.9	3.2
Portable Tape Equipment	1.5	2.5
Audio Systems	1.2	2.0
Home Radio	0.4	0.7

Source: *Appliance*
EIA
Dataquest
May 1990

Audio Electronics

The consumer electronics industry began with the mass production of audio equipment (see Table 9). Technologies that changed the industry in recent decades include magnetic and optical media, solid state components, and digital processing techniques.

Acceptance of product innovations in the consumer electronics market has been mixed. Stereo sound and personal systems have been successful, but quadraphonic sound and cartridge tapes have been failures.

Approximately 65 million units of audio equipment are consumed in the United States each year (see Table 10), with virtually every household penetrated. Over one-half of the audio equipment sold today is portable.

Table 9

Eighteen Key U.S. Consumer Audio Milestones

Year	Milestone
1877	Edison invents the phonograph
1920	Commercial radio broadcasts begin
1924	Loudspeaker replaces earphones
1926	AC-powered radio receivers introduced
1941	Commercial FM radio broadcasts begin
1949	Three-speed phonographs introduced
1954	Transistor radios introduced
1958	Stereo recordings introduced
1961	FM-stereo radio broadcasts begin
1964	Automobile stereo tape cartridge players introduced
1966	Audio/cassette recorders introduced
1969	Quadraphonic sound introduced
1979	Personal headset stereos introduced
1980	Optical digital audio disk standard established
1982	AM-stereo radio broadcasts begin
1983	Compact disc (CD) players introduced
1985	Digital/audio tape recorder demonstrated
1988	Recordable CDs demonstrated

Source: EIA
Dataquest
May 1990

Table 10

Estimated 1988 U.S. Audio Equipment Consumption (Millions of Units)

Audio Equipment	Consumption	Penetration	Replacement
Total Audio Equipment	64.7	99%	N/A
Portable Audio Equipment	36.4	N/A	50%
Players Only	4.0	N/A	N/A
Radio/Tape/CD Combinations	26.2	N/A	N/A
Recorders/Players	6.2	N/A	N/A
Home Radios	23.6	98%	N/A
Clock Radios	12.4	N/A	N/A
Portable Radios	11.0	N/A	N/A
Table Radios	0.2	N/A	N/A
Audio Hi-Fi Systems	4.7	90%	N/A
Compact Systems	3.0	56%	90%
Component Systems[1]	1.7	47%	75%
Speakers	3.5	47%	N/A
Compact Disc Players	2.8	13%	N/A
Cartridges	2.1	N/A	N/A
Receivers	1.1	N/A	N/A
Cassette Decks	0.8	N/A	N/A
Turntables	0.8	N/A	N/A
Amps and Preamps	0.3	N/A	N/A
Equalizers	0.2	N/A	N/A
Tuners	0.1	N/A	N/A

N/A = Not Available
[1]Subcategories do not add to total

Source: *Appliance*
EIA
Dataquest
May 1990

Video Electronics

Video equipment first appeared on the market over 60 years after audio equipment (see Table 11). One reason for this time lag is that technology had to advance, because video requires approximately one thousand times more bandwidth than audio. Innovations such as color pictures, stereo sound, personal sets, and cassette tapes have been successful. Component TV and video disks, on the other hand, have been disappointments.

Table 11

Eighteen Key U.S. Consumer Video Milestones

Year	Milestone
1939	Commercial TV broadcasts begin
1954	Color TV broadcasts begin
1960	Battery-operated transistorized TVs introduced
1967	Solid-state color TV sets introduced
1970	All-electronic TV tuners invented
1972	Home videocassette recorders (VCRs) introduced
1973	Projection TV sets introduced
1977	Home color TV cameras introduced
1978	Videodisk players introduced
1980	Closed captioning of TV programs begins
1982	Flat-screen personal portable TV set introduced
	Component TV systems introduced
1983	Camcorders introduced
1984	Stereo TV broadcasts begin
	Color TVs with all-DSP circuits introduced
1986	Satellite TV scrambling begins
1987	Super VHS and extended-definition Beta formats introduced
1988	Improved definition TV (IDTV) sets introduced

Source: EIA
Dataquest
May 1990

Approximately 37 million units of video equipment are consumed in the United States each year (see Table 12). More than 50 percent of these units are color televisions, which are present in 95 percent of households.

The top three suppliers to the video equipment markets in the United States have combined shares of over 30 percent (see Table 13).

Table 12

Estimated 1988 U.S. Video Equipment Consumption (Millions Of Units)

Video Equipment	Consumption	Penetration	Growth	Replacement
Total Video Equipment	36.6	98%	N/A	N/A
Color Receivers[1]	20.9	95%	0	54%
Table and Portable	18.4	N/A	N/A	N/A
Multichannel Sound	5.1	15%	N/A	N/A
Console	2.5	N/A	N/A	N/A
Projection TVs	0.3	4%	0	20%
LCD TVs	0.2	N/A	2%	N/A
Videocassette Recorders	12.7	68%	N/A	N/A
Table Model	10.7	61%	2%	13%
Camcorder	2.0	7%	0	N/A
Monochrome Receivers	2.6	58%	(4%)	99%
Satellite Earth Stations	0.3	2%	0	N/A
Videodisk Players	0.1	1%	10%	N/A

N/A = Not Available
[1]Subcategories do not add to total.

Source: *Appliance*
EIA
Dataquest
May 1990

Table 13

Estimated 1988 U.S. Video Equipment Market Shares

Video Equipment	Number 1	Share	Number 2	Share	Number 3	Share
Camcorders	Thomson	22%	Matsushita	18%	Sony	12%
Color TVs	Thomson	22%	Zenith	12%	North American Philips	11%
VCRs	Thomson	15%	Matsushita	10%	Emerson	8%

Source: *Appliance*
EIA
Dataquest
May 1990

Home Appliances

More than 300 million home appliances are consumed in the United States each year (see Table 14). Dataquest believes that this equipment will become a major opportunity for microelectronics in the 1990s because of tougher requirements for energy efficiency.

Table 14

Estimated 1988 U.S. Appliance Consumption (Millions Of Units)

Appliance	Consumption	Penetration	Growth	Replacement
Total Appliances	322.7	N/A	N/A	N/A
Electric Housewares	163.0	99%	N/A	N/A
Irons	14.9	99%	1%	68%
Coffeemakers	14.8	99%	0	89%
Vacuum Cleaners	11.2	98%	2%	N/A
Smoke Detectors	10.2	N/A	(3%)	N/A
Toasters	8.9	99%	1%	90%
Can Openers	5.8	76%	N/A	95%
Mixers	5.5	85%	1%	99%
Blenders	4.6	64%	0	54%
Slow Cookers	4.1	47%	1%	99%
Food Processors	3.7	49%	1%	N/A
Others	79.3	N/A	N/A	N/A
Personal Care	65.6	88%	N/A	N/A
Hair Dryers	20.0	88%	N/A	16%
Curling Irons	9.0	80%	0	67%
Shavers	8.2	87%	0	99%
Others	28.4	N/A	N/A	N/A
Major Appliances	55.6	99%	N/A	N/A
Microwave Ovens	10.8	76%	1%	22%
Refrigerators	8.2	99%	2%	80%
Ranges	8.0	99%	2%	66%
Water Heaters	7.2	99%	1%	69%
Washers	6.4	72%	1%	70%
Others	15.0	N/A	N/A	N/A
Comfort Conditioning	38.5	76%	N/A	N/A
Fans	19.9	52%	3%	51%
Air Conditioners	7.8	65%	1%	77%
Furnaces	2.8	76%	2%	82%
Others	8.0	N/A	N/A	N/A

N/A = Not Available

Source: *Appliance*
Dataquest
May 1990

The top three suppliers to the appliance markets in the United States have combined shares that exceed 30 percent (see Table 15).

Table 15

Estimated 1988 U.S. Appliance Market Shares

Appliance	Number 1	Share	Number 2	Share	Number 3	Share
Air Conditioners	Carrier	12%	Electrolux	11%	Fedders	11%
Can Openers	Rival	27%	Black/Decker	27%	Sunbeam	9%
Coffeemakers	Mr. Coffee	22%	Black/Decker	18%	Wear-Ever	15%
Food Processors	Sunbeam	24%	Hamilton Bch.	16%	Cuisinart	14%
Furnaces	Carrier	25%	Lennox	18%	Rheem	17%
Hair Dryers	Conair	50%	Windmere	12%	Clairol	7%
Irons	Black/Decker	34%	Sunbeam	20%	Wear-Ever	14%
Microwave Ovens	Samsung	17%	Goldstar	17%	Sharp	15%
Mixers	Black/Decker	34%	Sunbeam	25%	Hamilton Bch.	13%
Ranges	GE	24%	Electrolux	24%	Maytag	20%
Refrigerators	GE	34%	Whirlpool	27%	Electrolux	20%
Shavers	North American Philips	48%	Remington	32%	Braun	11%
Smoke Detectors	Pittway	49%	Probe	16%	Black/Decker	10%
Toasters	Toastmaster	29%	Wear-Ever	25%	Black/Decker	15%
Vacuum Cleaners	Hoover	35%	Eureka	22%	Whirlpool	10%
Washers	Whirlpool	50%	Maytag	18%	GE	15%
Water Heaters	State Ind.	27%	Rheem	25%	Mor-Flo	22%

Source: *Appliance*
Dataquest
May 1990

Home Information Products (For Reference Only)

Information products used in the home are covered by Dataquest in the Data Processing andCommunications segments. They are mentioned here, however, to illustrate the trend that office-related equipment is being purchased increasingly by people for their own personal use (see Table 16). We believe that as this market grows during the 1990s, versions of these information products will be developed solely for the consumer market.

Miscellaneous Electronics

Microelectronics technology is permitting the creation of new classes of electronic equipment for personal use (see Table 17).

Table 16

Estimated 1988 U.S. Home Information Equipment Consumption (Millions of Units)

Information Equipment	Consumption	Penetration
Corded Telephones	20.0	98%
Answering Machines	8.0	24%
Cordless Telephones	6.3	22%
Personal Computers	4.5	21%
Cellular Telephones	0.1	N/A
Facsimile Machines	0.1	N/A
Personal Copiers	0.1	N/A
Word Processors	0.1	N/A

N/A = Not Available

Source: EIA
Dataquest
May 1990

Table 17

Eight Key U.S. Personal Electronics Milestones

Year	Milestone
1958	Citizens band (CB) radio introduced
1960	Telephone answering devices introduced
1970	Digital watches introduced
1971	Handheld calculators introduced
1972	Home video games introduced
1976	CB radio expands from 23 to 40 channels
1979	Portable language translators introduced
1986	Consumer video telephone introduced

Source: EIA
Dataquest
May 1990

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

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.

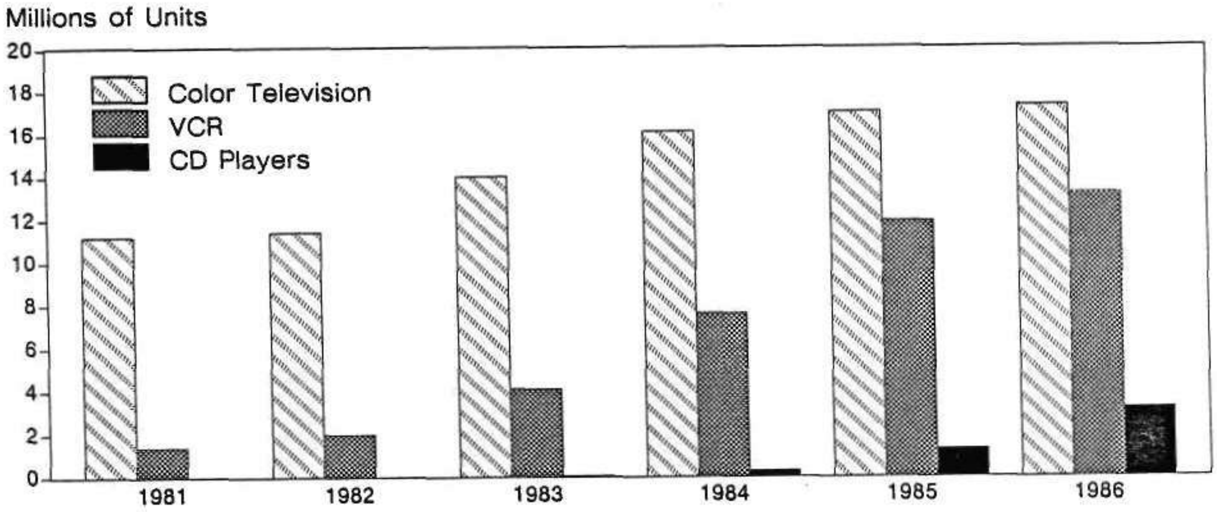
Source: Dataquest
December 1986

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



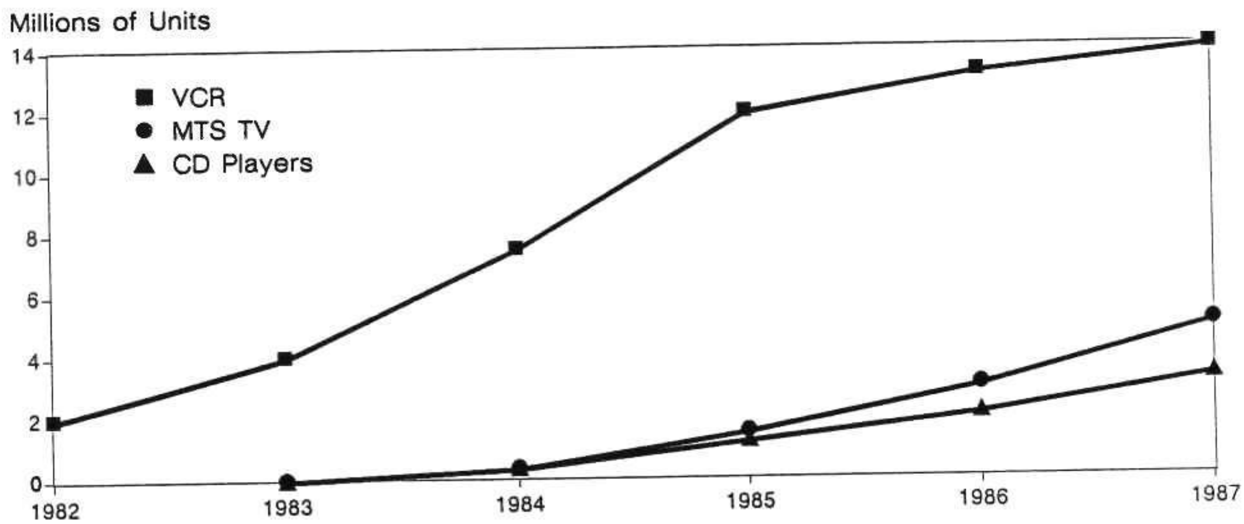
Source: Dataquest
December 1986

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

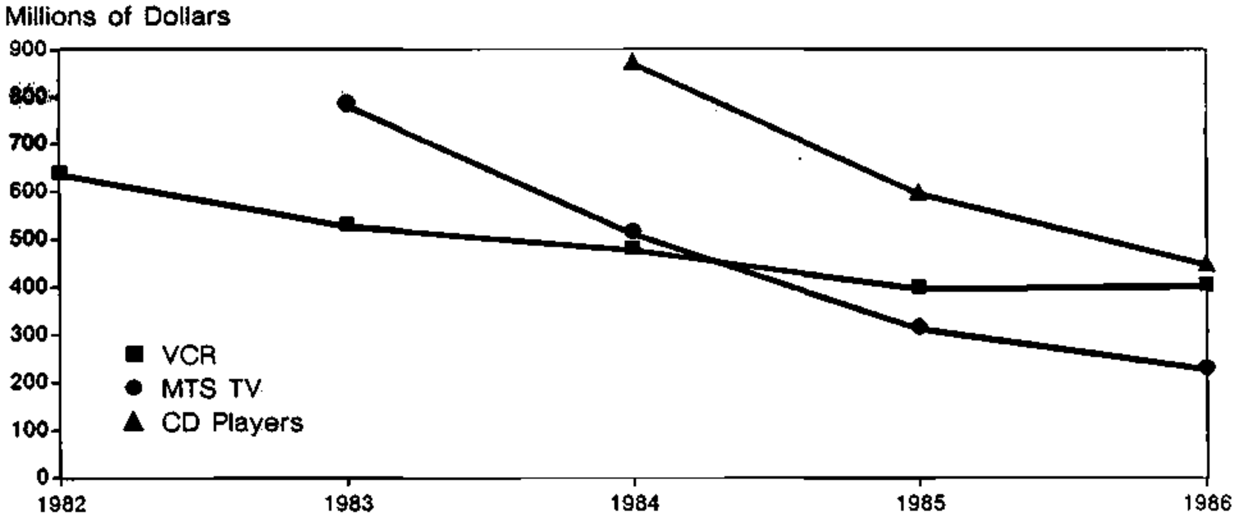
For the major consumer product areas, price is perhaps the single most significant factor affecting success in the marketplace. The electronic products sold to the consumer are generally lower margin than those in the other five application market segments. As a consequence, profitability is dependent 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

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.

Trends in Consumer Electronics

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

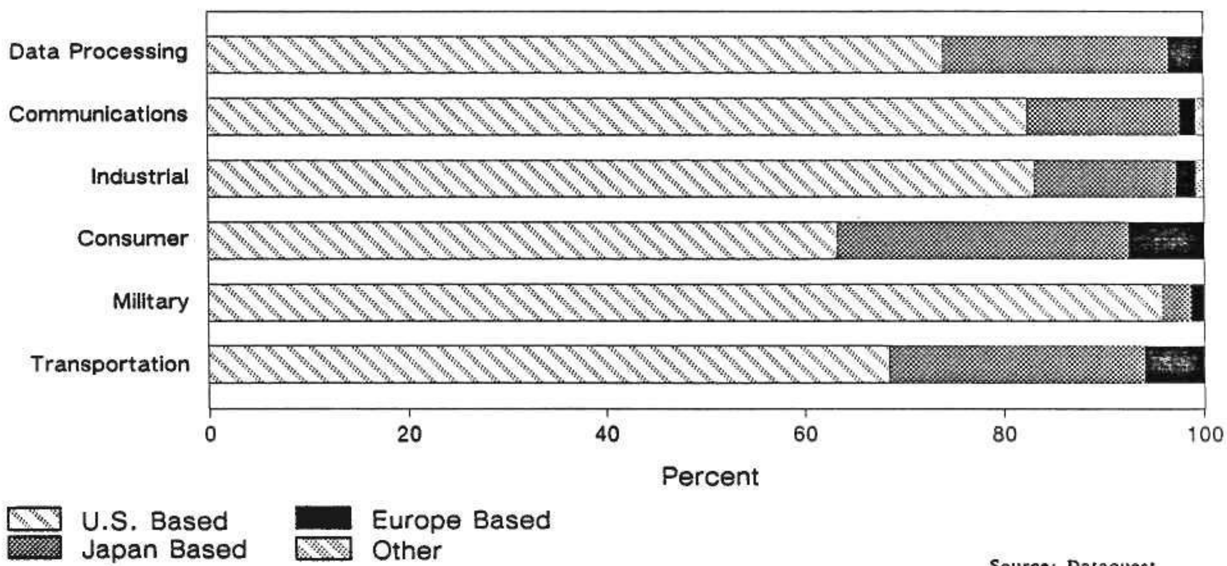
Regional Supplier Base

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

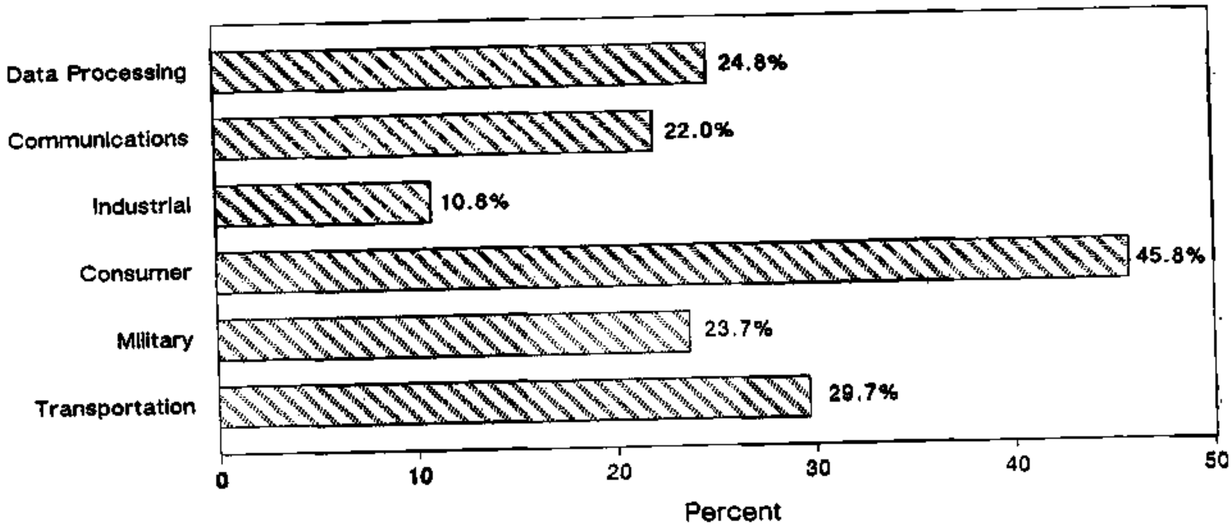
1985 SEMICONDUCTOR PROCUREMENT BY REGIONAL SUPPLIER BASE



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

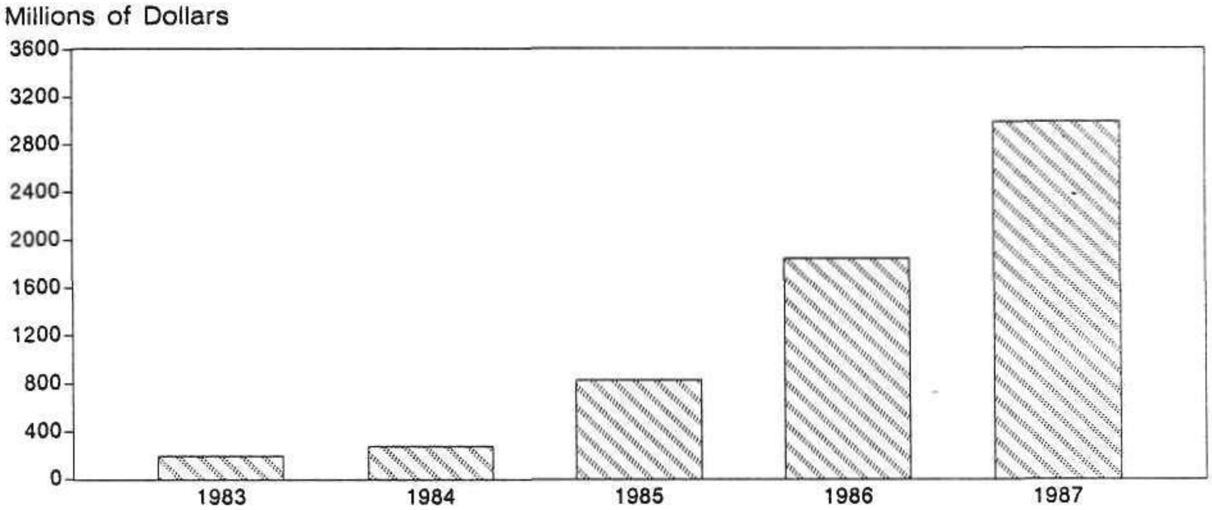
Compact Disk Players

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.

Military

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

- Semiconductor Consumption Military
- Trends In Military Electronics

NOTE: The arrow symbol indicates the latest document(s) correct location behind this subject tab.

Semiconductor Consumption—Military

Index of Tables

Table 1

Forecast North American Electronic Equipment Production
Military
(Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR (%) 1989-1990	CAGR (%) 1989-1994
Factory Revenue	51,063	51,727	52,918	54,263	55,845	57,866	59,998	2.3	3.0

Source: Dataquest (July 1990)

Table 2

Forecast North American Merchant Semiconductor Revenue
Military
(Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR (%) 1989-1990	CAGR (%) 1989-1994
Total Semiconductor	1,669	1,679	1,716	1,766	1,843	1,946	2,069	2.2	4.3
Total IC	1,313	1,338	1,375	1,417	1,484	1,575	1,684	2.7	4.7
Bipolar Digital	368	356	336	309	284	263	243	(5.6)	(7.4)
Bipolar Memory	66	58	51	44	39	35	32	(12.8)	(11.1)
Bipolar Logic	302	298	286	265	246	228	211	(4.2)	(6.7)
MOS	619	671	727	791	868	955	1,054	8.4	9.5
MOS Memory	241	268	291	315	345	382	423	8.5	9.6
MOS Micro	141	150	162	176	195	215	238	8.0	9.7
MOS Logic	237	253	274	299	328	359	393	8.5	9.2
Analog	326	312	312	318	332	357	387	0	4.5
Discrete	293	281	283	288	295	303	311	0.5	2.0
Opto	63	60	59	61	64	69	74	(1.5)	4.3

Source: Dataquest (July 1990)

Table 3

Forecast North American Merchant Semiconductor Revenue
Military
(Input/Output Ratios, Percentage)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	3.3	3.2	3.2	3.3	3.3	3.4	3.4
Total IC	2.6	2.6	2.6	2.6	2.7	2.7	2.8
Bipolar Digital	0.7	0.7	0.6	0.6	0.5	0.5	0.4
Bipolar Memory	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Bipolar Logic	0.6	0.6	0.5	0.5	0.4	0.4	0.4
MOS	1.2	1.3	1.4	1.5	1.6	1.7	1.8
MOS Memory	0.5	0.5	0.5	0.6	0.6	0.7	0.7
MOS Micro	0.3	0.3	0.3	0.3	0.3	0.4	0.4
MOS Logic	0.5	0.5	0.5	0.6	0.6	0.6	0.7
Analog	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Discrete	0.6	0.5	0.5	0.5	0.5	0.5	0.5
Opto	0.1	0.1	0.1	0.1	0.1	0.1	0.1

Source: Dataquest (July 1990)

Table 4

Forecast North American Electronic Equipment Production
Military
(Annual Percentage Growth)

	1989	1990	1991	1992	1993	1994
Factory Revenue	1.3	2.3	2.5	2.9	3.6	3.7

Source: Dataquest (July 1990)

Table 5

Forecast North American Merchant Semiconductor Revenue Military (Annual Percentage Growth)

	1989	1990	1991	1992	1993	1994
Total Semiconductor	0.6	2.2	2.9	4.4	5.6	6.3
Total IC	1.9	2.7	3.1	4.7	6.1	7.0
Bipolar Digital	(3.3)	(5.6)	(8.1)	(8.0)	(7.6)	(7.4)
Bipolar Memory	(12.0)	(12.8)	(12.5)	(12.2)	(9.8)	(8.3)
Bipolar Logic	(1.4)	(4.2)	(7.3)	(7.3)	(7.3)	(7.3)
MOS	8.3	8.4	8.8	9.7	10.1	10.3
MOS Memory	11.1	8.5	8.5	9.5	10.5	11.0
MOS Micro	6.3	8.0	9.0	10.6	10.5	10.5
MOS Logic	6.8	8.5	9.0	9.5	9.5	9.5
Analog	(4.5)	0	2.0	4.5	7.5	8.5
Discrete	(3.8)	0.5	1.8	2.3	2.7	2.7
Opto	(5.1)	(1.5)	2.5	6.4	7.0	7.5

Source: Dataquest (July 1990)

Table 6

Forecast North American Merchant Semiconductor Revenue Military (Percentage of Total Military)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total IC	78.7	79.7	80.1	80.3	80.5	80.9	81.4
Bipolar Digital	22.1	21.2	19.6	17.5	15.4	13.5	11.7
Bipolar Memory	3.9	3.4	2.9	2.5	2.1	1.8	1.6
Bipolar Logic	18.1	17.8	16.6	15.0	13.3	11.7	10.2
MOS	37.1	39.9	42.3	44.8	47.1	49.1	50.9
MOS Memory	14.4	15.9	16.9	17.9	18.7	19.6	20.5
MOS Micro	8.4	8.9	9.4	10.0	10.6	11.1	11.5
MOS Logic	14.2	15.1	16.0	16.9	17.8	18.4	19.0
Analog	19.6	18.5	18.1	18.0	18.0	18.3	18.7
Discrete	17.5	16.8	16.5	16.3	16.0	15.5	15.0
Opto	3.8	3.6	3.4	3.4	3.5	3.5	3.6

Source: Dataquest (July 1990)

Trends in Military Electronics

OVERVIEW

In 1989, as in the previous three years, the U.S military posture has been determined mostly by the country's fiscal situation. The nation's continuing refusal to consider significant increases in taxes, reinforced by the apparent effectiveness of the tax issue in the 1988 election, ensures that deficits will remain high. Draconian cuts in federal outlays thus remain necessary even to approach the deficit reduction targets required by the Gramm-Rudman-Hollings (GRH) legislation. Unilateral reductions in Soviet military forces and the general "soft" line pursued by Soviet leader Mikhail Gorbachev ensure that cutbacks in defense expenditure should assume at least a proportionate share of the overall reduction in federal spending.

BUDGET REVIEW

The fiscal 1990 budget and fiscal 1990 to 1994 defense program developed under former President Reagan envisioned a 2 percent real growth in defense spending in 1990 and a 19 percent real increase during the full five-year period (see Table 1).

These plans fell by the boards in March when U.S. President George Bush reached a budget compromise with congressional leaders that will hold defense appropriations constant in real terms during the next two years (see Table 2). The resulting $10 billion reductions in the planned fiscal 1990 and 1991 defense budgets were apportioned among individual programs by the new secretary of defense, Richard Cheney, in one of his first actions. Cuts fell disproportionately on investment accounts (see Table 3). Reductions in investment accounts made up more than 70 percent of Secretary Cheney's proposed cuts although they account for only 40 percent of the overall budget.

Table 1

U.S. Defense Budget by Appropriation Title
(Budget Authority in Billions of Constant 1990 Dollars)

	Actual 1989	Actual 1990	Reagan Proposed 1990	Reagan Proposed 1991
Personnel	80	79	80	80
Operation and Maintenance	89	86	92	92
Investment Procurement	82	84	84	90
R,D,T, & E	39	38	41	41
Construction/Other	10	8	9	10
Total	300	295	306	312

Source: U.S. Department of Defense

Table 2

Bush Budget Proposals, Fiscal Years 1990-1994 (Billions of Dollars)

Fiscal Year	Revenue	Outlays Defense	Nondefense	Deficit	GRH Target
1990	1,059.3	289.8	862.0	98.6	100
1991	1,140.5	297.9	909.4	69.2	64
1992	1,212.2	306.8	937.6	34.3	28
1993	1,281.4	317.4	961.6	1.6	0
1994	1,345.0	329.5	982.1	33.4*	N/A
Totals	6,038.4	1,541.4	4,652.4		

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

Source: U.S. Department of Defense

Table 3

Secretary Cheney's Reductions from the Reagan Defense Budget (Budget Authority in Billions of Dollars)

	Fiscal 1990	Fiscal 1991
Military Personnel	0.7	0.8
Operations and Maintenance	1.5	1.5
Investment		
Procurement	5.4	4.7
Research and Development	1.5	1.8
Construction	0.5	0.4
Other	0.6	0.8
Total	10.0	9.9

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

Source: U.S. Department of Defense

This decline continued a four-year trend. In real terms, U.S. defense investment doubled between fiscal 1980 and 1985; it then dropped 15 percent between fiscal 1985 and 1989. Procurement actually declined 22 percent in real terms during this latter period, while R&D continued to increase. The result has been quite marked in less politically visible appropriations. The munitions accounts were hit hard, for example, as were weapon accounts, army and marine corps procurement, and some activities in the "Other" procurement account category (see Table 4).

Table 4

Forecast Trends in Selected Procurement Accounts
(Millions of Dollars)

	FY 1980	FY 1985	FY 1989	FY 1991
Total Procurement	34,994	91,382	76,699	87,830
		Winners		
Missiles, Army	1,150	3,167	2,592	2,662
Weapons, Navy	1,993	4,354	6,093	5,725
Shipbuilding and Conversion, Navy	6,621	11,636	9,532	9,551
Other, Navy	2,607	5,342	4,625	4,915
Missiles, Air Force	2,144	6,888	7,120	7,382
Other, Air Force	2,653	8,858	8,154	8,562
		Losers		
Aircraft, Army	946	3,942	2,872	2,906
Ammunition, Army	1,136	2,646	2,005	1,705
Other, Army	1,480	5,141	4,660	4,169
Weapons and Tracked Combat Vehicles, Army	1,724	4,504	2,820	2,724
Aircraft, Navy	4,345	10,897	9,314	8,826
Procurement, Marine Corps	284	1,816	1,292	1,197
Aircraft, Air Force	7,911	26,091	15,619	16,787

Source: U.S. Department of Defense

Under the Reagan program, this trend in investment was to be reversed; for example, procurement was to increase by 10 percent in real terms by 1991. Secretary Cheney's cuts already have deferred this increase until later in the five-year defense program. Additional reductions in defense spending that are likely to be made in 1990 and are now being considered within the Pentagon will make them impossible.

Because of the previous cuts in less visible procurement accounts, Secretary Cheney was forced to cut back some big-ticket items in his review of the defense budget. The Strategic Defense Initiative (SDI), for example, was reduced from $5.6 billion to $4.6 billion in fiscal 1990 and from $6.7 billion to $5.5 billion in fiscal 1991; the B-2 Stealth bomber appropriation request was cut by $0.8 billion in fiscal 1990 and more than $3.0 billion in fiscal 1991. Secretary Cheney's cuts fell particularly hard on aviation. The V-22 Osprey helicopter program was canceled outright and planned buys of the Army's AH-64 Apache and UH-60 Blackhawk helicopters were foreshortened. Anticipated purchases of variants of the Navy's F-14 Tomcat and Air Force's F-15E Eagle fighters also were reduced.

MACROTRENDS IN U.S. DEFENSE SPENDING

Overview

The General Accounting Office has estimated that the revised Cheney five-year defense program would be underfunded by $150 billion in the defense budgets now planned by the Administration. Factors contributing to the underfunding include underestimates of certain program costs and unrealistic estimates of the rate of inflation. If this estimate is accurate, and if the Administration and Congress continue to stress preservation of the size and readiness of U.S. armed forces at the expense of modernization programs, cuts will continue to fall disproportionately on procurement and R&D development.

Other than the possibility of an unexpected increase in federal revenue, the main factor that could alter this prognosis would be conclusion of arms control agreements, particularly an agreement requiring major reductions in U.S. forces in Europe. Such an agreement could lead to reductions in the size of U.S. ground and air forces, offsetting pressures on investment accounts to a degree. This possibility notwithstanding, the impact of any future cuts will depend strongly on the priorities that the Bush administration establishes among military missions, as well as the strategy it adopts for modernizing the U.S. armed forces.

KEY ELECTRONIC PROGRAMS

Fifty major defense programs with large and interesting electronics contents are listed in Table 5.

Table 5

Fifty Key U.S. Weapon Programs with High Electronic Content (Millions of Dollars)

Program	Planned FY 1989	Approx. FY 1990	Projected FY 1991-1994
Air Force Aircraft Programs			
B-2 Stealth Bomber	5,200	4,700	18,000
B-1B Bomber Avionics	200	100	700
C-17 Cargo Aircraft	1,100	2,100	6,400
Advanced Tactical Fighter	700	1,000	6,000
F-16	3,300	3,100	10,500
F-15 Fighter	1,600	1,500	2,500
Navy Aircraft Programs			
A-12 Attack Aircraft	1,500	2,600	9,800
F/A-18 Fighter	2,500	2,400	8,900
P-7 Antisubmarine A/C	70	200	2,100
V-22 Osprey Helicopter	600	300	800

(Continued)

Table 5 (Continued)

Fifty Key U.S. Weapon Programs with High Electronic Content (Millions of Dollars)

Program	Planned FY 1989	Approx. FY 1990	Projected FY 1991-1994
Army Helicopter Programs			
LHX Light Helicopter	200	300	2,400
AH-64 Apache	1,100	800	3,100
UH-60 Blackhawk	500	400	1,600
OH-58 Modifications	200	200	500
Avionics			
INEWS/ICNIA	70	40	800
Joint Surveillance Target Attack Radar System (JSTARS)	260	140	600
Airborne Self-Protection Jammer (ASPJ)	20	20	140
Advanced Tactical Air Reconnaissance System (ATARS)	140	290	1,060
Joint Tactical Information Distribution System (JTIDS)	40	30	180
Low-altitude Navigation and Targeting Infra-Red System for Night (LANTIRN)	730	200	100
Strategic Missile Programs			
Trident II Submarine-Launched Ballistic Missile	2,400	2,000	6,100
M-X Rail-Mobile Land-Based Ballistic Missile	1,400	1,800	7,500
Midgetman Land-Mobile Ballistic Missile	240	200	1,000
Short-Range Attack Missile (SRAM II)	200	230	1,200
Tomahawk Sea-Based Missile	700	570	2,000
Tactical Missile Programs			
AGM-65D/G/G Imaging Infra-Red Maverick Missile	350	380	1,300
Advanced Medium-Range Air-to-Air Missile (AMRAAM)	840	860	3,900
AGM-88 HARM	60	350	1,200
AIM-54 Phoenix	400	320	950
Harpoon Antiship Missile	170	210	600
SM-2 Navy Air Defense Missile	590	390	1,400
Patriot Army Air Defense	870	800	3,000
Stinger Army Air Defense	380	120	800
Chaparral Army Air Defense	20	30	160

(Continued)

Table 5 (Continued)

Fifty Key U.S. Weapon Programs with High Electronic Content
(Millions of Dollars)

Program	Planned FY 1989	Approx. FY 1990	Projected FY 1991-1994
Tactical Missile Programs (Continued)			
Advanced Heavy Antitank Missile System	180	270	1,200
Army Tactical Missile System (ATACMs)	150	200	800
Space Systems			
Strategic Defense Initiative	3,630	3,900	14.000
Space Boosters	1,100	1,000	4,600
MILSTAR Satellites	400	400	900
NAVSTAR System	100	100	700
Defense Support Program Satellites	300	430	1,200
Defense Meteorological Satellite Program	100	190	500
Advanced Launch System	100	100	750
Ships			
Burke-Class Destroyer	2,900	3,700	14,000
Seawolf-Class Submarine	1,700	1,800	12,000
Ohio-Class Ballistic Missile Submarine	1,300	1,300	5,600
Communications			
Mobile Subscriber Equipment	950	900	2,200
Single-Channel Ground and Airborne Radio System (SINCGARS)	300	300	1,300
Worldwide Information System (WIS/WAM)	100	100	550
Army Tactical Systems	300	400	1,800

Source: Defense Forecast

AIRCRAFT AND AVIONICS

Overview

Aircraft rely heavily on electronic and optoelectronic devices to perform almost all functions: navigation, flight control, surveillance, target acquisition, and defensive functions. This reliance is reflected in the estimate that avionics will comprise between 40 and 60 percent of the cost of next-generation aircraft. All the military services seek to integrate more closely and improve the commonality of avionics. Next-generation aircraft will use a new avionics systems architecture that divides avionics into three functional categories: mission management, sensor management, and vehicle management. Technologies for mission management include radars, fire control systems, and sensors for target surveillance and acquisition. Sensor management technologies are less established than those for mission management, as fully integrated programs like Integrated Electronic Warfare Systems (INEWS) are just beginning to be deployed. Although airborne computers have been used for quite some time, artificial intelligence methods will provide real-time options for the pilot and will be indispensable for future innovations like the mission adaptive wing. Vehicle management technologies are used for flight control instruments, such as cockpit displays and fly-by-wire or fly-by-light, and for navigational aids, such as inertial navigation units and communications gear.

New Aircraft Models

Advanced Tactical Fighter (ATF)

The ATF will replace the F-15 as the air force's top fighter from the mid-1990s to the year 2020 and may eventually also serve the navy in place of F-14s. The air force expects to procure 750 ATF aircraft, whereas the navy estimates a need for 552 carrier-capable versions of the ATF. Through 1989, approximately $1.1 billion has been funded for engine, airframe, and critical subsystem R&D.

The two prime contracting teams, Lockheed-General Dynamics-Boeing and Northrop-McDonnell Douglas, have less than a year before prototype flights, after which a $7 billion full-scale development contract will be awarded (June 1991).

Light Helicopter Experimental (LHX)

The army's LHX program to replace AH-1, OH-58 (A,C,D), and OH-6 helicopters and complement the AH-64 has been scaled back considerably from the original concept defined a few years ago. Since the utility version was dropped in 1988, the number of aircraft to be procured fell to 2,096 from more than 4,100. An independent study has been conducted to determine whether competitive production is still warranted, given these lower numbers.

In November 1988, the army awarded two $158 million contracts to the contractor teams of Bell Helicopter Textron-McDonnell Douglas Helicopter Co. and Boeing Vertol-Sikorsky Aircraft for a 23-month demonstration/validation phase, ending September 1990. A full-scale development and production contract is planned to be awarded in December 1990, and initial operating capability is scheduled for 1996. Additional slippage in the program can be expected.

V-22 Osprey Tilt Rotor Aircraft

Before cancellation, procurement of V-22 Ospreys was planned to begin in fiscal year 1990, with a request by the navy and marine corps in the original Reagan budget of about $1.3 billion for 12 aircraft. Designed to meet all four services' requirements, the tilt-rotor aircraft is capable of many different missions and incorporates significant new technologies like composite materials (more than 60 percent of the airframe) and full integration of avionics. The total cost of research, development, and production of the V-22 is $60 billion.

Advanced Tactical Aircraft (ATA)

The U.S. Navy began development of the Advanced Tactical Aircraft (ATA), or A-12, in 1985 to replace carrier-based A-6 attack planes and possibly F-111s. Details on capabilities, costs, and schedule of the program are classified, although some milestones have been made public. The navy began a demonstration/validation phase in late fiscal year 1988, with full-scale development beginning in late fiscal year 1990, first flights in the mid-1990s, and first delivery in 1997. The navy will probably procure about 450 aircraft if it expects to replace its current inventory of A-6s. McDonnell Douglas and General Dynamics were chosen as the prime contracting team in 1987 and awarded a $4.4 billion development contract.

B-2 Stealth Bomber

Details on the cost and specific technologies of Northrop's Advanced Technology Bomber still remain classified, although the B-2 was officially unveiled in November 1988. First flight was planned for early this year but was delayed until the summer of 1989. Total program cost has risen 16 percent from $36.6 billion for 132 aircraft to $68.1 billion ($42.5 billion in 1981 dollars). One-third of that amount will be expended in R&D; currently 70 percent of that R&D budget has been spent, according to air force officials. At present, each aircraft is estimated to cost $530 million.

The B-2 industrial team is led by Northrop Corp. and includes Boeing Advanced Systems Co., GE Engine Group, and LTV Aircraft Products Group as key members.

Modernization Programs

Fighters

The following modernization programs apply to fighters:

- F-16 Falcon. The air force's F-16 Falcon is undergoing at least two different modification programs. The first of these, the Operational Capabilities Upgrade for F-16 A/Bs includes wiring for AIM-7 Sparrow, AIM-9 Sidewinder, or Penguin antiship missiles, expanded avionics memory, and radar improvements. In December 1988, Block 40 aircraft were delivered to the air force. These included a digital flight control system, Low-Altitude Navigation and Targeting Infra-Red System for Night (LANTIRN), Global Positioning System (GPS), automatic terrain following, and a diffractive optics HUD. Block 50 aircraft of the upgrade program will be delivered in mid-1991. These new aircraft will include HARM/Shrike missile-carrying capabilities, radar and cockpit improvements, ASPJ, ALE-47 advanced chaff flares and an advanced threat warning radar (ALR-74 and ALR-56M).

- F/A-18 Hornet. The F/A-18 Hornet is replacing the F-4, RF-4, A-7, and the A4M in the marine corps and navy. The F/A-18D is a two-seat all-weather version for marine night attack and reconnaissance. Beginning in October 1989, all F-18s will have all-weather and night capability and will incorporate the Hughes AN/AAR-50 FLIR thermal imaging navigation set, as well as a Honeywell color digital moving map. Further upgrades include a program to begin in fiscal year 1990 that will improve the F-18's air-to-air capability.

- F-15 Eagle. Procurement of the E variant of the F-15 continues at slightly lower levels than in fiscal year 1989; 36 aircraft have been requested for fiscal year 1990, down from 42 in fiscal year 1989. The air force, which hoped to procure a total of 392 F-15Es, requested $125 million in additional R&D funds this year. Procurement of F-15Es will likely continue at or near current rates until 1991; the total number will fall short of the air force goal by 78 aircraft according to the amended Cheney budget. Among the improvements to the F-15 are the installation of LANTIRN, the first VHSIC radar (APG-70), ECCM, ASPJ, and new missile systems. The prime contractor, McDonnell Douglas, recently received an $880 million contract for production of 42 F-15Es.

Helicopters

The SH60B LAMPS MK-1 will receive an Interface Converter Unit produced by Computer Devices Co. under subcontract to Kaman Aerospace. The equipment converts information from radar, sensors, and analog flight information to digital data form. The interface converter unit works in conjunction with the AN/ASN-150 tactical data handling system to present an aggregate picture of the threat situation. Other upgrades to the SH60B include a GPS receiver, Penguin antiship missiles, and the MK-50, or Advanced Lightweight Torpedo. Six SH60 LAMPS MK IIIs each year have been requested by the navy for fiscal year 1990 and fiscal year 1991. Block I improvements to MK IIIs are currently under way. These include an AN/ARC-182 UHF/VHF transceiver, an enhanced AN/AYK-14 computer, and the more versatile MIL-STD-1553B data bus.

The army's CH 47 medium lift helicopter is currently being upgraded to the D configuration at the rate of about 48 aircraft per year. Boeing was contracted for $713 million to modernize 144 of these CH 47s; the army requested $304.5 million for fiscal year 1990 for the program. Full lot production of 18 helicopters began in 1988.

Surveillance Aircraft

The AWACS (E-3) aircraft is currently in the midst of its Block 30/35 upgrade, also known as Integration Contract, or ICON. ICON includes installation of an IBM CC2-3 computer with advanced bubble memory, Joint Tactical Information Distribution System (JTIDS), Global Positioning Satellite receiver, and ESM systems. Boeing recently received a $241 million contract to develop the U.S.-NATO cooperative electronic support measures system (ESM) for the AWACS, to be completed in mid-May 1990.

The E-2C Hawkeye carrier-based airborne surveillance aircraft will be improved with the APS-145 enhanced radar by fiscal year 1991 and will incorporate improved identification, friend or foe (IFF) measures. Beginning in fiscal year 1991, the navy hopes to procure nine new E-2Cs annually. Grumman will integrate JTIDS into the E-2C by the end of this year. Two contracts also have been awarded for upgrading the ES-3A and S-3B for radar systems and general modifications. Texas Instruments received a contract for $24 million for 33 AN/APS-237 radar systems, and Lockheed recently was contracted to modify S-3A aircraft into ES-3A at the cost of $56 million. Work should be completed in mid-1992.

Transport and Trainers

The T-45, a derivative of the British Hawk, will replace the T-2 and TA-4 as the navy's trainer. The navy requested $413 million in fiscal year 1989 production funds, but flight testing revealed deficiencies causing the navy to withhold funding until Douglas Aircraft corrected them. The T-45 was expected to be operational in fiscal year 1990, but the flight test program was seven months behind schedule in January 1989.

Components

The air force program recently selected the team of Allied-Signal Aerospace Company (formerly Bendix) and Raytheon to produce the Mark XV IFF system, an upgraded version of the Mark XII. The Mark XV IFF could enhance survivability of aircraft by its improved ability to identify aircraft at great distances in adverse weather and hostile jamming conditions. The production award made in early 1989 covers 5 years of full-scale development followed by a 10-year production program and could exceed $4 billion. The Mark XV IFF system is also the U.S. element of the NATO identification program and therefore holds considerable potential for other production contracts.

LANTIRN

The LANTIRN system will provide the air force with the ability to conduct offensive tactical missions at night. Martin Marietta is producing the LANTIRN navigation pod under the terms of a $715 million contract awarded in December 1986 by the air force. The air force plans to install some 700 LANTIRN systems on F-15E and F-16C/D aircraft, with the first operational unit on the F-16 in 1989 and the F-15 model to follow shortly thereafter.

ELECTRONIC WARFARE

Overview

The electronic environment on the battlefield continues to grow more hostile, and a wider range of jamming equipment is being fielded than ever before. In the past, most electronic warfare equipment, such as radar warning receivers and jammers, operated at radio frequencies. Improved Soviet capability in heat-seeking missiles, which operate in the infrared range of the electromagnetic spectrum, as well as in other systems operating in the visible range of the spectrum, have spurred the military services to create a broader array of countermeasure programs.

The U.S. inventory contains more than 400 signals intelligence and EW systems. The market for EW systems grew at an average rate of 25 percent from fiscal 1982 to 1985, but it has since leveled off at approximately $6 billion annually. Procurement of electronic warfare equipment may even suffer some small cutbacks in the near term. The acquisition of spares, however, will continue to grow as electronic equipment is used more widely than ever before. Overall spending on electronic warfare is likely to increase in the early 1990s, moreover, when the next generation of EW systems goes into production.

Aircraft Modifications and Upgrades

F-4G Performance Update Program

The F-4G Wild Weasel has been the mainstay of air force electronic countermeasures platforms. The F-4G's capabilities are being enhanced with improved receivers and signal processing capabilities. Total funding for F-4G modifications was $95 million in the fiscal year 1990 budget request and $108 million in the fiscal year 1991 request. Under a 1986 contract to McDonnell Douglas, approximately 150 new units, including spares, will be produced for 119 F-4G aircraft.

F-111

The program to upgrade the entire F-111 fleet—including the F-111, FB-111, and EF-111—with new self-protection avionics equipment was canceled in 1987. Nevertheless, some other improvements are being made. Rockwell International's Collins Government Avionics Division delivered integrated communication navigation sets under a $1.9 million contract with the USAF Sacramento Air Logistics Center in late 1988. With options, total value of the contract could reach $7.5 million. Other upgrades include the ALR-62I radar warning receiver and the ALQ-97/137 self-protection jamming system. Production has begun on the ALR-62I, and the air force is currently procuring ALQ-131/184 pods for the F-111. The EF-111 will retain its ALQ-94/137 internal jammer, but there are plans to upgrade this system in 1992.

EA-6B

Capabilities of the navy's EA-6B tactical support aircraft were enhanced under the Improved Capability Program (ICAP II) by Boeing Aerospace, which was awarded an $11 million contract. Grumman subsequently received an $18 million contract in January 1989 to perform the next upgrades on the EA-6B. Additional modifications will be made under the Advanced Capability Program (ADVCAP), scheduled to begin in fiscal 1990. The ALQ-99 is the backbone of the ADVCAP. Litton was selected by Grumman to produce the ALQ-99, and flight testing was conducted last year; full-scale development is expected in 1991. An improved electronic countermeasures set for the EA-6B, the Lockheed Sanders Associates AN/ALQ-149, has been delivered to the navy, increasing the radar and radio frequency jamming coverage of the aircraft. The Sanders contract included options for 95 sets. The ALQ-149 consists of eight line-replaceable units, including antennas, receivers, signal recognizers, computers, and controls.

Tactical Protective Systems

This program includes upgrading the self-protection and electronic combat capabilities of the F-15 and F-16. The F-15 upgrades include incorporating the ALR-56C radar warning receiver, the ALQ-135 internal jammer, and the ALE-45 chaff dispenser. The ALQ-135 jammer is being produced in fourth and fifth lots. This jammer counters the full range of modern SAMs, antiaircraft artillery, and interceptor radars.

Integrated Defensive Avionics Program (IDAP)

The navy's IDAP program will combine off-the-shelf devices into an integrated ECM suite for navy tactical aircraft, beginning with the A-6E. IDAP will include the following:

- New version of ALQ-156 (IR)
- ALR-67 RWR
- Airborne Self-Protection Jammer (or ALQ-126B)
- ALE-39 expendable CM dispenser or ALE-47
- Towed decoy

Sanders was awarded $12 million in 1989 funds for the full-scale engineering development phase of the ALQ-156 (V) N, with work to be completed by September 1990. The contract includes a receiver/transmitter, a buffer box, and antennas. The receiver is a 1976 pulse Doppler radar developed by Sanders. Total funding for the ALQ-156 (V) N has been $121 million.

Electronic Countermeasure and Support Measure Systems

ECM Pods

The air force is currently in the process of upgrading its inventory of externally mounted electronic countermeasure pods for the F-16, the F-111, the F-4, the A-10, and the A-7. Raytheon is the prime contractor to upgrade the ALQ-119 pods, which passed qualifying tests in 1988. Westinghouse has delivered ALQ-131 Block II pods to the air force.

Decoys

The services are developing new active radio-frequency-expendable decoys. The navy awarded a contract to a Raytheon-Hughes team in July 1988 for full-scale development of the Advanced Airborne Expendable Decoy. Two versions are being explored: a rocket-propelled system fired forward of the aircraft and a towed decoy.

AN/ALR-67

In production for several years, the AN/ALR-67 is deployed on navy F-14 A/D Tomcats, F/A-18C/D Hornets, and AV-8B Harriers. The ALR-67 is a countermeasure radar warning system that will be integrated with the Airborne Self-Protection Jammer (ASPJ). Litton is the prime contractor; Dalmo Victor is a second source. Litton received two production contracts for $37 million total in early 1989 and a third contract for $49 million in March 1989 for spares procurement. Deliveries are scheduled to begin in April 1990 and last through 1991. The contract includes quadrant receivers, computers, and special receivers.

Integrated Electronic Warfare Systems (INEWS)

The largest EW program in history, INEWS will be standard equipment aboard the next generation of combat aircraft, including the air force ATF and B-2, and the navy ATA. The DOD spent $128 million on INEWS in 1988. INEWS will be used to replace the AN/ALQ-165 (ASPJ) on existing aircraft. For combat aircraft of the next century, INEWS will fuse the capabilities of jammers, missile detection/warning, laser-radiation detection/warning, and infrared missile jammers using VHSIC technology. Each chip will contain as many as 30,000 logic gates.

In a radical departure from past designs, INEWS will share common processors and antennas among the aircraft's electronic systems, allowing savings in weight, space, and cost. INEWS will incorporate the latest microelectronic technologies, including VHSIC and MIMIC.

Two industry teams are presently working on demonstration and validation of the system: TRW/Westinghouse (with Honeywell, Perkin-Elmer, GTE, Northrop, and Tracor as subcontractors) and Sanders Associates/General Electric (HRB-Singer and Motorola as subcontractors).

Other Countermeasure Programs

Expendable Jammers

A classified program to develop expendable jammers is being conducted by the DOD. A second program, called GEN-X Expendable Cartridge, has been conducted since 1987. Texas Instruments was awarded a $117 million contract to develop and produce the GEN-X, which operates over a wider frequency band than its predecessor, the Primed Oscillator Expendable Transponder (POET); Raytheon was selected as a second source. The GEN-X emits radar-like signals to lure radar-guided missiles away from target aircraft.

Electro-Optic Countermeasures (EOCM)

A new niche is beginning to appear in the defense electronics market. As every military measure begets a countermeasure, the increasing use of laser guidance and optical detection will create a need for electro-optical countermeasures (EOCM).

Have Glance

At present, IR jammers are deployed on helicopters, but advances in power and decreased size are necessary before they can be used effectively on aircraft. The classified Have Glance program aims to develop potential solutions to those problems in infrared countermeasures. The Have Glance system will use an infrared or pulse Doppler warning system to detect the missile and trigger the laser. In September 1988, Loral was selected over TRW to develop a laser-based IR countermeasures system. The resulting system will be used for strategic systems until its size can be reduced for tactical systems. Loral will develop a gimballed, low-power laser to locate, identify, and track approaching missiles and confuse or disable their guidance systems. Demonstration testing is expected in 1991.

SIMULATION AND TRAINING

Overview

As weapons and combat become more complex, training requirements increase. Although live training is most desirable, it is very expensive, and hence the services are turning increasingly to simulation to meet their training needs. Although it is a significant part of readiness, which is being highlighted by the Bush administration as a priority, training probably will not be immune to prospective budget cuts, and the reductions will likely reinforce upward trends in the use of simulators.

Simulators have become attractive to the services for their potential to increase training hours while reducing costs. The navy estimated that increased use of simulators would reduce fuel consumption by 64 percent, manpower by 44 percent, and the total training cost of a navy pilot by 45 percent.

Although simulators have been commonplace in both military and civilian aviation, the changing nature of warfare makes armored and even infantry battle sufficiently complex to warrant simulations. Training and simulation is approximately a $2 billion market in the United States, with moderate growth forecast for the next five years.

MISSILE SYSTEMS

Overview

There are two discernable trends in missile technology: emphasis on fire-and-forget capability for all classes of missiles (air-to-air, air-to-surface, surface-to-air, and surface-to-surface) and increased range sufficient for the missile to be fired before being detected, sometimes called beyond-visual-range or standoff range. Both developments are intended to decrease the vulnerability of the missile platform, an increasing concern given the smaller number and higher cost of modern military equipment, and the increased lethality of enemy forces. Fire-and-forget capability depends on the development of autonomous or semiautonomous guidance for the missiles. Such missile guidance allows aircraft, ships, or ground units to designate and lock on a target, launch the missile, and leave the area immediately, significantly increasing its survivability. Missiles with fire-and-forget capability require independent navigation units, independent radars or other seekers, and, often, small on-board computers.

Among the most important new missiles incorporating such capabilities are the army's Fiber-Optic Guided Missile (FOG-M) and Advanced Anti-Tank Weapon System (AAWS-M), the navy's Advanced Interdiction Weapon System (AIWS) or Sea Lance, and the air force's Advanced Cruise Missile. Key manufacturers of the critical components are Northrop and Litton for navigation units; Emerson Electric, Hughes, and Westinghouse for radars; Martin Marietta and Texas Instruments for infrared seekers; and Delco and IBM for on-board computers.

New Procurement

Trident II D-5 Missile

The navy requested a total of $2 billion for development and procurement of the D-5 missile in fiscal year 1990: $222 million for development and $1.8 billion for 63 missiles. The navy expects to spend slightly less in fiscal year 1991: $71 million for development and $1.5 billion for 52 missiles. Lockheed, the prime contractor for the D-5, was awarded some additional $700 million for development and production of the missile, scheduled to be completed in March 1990. Some subcontracts include $47 million to Rockwell for production and support of inertial navigation subsystems and $9.6 million to Westinghouse for launcher system hardware, to be completed by September 1990; Atlantic Research will develop the post-boost control system for the Trident II under an $80 million contract.

Charles Stark Draper Laboratory is working on guidance; Interstate Electronics is working on instrumentation.

Short-Range Attack Missile (SRAM II)

The SRAM II, a supersonic low-radar cross-section nuclear-armed missile, will upgrade existing armaments on long-range bombers deployed from the 1990s on. Boeing, the prime contractor, has emphasized the use of state-of-the-art technology, such as VHSIC, composite materials, and ring-laser gyros to increase the missile's range and accuracy and to reduce its radar observability. Contracts let to Boeing in fiscal year 1989 totaled about $197 million to continue full-scale development, including design completion of the air vehicle, its components, and aircraft interfaces.

Advanced Medium-Range Air-to-Air Missile (AMRAAM)

The AMRAAM will replace the AIM-7 Sparrow as the principal medium-range radar-guided air-to-air missile in the U.S. inventory and has been selected as a standard NATO weapon. Unlike the Sparrow, AMRAAM has launch-and-leave capability by virtue of its built-in radar, as well as greater speed (Mach 4) and increased reliability. Total air force and navy contracts for the primary team of General Motors and Hughes and for the second source, Raytheon, were $849 million in fiscal year 1989. The two services have requested a total of $1.2 billion in fiscal year 1990 and $1.3 billion in fiscal year 1991.

Advanced Antitank Weapon System-Medium Tankbreaker (AAWS-M)

After a 27-month technology demonstration phase, the army selected the team of Martin Marietta and Texas Instruments in February 1989 for full-scale development of the AAWS, the follow-on to the shoulder-fired Dragon antitank weapon system. Fiscal year 1989 contracts for $157 million included work for the competing teams of Ford Aerospace and General Dynamics, which developed a laser-beam-riding missile, and Hughes and Honeywell, which proposed IR focal plane array guidance with optional fiber-optic data links.

Fiber-Optic Guided Missile (FOG-M)

The FOG-M is one of three missiles incorporated in the army's Advanced Antitank Weapon System-Heavy (AAWS-H) program and also was chosen for the Non-Line-of-Sight portion of the Forward Area Air Defense System. The FOG-M is an antiarmor, antihelicopter missile and guidance system that uses fiber-optic technology to view a battlefield and attack targets from a range of roughly 10 kilometers. The Boeing Company and Hughes Aircraft Company team was selected by the army in late 1988 as codevelopers of the FOG-M. Contracts awarded to Boeing and Hughes are estimated at $172 million for fiscal year 1990 and $230 million for fiscal year 1991.

Continuing Procurement

AGM-88 High-Speed Anti-Radiation Missile (HARM)

The High-Speed Anti-Radiation Missile, or HARM, is designed to defend aircraft against surface-to-air missiles while they are performing strike missions. Texas Instruments is the prime contractor for the HARM and received about $531 million in contracts in fiscal year 1989. Ford Aerospace and Communications Corporation is expected to be qualified as a second source in 1989.

AGM-65 Infrared Maverick

This successful air-to-surface missile program procured by both the air force and navy may be upgraded in the future to improve its range. The prime contracting team is General Motors-Hughes, although production is currently shared with Raytheon, which currently has orders for more than 4,400 missiles, including 60 percent of the fiscal year 1988 purchase (2,483 missiles).

Multiple Launch Rocket System (MLRS)

The Multiple Launch Rocket System, first deployed in fiscal year 1983, carries 12 conventionally armed rockets and supplements cannon artillery fire. The MLRS will be used to fire the army's ATACMs and could be configured for binary chemical weapons and the Tacit Rainbow drone. LTV is the primary contractor and received about $454 million in contracts in fiscal year 1989. The army has requested $79 million in development funds for fiscal year 1990 and $336 million to procure 24,000 MLRS systems; for fiscal year 1991, the army has requested $380 million in development and procurement for 24,000 MLRS systems.

Research and Development

In the near term, R&D in missiles will probably focus on improved guidance, including fiber-optic data links and millimeter wave guidance. Some feasibility studies have been conducted on fiber-optic applications, specifically by the Hughes Missile Systems Group, on controlling long-range, air-launched missiles with fiber-optic data links. Hughes will conduct a flight concept demonstration program (18 months) to study the dynamics and kinematics of fiber-optic data links as they interact with the turbulent air flow field around an aircraft. Other near-term trends include research on target acquisition to allow weapons operators to adjust targeting manually.

MILITARY SPACE

Overview

Until components of the Strategic Defense Initiative (SDI) reach full-scale development, military space procurement will continue to be shaped predominantly by requirements for space launchers and satellites. New programs are emphasizing reductions in weight requirements and enhanced power supplies for space vehicles. At the same time, there is a push toward expendable launchers and cheap, disposable satellites. Currently, a backlog of about two-dozen spacecraft is waiting for launch, the result of the Space Shuttle's problems and the failure of several military launches. This backlog may take up to five years to eliminate. As a result, the DOD is focusing on procuring satellites and launchers that can be boosted into space more quickly and cost-effectively; by the mid-1990s, all DOD payloads will be launched by expendable boosters.

Systems Development and Procurement

UHF Follow-On Satellite Program

The navy currently uses a constellation of five Fleet Satellite Communications satellites and three leased satellite spacecraft for worldwide ultrahigh-frequency communications. In summer 1988, the Defense Acquisition Board approved the construction of one HS 601 advanced satellite for $120 million by Hughes; the contract included an option to build the other nine. In August 1989, the Board decided to procure nine additional satellites as part of a program to upgrade this UHF constellation. The total program will cost about $1.5 billion and will be completed in fiscal 1993. The navy hopes to procure two satellites in fiscal year 1990 at a cost of $313 million and three in fiscal year 1991 at a cost of $201 million.

Defense Support Program (DSP)

Third-generation satellites currently are being procured for the Defense Support Program, which provides early warning of missile launches in foreign nations and at sea. The first DSP spacecraft were launched in 1971; the first of the current Block 14 upgraded spacecraft were launched in March 1989. The new DSP satellites have greater survivability, greater sensitivity, higher power, and a longer lifetime than their predecessors. Built by TRW, nine of these $180 million satellites are expected to be put in orbit in the next few years. Aerojet ElectroSystems developed and builds the infrared telescope and sensor subsystem; IBM developed the software for the DSP. Total cost of the program is estimated to be more than $2 billion.

Defense Meteorological Satellite Program

Funded at a level close to $200 million annually, the Defense Meteorological Satellite Program maintains two satellites in polar orbit continually to record visual and infrared imagery for strategic and tactical missions. RCA is the prime contractor for this program. Second-phase studies are currently being conducted for the program's Block VI satellites, scheduled for launch beginning in November 1990, and to continue through 1993 or 1994. Potential upgrades include active sensing techniques, increased survivability and autonomy, satellite internetting for relaying data, and integration into the Air Force Satellite Control Network.

NAVSTAR Global Positioning Satellite

The NAVSTAR Global Positioning Satellite (GPS) program will provide aircraft, artillery, ships, tanks, and other weapons systems with information on their position, velocity, and time. The prime contractors are General Dynamics and Rockwell International. The air force requested $104 million for fiscal year 1990 and $32 million for fiscal year 1991. Although Block II NAVSTAR satellites, first launched in February 1989, were four years behind schedule, the outlook for the GPS program is good, since the technology is established and is being used on many types of military systems.

MILSTAR

The Military Strategic/Tactical and Relay constellation of satellites will provide extremely high-frequency communications transmissions for U.S. nuclear and other military forces. Most details of the program are classified, but the air force expects to begin deployment in the mid-1990s using Titan IV/Centaur boosters. The final integration of MILSTAR payloads will be tested by Lockheed, the prime contractor, in 1990. Total cost of the MILSTAR program may reach $10 billion, with each satellite and booster combination costing $1 billion.

Medium Launch Vehicles

Procurement of the Delta II and Atlas II space boosters are funded under the Medium Launch Vehicle program. McDonnell Douglas is the prime contractor for the Delta II; General Dynamics is the prime contractor for the Atlas II. The Delta II will be used to launch the NAVSTAR GPS, whereas the Atlas II will launch the Defense Satellite Communications Systems satellites. First flown in December 1988, Delta II carries an 8,400-pound payload into low-Earth orbit (or 2,500 pounds to a 22,300-mile height) and costs about $50 million each. The first seven launch vehicles will be produced under a $316 million contract to McDonnell Douglas. Production of and launch support for all 20 MLVs has an estimated value of $750 million.

Special-Purpose Inexpensive Satellite (Spinsat)

The navy's program to develop small, inexpensive satellites cost about $8 million last year. Defense Systems Inc. was awarded a two-year, $6 million contract in August 1987 for three Maestro (multiple autonomous spacecraft for telecommunications, recording, and observation) satellites. Ardak Inc. was contracted to develop a fourth Spinsat for $2 million, which is called Profile, or passive radio frequency interference location experiment. Although funding for light satellites is not consolidated under one program, the Office of Naval Research, which manages the Spinsat program, expects to undertake future technology demonstrations and issued a request for proposals to that effect in September 1988. Spinsats potentially could be used for communications, oceanography research, and possibly antisatellite, surveillance, and naval-targeting missions. Given the growing emphasis on satellite survivability, redundancy, and autonomy, this program can be expected to grow in the future.

Advanced Launch System (ALS)

The Advanced Launch System is a new family of space vehicles that will provide relatively low-cost and high launch rates across a wide range of payload sizes. The goal of the ALS program, in place since 1986, has been to reduce the cost of space launches from the current roughly $3,000 per pound to $300 per pound by using simpler booster and engine designs, composite materials, and advanced production processes. Some progress has been made. Current cost estimates for the hydrogen engine for the ALS, for example, are about $5 million, compared with $40 million for a Space Shuttle engine. One factor in keeping prospective costs low, however, would be a high rate of production. The total cost of an ALS fleet could run as much as $80 billion through 2010, but this would depend critically on U.S. launch requirements, especially those of SDI.

National Aerospace Plane (NASP)

The National Aerospace Plane is a hypersonic plane (+Mach 5) designed to take off horizontally from conventional airfields and achieve an orbital speed of 18,000 miles per hour. NASP is intended to deliver both military and civilian payloads into space. Some defense applications might include strategic reconnaissance, high-velocity strategic bombardment, and rapid surgical strike missions. NASP is envisioned as an air-breathing, hydrogen-fueled, single-stage-to-orbit vehicle. The NASP (X-30) is planned to fly in late 1994 or early 1995 after an investment of $4 billion. Approximately $1.5 billion has already been spent, with 70 percent of that figure swallowed by relevant contractors. By June 1989, the NASP program was one year behind schedule and $700 million over budget.

Strategic Defense Initiative (SDI)

Several changes are in store for the Strategic Defense Initiative, which is cautiously emerging from basic research into demonstration and validation of systems that could be deployed in the mid- to late 1990s. With the departure of Lieutenant General James Abrahamson as the Strategic Defense Initiative's lead proponent and the change in administrations, however, to say nothing of the defense budget squeeze, the SDI program is losing a great deal of political and financial momentum. The new director of the SDI Organization, Air Force Lieutenant General George Monahan, has stated that he intends to act as a program manager rather than an advocate for SDI.

The SDI research program is divided into five key technology areas: directed energy weapons; kinetic energy weapons; surveillance, acquisition, tracking, and kill assessment systems (SATKA); systems analysis/battle management; and survivability, lethality, and key technologies for space logistics and power.

President Bush proposed cutting $7 billion from former President Reagan's SDI plan over the next four years, including a cut of $1 billion for fiscal year 1990. Funding requests now stand at $4.6 billion in fiscal year 1990 and $5.4 billion in fiscal year 1991. SDI will not be funded at these levels, given Congress' past decisions on the program. Of the $1 billion in cuts, about one-third came from the directed energy weapon program (DEW). Funding for the surveillance, acquisition, tracking, and kill assessment program element actually increased by $60 million from the Reagan projections. Finally, the Cheney amendments do not allow for deployment funds in fiscal year 1990.

Some SDI technologies entered the demonstration and validation phase in 1987, including the Boost Surveillance Tracking System; the Space Surveillance Tracking System; the Space-Based Interceptor; the Ground-Based Interceptor; the Ground-Based Surveillance and Tracking System (GSTS) sensor satellite; the Ground-Based Radar; and battle management/command, control, and communications. These technologies have been grouped together in a Phase I SDI system, approved for Milestone I development by the Defense Acquisition Board (DAB) in 1988. SDI's official cost estimate for Phase I was $69 billion in March 1989, a little more than half of the previous estimates. Half of all SDI resources are devoted to this Phase I system, with the other half allocated to more fundamental research. SDI Phase I will be reviewed formally in 1989; in spring 1990, a Systems Requirement review for Phase I will be conducted. General Electric is the systems engineering contractor for SDI Phase I.

SDI tested the Beam Experiment Aboard Rocket in April, which demonstrated the first neutral particle beam in space, and launched the Delta Star in March 1989. Delta Star, a satellite carrying eight sensors, will observe U.S. launches of rockets and missiles for six months to collect information about rocket plumes and Earth background. The Space Power Experiment Aboard Rocket II investigated how high-voltage equipment operates in space in August 1989. Four key tests are scheduled for 1990, including a flight test of Lockheed's ERIS interceptor; the launch of two laser relay test satellites; a ground test of the main boost-phase sensor satellite; and Starlab, an acquisition, tracking, and pointing system based on the Space Shuttle.

The emergence of the "Brilliant Pebbles" concept from Livermore Laboratory may sidetrack early deployment of the Phase I SDI system. Under the concept, thousands of 3-foot long sensor-guided independent projectiles would be dispersed in a low-Earth orbit, and in the event of a ballistic missile launch, directed to target and collide with attacking missiles in the boost phase of their trajectory. Proponents maintain that Brilliant Pebbles would cost less than $10 billion, with each projectile costing only a few hundred thousand dollars. Brilliant Pebbles would be linked to Phase I sensors, including the Boost Surveillance and Tracking System and the Space-Based Surveillance and Tracking System. Combined with an orbiting surveillance satellite system and C2 ground complex for $15 billion, the total cost could be as low as $25 billion, according to its sponsors. Brilliant Pebbles technology was demonstrated in ground tests in 1988 and a comparably sized vehicle was flown in a laboratory in April 1989. Although the program would use off-the-shelf electronics technology, the projectiles still will require the computing power of a

CRAY-1 in the size of a deck of cards. Brilliant Pebbles is not yet linked to Phase I but will be evaluated in that context this year. The program will receive $46 million in fiscal year 1989; if successful, it would receive a lion's share of the $200 million planned for kinetic energy weapons in fiscal year 1991.

One disadvantage of the system is the lack of sensors for midcourse discrimination. Another is the political difficulty of justifying the placement of thousands of weapons in orbit. A third, and most important, is the unproven character of the technologies involved. A fourth is the incredibility of current cost estimates.

In effect, the DOD will have to choose next year among three options: continuing with the relatively proven, if limited, technologies of the current Phase I system; shifting to the Brilliant Pebbles concept, meaning a several-year delay at least in deployment; or moving away from any definite deployment plan toward a more diverse technology development program.

SHIPBOARD ELECTRONICS SYSTEMS

Overview

Procurement of naval ships may take a dramatic turn if the navy's new warfare plan is implemented, but it will not likely diminish the importance of shipboard electronics. Outlined in the Surface Combat Force Requirements Study, the plan calls for a fleet of 120 "battle force combatants" (BFC) and 104 "protection of shipping ships" (POS). Approved in December 1988 by acting Secretary of Defense William Taft, the plan allows for the BFC to replace several classes of cruisers and destroyers: The BFC is envisioned with a phased array radar, vertical launching system, advanced surface-to-air missiles, improved sonars, and two LAMPS III helicopters. The existing DDG-51 with improved electronics would be a prime candidate for the BFC function. The POS would probably include improved antiair warfare systems, improved sonar, two LAMPS III helicopters, and shipboard standoff ASW weapons. The Surface Combat Force Requirements Study calls for building five or six BFCs beginning in 1990, with total force levels achieved by 2025.

As in avionics, greater commonality and integration will probably be the focus of future electronics procurement for naval systems. Emphasis will be placed on two areas: antisubmarine warfare sensors and air defense.

Submarines and Related Systems

SSN-21 Seawolf

General Dynamics was selected early in 1989 to build the first of the new Seawolf-class of nuclear attack submarines, with a contract valued at about $726 million. Construction began at the end of 1989, with delivery expected in 1995. Newport News is expected to compete for the contract for the second submarine, which could be funded in 1991. A total of 29 vessels is expected to be built from 1989 to 2000. The navy has requested two SSN-21s in fiscal year 1991 and three per year thereafter. Total procurement is expected to cost about $36.0 billion, with the first SSN-21 costing as much as $2.0 billion and additional copies costing about $1.2 billion each. The DOD projects that it will spend $2.8 billion just for the C2 computer system on board the Seawolf.

Unmanned Undersea Vehicles

Unmanned undersea vehicles may play a larger role in navy operations given their lower cost relative to submarines. The navy is in the process of developing a master plan for these vehicles. Martin Marietta was awarded a $15 million contract in December 1988 for an acoustic sensor for an unmanned undersea vehicle as part of a DARPA prototype development program. The vehicle is supplied by the Charles Draper Lab, with the entire system planned for delivery in late 1989. The DOD expects to award one unmanned undersea vehicle payload contract annually.

Surface Ships and Related Systems

DDG-51 Arleigh Burke Class

The Arleigh Burke guided missile destroyer is expected to be operational by October 1989. Manufactured by the Bath Iron Works and Ingalls Shipbuilding, the DDG-51 class of ships is planned to be procured at a rate of three per year from fiscal year 1987 to fiscal year 1990, and five per year thereafter. The DDG-51 uses the following subsystems: two Mk 41 Mod 0 vertical launchers for Standard Missiles, ASROC, and Tomahawk missiles; one SPS-64, one SPS-67, one SPY-1D phased array radars and three SPG-62 radars; and the SQS-53C and SQR-19 towed array sonars. A total of 29 ships is expected to be procured through 1993.

Aegis

With the end of the CG-47 Ticonderoga (Aegis cruiser) procurement program in fiscal year 1988, the Aegis advanced surface missile system will continue to be procured for DDG-51 Arleigh Burke destroyers, but no new hulls will be built. The Aegis system reached initial operating capability in 1983. Although it has been criticized by Congress and the GAO as expensive and not completely reliable, the final report on the USS *Vincennes* incident, which pointed to human error, has diverted attention away from technical shortcomings of the hardware.

SQQ-89 Integrated Combat System

The SQQ-89 is one of three integrated navy weapons systems programs incorporating computer-controlled surveillance and detection equipment as well as communications facilities and weaponry. Currently in production, the SQQ-89 is a sonar system for surface ships that integrates detection, location, tracking, and fire control functions, installed on the CG-47 Ticonderoga-class Aegis cruiser and DDG-51 Arleigh Burke-class Aegis destroyers.

Information Processing and Display

Improved information processing systems and displays are critical to the highly integrated systems that the navy will be procuring into the next century. Some of the key programs are described in the following paragraphs.

Naval Tactical Data System (NTDS)

The Naval Tactical Data system, deployed on all major naval combatants, combines digital computers with displays and data links for the automated organization and display of information for command and control of threat assessments and weapons allocation. Although early systems employed AN/UYK 20 or AN/UYK-7 computers, these are scheduled to be upgraded to the AN/UYK-43 and AN/UYK-44 computers. Hughes is the prime contractor for the Tactical Data System, and has already delivered 2,500 UYA-4 and UYQ-21 displays. The navy plans to spend $93 million in fiscal year 1989, $69 million in fiscal year 1990, and $81 million in fiscal year 1991.

AN/SPA-25G Radar Display

ISC Cardion Electronics manufactures AN/SPA-25G radar displays. The AN/SPA-25 G uses digital scan converter to overlay sensor data with graphic symbols on ships' tactical displays. Production is presently under way; the development contract was valued at about $13 million. Key features of the AN/SPA-25G include VME-based digital architecture and use of 68000 processors.

Shipboard Computers

The navy currently uses two standard shipboard computers: the UYK-43 and the UYK-44. The UYK-43 is a large-scale computer installed on surface ships and submarines for radar processing, weapons fire control, carrier air traffic control, communications, and navigation. The UYK-44 is a medium-size computer used for much the same purposes. The latest Aegis cruisers are equipped with 6 UYK-43s and 23 UYK-44s; SSN 688s are equipped with 2 UYK-43s and 5 or 6 UYK-44s. Unisys produces UYK-43s, and Control Data was chosen in 1988 as a second source; Unisys and Control Data will compete for production in 1990. At present, General Electric, Microlithics, and Raytheon are being qualified as additional UYK-44 suppliers.

Signal Processors

The navy will receive a new signal processor in the mid-1990s. Developed by AT&T, the Enhanced Modular Signal Processor (EMSP), or UYS-2, will replace IBM's UYS-1 as a key element in all platforms used for antisubmarine warfare. Using VHSIC chips developed by Honeywell, the EMSP will be able to process data from acoustic detection systems, synthetic aperture radars, adaptive beam forming, and electronic warfare systems. The navy projects software development costs to total about $60 million for the EMSP, in contrast to $150 million for its predecessor, the UYS-1. In addition to lower development costs, the EMSP's open architecture, designed for flexibility and adaptability, may offer further advantages. The EMSP will be installed on the LAMPS III helicopter and on platforms using the SQQ-89 integrated combat system. The navy also expects to install the EMSP in the SSN-21's BSY-2 system, SURTASS, and the Advanced Low Frequency Sonar System. Original estimates of the total cost were $2 billion, but budget cuts have reduced that figure.

VEHICLES AND WEAPONS

Overview

Systems included in this category are powered and motorized vehicles, torpedoes, artillery, and crew-served weapons. These types of equipment, of course, tend to have relatively small electronic content. Increasingly, the services are attempting to integrate different weapons to make a combined arms approach on the tactical battlefield feasible. A key element of successful combined arms is the coordination and integration of fire control, which requires that diverse types of weapons be made compatible. One example of this trend in current procurement is the army's effort to coordinate several gun and missile development programs as part of the Forward Area Air Defense System. Another trend in vehicle and weapon procurement is toward greater commonality, apparent in the army's plan to procure a common chassis for families of vehicles. The army's artillery procurement all will probably reflect greater commonality, as it is guided by the Fire Support Master Plan, approved in September 1988 by Army Chief of Staff, General Carl Vuono. The plan calls for an increase of $7 billion in the army's spending for artillery, including the accelerated deployment of a new self-propelled Howitzer, the Multiple Launch Rocket System, Sense and Destroy Armor Munition, and the development of the Advanced Field Artillery System, among other things.

Forward Area Air Defense

The army could spend as much as $8.8 billion on research, development, and procurement of systems in the Forward Area Air Defense (FAAD) program over the next five years. Some of the elements of the FAAD include fiber-optic guided missiles; the air defense antitank system; the pedestal-mounted Stinger air defense missile; a new command, control, communications, and intelligence system; and a program to upgrade guns and ammunition of M-1 tanks and Bradley Fighting Vehicles. This last program, called the FAAD Ground-Based System, is scheduled to begin in fiscal year 1990 with an army request for $48 million for both fiscal years 1990 and 1991.

M1 Abrams Tanks

The M1 program is one of the largest weapon procurement programs at almost $1.5 billion per year. Block 1 tanks, or M1A1s, are in production, and Block II upgrades, the M1A2, are in the development stage. The Abrams, which replaces the M60 series of tanks, is manufactured by General Dynamics. The M1A2 will feature an improved 120mm cannon, a nuclear-biological-chemical overpressure system, a Texas Instruments' Commander's Independent Thermal Viewer, an improved carbon dioxide laser rangefinder, and an internal data bus to connect electronic sensors and control systems. Upgrades have been subject to a $300,000 per tank cost limit, but it appears unlikely that this goal will be met. M1A2s could cost as much as $3 million each when they are procured beginning in 1992; General Dynamics expects to manufacture between 2,000 and 3,000 tanks.

High-Mobility Multipurpose Wheeled Vehicle (HMMWV)

This contemporary version of the army's jeep can be used as a TOW and Stinger weapons carrier, as a command and control vehicle, as a forward observer, as a forward air controller, or to protect rear areas. The army has requested funds to procure more than 8,500 HMMWVs in fiscal year 1990 and more than 9,400 in fiscal year 1991, and it awarded $1.6 billion to LTV's AM General for 69,077 Hummers in January 1989.

COMMAND, CONTROL, COMMUNICATIONS, AND INTELLIGENCE

Overview

Although the Reagan Administration greatly elevated command, control, communications, and intelligence (C3I) as a national security priority, budget growth was relatively modest in these categories during the Reagan years. Spending on C3I will grow even more slowly over the next few years, but no major C3I programs were cut during Mr. Cheney's review of the fiscal year 1990 and 1991 budget requests. Despite the limits on growth, C3I programs offer significant opportunities for defense electronics firms.

Programs can be divided into three major categories: warning and attack assessment, command and decision, and strategic communications. Under warning and attack assessment, the DOD is funding programs to increase the survivability of early warning satellites, mobile ground terminals, advanced warning concepts (particularly in space), and modification of the Ballistic Missile Early Warning System (BMEWS). In command and decision, funding covers hardened airborne command and control posts, mobile command centers, and improved survivability of fixed command centers. In strategic communications, the following programs are being funded: GWEN, New ECX aircraft for TACAMO, MILSTAR, LF/VLF receivers on bombers, DSCS-III satellites, ELF communication with submarines, and FLTSATCOM.

Systems Development and Procurement

The major command, control, communications, and intelligence programs currently in systems development and procurement are described in the following paragraphs.

Tactical Systems

Congress requested three reports last year from the army on the progress of tactical communications programs because the fielding of the Mobile Subscriber Equipment, Single Channel Ground and Airborne Radio Systems, and Army Data Distribution System radios were not coordinated with the army's Tactical Command and Control System (ATCCS) program. These three systems are critical to information flow in the ATCCS. Delays in tactical programs are likely as budget cuts are implemented.

Mobile Subscriber Equipment (MSE). The Mobile Subscriber Equipment System will provide the army with mobile voice, high-volume data, and facsimile communications capabilities. MSE must be compatible with a wide range of communications equipment, including SINCGARS, JTIDS, and TRI-TAC. It will be used in conjunction with army and NATO satellites.

The "backbone" of the MSE is message switching and relay equipment; subscriber equipment includes the Digital Subscriber Voice Terminal and Digital Non-Secure Voice Terminal field telephones, the Line-Of-Sight AN/TRC-190 radio, and the AN/UXC-7 facsimile machine. The prime contractor is GTE. In December 1988, the army awarded GTE a high-volume production option contract worth $948 million, covering the fourth year of a six-year program.

Army Data Distribution System (ADDS). The ADDS is a control station that performs data management functions. The ADDS will provide secure, jam-resistant data communications, as well as position/location, navigation, and identification capabilities to support the army automated battlefield. Fiscal year 1990 funds were requested for low-rate initial production equipment; fiscal year 1991 and fiscal year 1992 funds are scheduled for full-scale production. The army spent about $75 million on the system in fiscal year 1989. Total cost of the program is expected to run about $3.4 billion for 140 systems.

Single-Channel Ground and Airborne Radio Systems (SINCGARS). SINCGARS are frequency-hopping VHF-FM radios planned to replace the AN/VRC-12, AN/PRC-77, and AN/ARC-54-131 family of radios. SINCGARS will be the army's main combat radio and the primary means of communicating with infantry, armor, airborne, and artillery units. ITT, the prime contractor, has received a contract estimated at about $316 million, including funds for production and introduction of the system into operational use. A team of General Dynamics and Tadiran (Israel) was chosen in mid-1988 as a second source for the radios. The General Dynamics team will build a different, but interoperable, radio that will match the "form, fit, and function" of the original model.

Army Tactical Command and Control System (ATCCS). ATCCS has experienced considerable delays throughout the 1980s, but its major components are now being prepared to enter production in the 1990s. The system is composed of five elements: the Maneuver Control System (MCS); the Forward Area Air Defense Command, Control, and Intelligence System (FAADC2I); the Advanced Field Artillery Tactical Data System (AFATDS); the All-Source Analysis System (ASAS); and the Combat Service Support Control System (CSSCS). The total budget for these elements is slightly more than $7 billion. The army requested a total of $333 million in fiscal year 1990 and $395 million in fiscal year 1991.

Defense-Wide Programs

Defense-wide programs are conducted by the Defense Communications Agency. Two key programs are TRI-TAC and WIS/WAM.

Worldwide Military Command and Control Information System (WIS). The WIS will provide crisis planning and execution aids to the National Command Authorities and specified and unified commands. When it is completed after 1993, it will replace the World Wide Military Command and Control System hardware and modernize its software. WIS includes local area networks, automated message handling, intelligent workstations, modern processors, database management, and multilevel security systems. The prime contractor is GTE Government Systems Corporation. The total program cost is estimated at about $2 billion for 35 systems. Program management was transferred from the air force to the Defense Communications Agency (DCA) in 1988. The DCA restructured and renamed the program to accommodate technical and financial difficulties. The new program, called World Wide Military Command and Control System Automatic Data Processing Modernization (WAM), will use about 80 percent of the $115 million requested for both fiscal years 1990 and 1991 to run software on existing computer hardware.

Joint Tactical Communications Program (TRI-TAC). The DOD has been pursuing TRI-TAC for almost 15 years. TRI-TAC provides common, ground-based, tactical digital communications for all the services. These include mobile and transportable systems for voice and data communications. Contractors include General Atronics Corporation, Martin Marietta, and Raytheon. The total program cost is estimated at approximately $2 billion for 555 systems. Fielding of the systems will continue through 1995. As part of the TRI-TAC program, AT&T was awarded a two-year, $23 million contract to supply new fiber-optic cables to connect TRI-TAC and the Patriot air defense system. Fibercom supplied modules to convert electronic signals into light, which will pass through the cables, under a $15 million contract with the DOD.

MILITARY COMPUTING TECHNOLOGY

Overview

The Department of Defense played a key role in developing the U.S. computer and semiconductor industries. Although that role has diminished greatly, the DOD remains dependent on information systems for its technological edge. DOD requirements for information systems often lag those in the civilian sector, with exceptions for military-specific qualifications like radiation hardness. DOD procurement of electronics systems and microelectronics devices follows the civilian lead in areas such as general-purpose computers and advances the state of the art in areas such as optoelectronics and neural networking.

Electronic Components

The procurement of integrated circuits by the DOD will be streamlined when the services adopt a new method of generic qualification known as the qualified manufacturer's list (QML). The generic military specification Mil-I-38535 will certify manufacturing process and lines instead of individual chips. This will have a critical impact on the certification of application-specific integrated circuits (ASICs).

Very High Speed Integrated Circuits (VHSIC)

The goal of the Very High Speed Integrated Circuits Program was to develop very large scale integrated circuits and cause them to be used in military systems. The $1 billion, 10-year program has resulted in faster chips that will be used for real-time processing of images and signals, automatic target recognition, infrared focal plane staring and scanning arrays, and fusion of sensor data.

The VHSIC program was conducted in three phases. Phase I resulted in 1.25-micron chips with functional throughput 100 times greater than commercially available integrated circuits, and with operating speeds of about 25 MHz. Phase I contractors included Honeywell, Hughes Aircraft, IBM, Texas Instruments, TRW (teamed with Motorola), and Westinghouse (with National Semiconductor).

Phase II has produced 0.5-micron chips that increase processing power 1,000 percent. IBM claimed to be the first to produce a functional Phase II chip in May 1988, containing 37,000 logic gates and operating at 100 MHz, four times faster than Phase I chips. Other Phase II contractors include Honeywell, TRW, Motorola, and Westinghouse.

TRW and Motorola demonstrated their Phase II "superchip," the CPUAX, in late 1988. The VHSIC team demonstrated the first of eight macrocells for digital signal processing; the superchip will contain 142 of these macrocells on a 1.5 by 1.7-inch space. Incorporating 4 million devices, the superchip will operate at 200 million flops, the speed of a Cray supercomputer. Other features of the superchip include self-contained spare parts (almost one-half of the 4 million devices are spares), built-in testing, and the ability to be reconfigured using software.

Microelectronics Manufacturing Science and Technology (MMST)

Increasing manufacturing yields in microelectronics has been a goal of the semiconductor industry for some time. Yields are most important in the ASIC market, where ICs are customized. This implies a requirement for flexible manufacturing techniques. The MMST program focuses on flexible manufacturing of high-yield and low-volume integrated circuits, including very large scale integrated circuits (VLSI), millimeter-wave monolithic ICs (MIMICs), and infrared focal plane arrays. The effort, undertaken by Texas Instruments for the air force and DARPA, will include developing processing equipment for a single wafer at a time, in contrast to the batch processing used today. This requires a significant improvement in yield to be cost-effective. With higher yields, the production of ASIC chips may become more cost-effective for the DOD.

MMST will fund the development of advanced process sensors, process-control expert systems, and an integrated factory-control approach applicable to other fabrication facilities. Production goals include less than 0.5-micron feature sizes, more than 1,000 designs per year, with 800 wafers per month. Cost goals are 10 times less expensive than conventional facilities. Texas Instruments will receive $113 million in the course of five years, sharing the total cost with the government. Funding in fiscal year 1989 was $40 million.

Millimeter Wave and Microwave Monolithic Integrated Circuits (MIMIC)

A growing number of military systems depend on sophisticated sensors for their operation, but analog circuitry for such sensors continues to be very expensive. The MIMIC program, launched in 1986, is aimed at reducing the cost of these components, making advanced sensor technology more widely available and affordable than ever before. The means for this improvement is monolithic solid-state technology, using exotic materials such as gallium arsenide (GaAs). In addition to operating at higher frequencies (1 to 300 GHz), gallium arsenide offers the advantages of greater radiation hardness than silicon, extremely low noise signal amplification, and wide temperature operating ranges.

Commercial demonstrations of MIMIC technology already have been made on a small scale, beginning in 1974 with Plessey's demonstration of the first GaAs MIMIC chip. The Microwave/Millimeter Wave Integrated Circuit (MIMIC) Program could mobilize the U.S. electronics industry behind this effort. Industry observers predict that individual defense programs could require as many as 200,000 GaAs chips per month; the entire U.S. industry produced only 300,000 GaAs chips in 1987.

An integral part of the MIMIC program is to create faster, less expensive tools for RF circuit design. The TRW MIMIC team is developing expert-based software to cut the design and layout time by as much as 97 percent—from four weeks to two hours. Libraries of circuit designs will be stored to guide engineers in developing new chips.

The program has been divided into four phases. Phase 0, the initial study phase, was completed in 1988 and involved 16 teams exploring a wide range of fabrication technologies for gallium arsenide.

Like VHSIC, MIMIC will have broad application in a number of military systems. Electronic warfare systems engineers are looking at GaAs monolithic microwave integrated circuits particularly for their wider bandwidth capability, higher frequencies, and multifunction capability. Additionally, GaAs MIMICs offer better performance, functional integration, reduced system size and weight, and cost-effective production. Part of the success of the MIMIC program has been its active pursuit of applications for MIMIC technology.

Phase I, with a three-year planned duration, will culminate in demonstrations of MIMIC hardware in an operational environment. Phase I tasks include material and technology development; design, fabrication, and demonstration of modules; development of computer-aided design tools; identification of affordability barriers; and system brass-board demonstrations. Second sources will be selected for all components in this phase.

Another three-year phase (Phase II) will continue technological improvements in MIMIC, perhaps using more exotic materials, with additional technology demonstrations. Phase III will run concurrently with Phases I and II of the program. Its activities will center on ancillary research, including computer-aided circuit design and new testing approaches.

SYSTEM SEMICONDUCTOR UTILIZATION

Overall, military equipment in production today is utilizing mature and multisourced semiconductor technology. This fact is a result of very long development and production lifetimes of the majority of both military systems and commercial aircraft. We estimate that 45 percent of the semiconductor technology currently built into these systems was initially available 10 years ago or before.

The following megatrends affect the future application of semiconductor solutions to military and aerospace equipment:

- Continued aggressive footprint, functional density, and power reduction on all platform-oriented systems
- Increased use of commercial grade and/or plastic packaging for components, as environmental needs are better segregated and as improvements in packaging technology emerge
- A procurement system that is better oriented toward ASICs and VLSI
- Improved hierarchical design and simulation software creating more transparency from the actual semiconductor implementation, quickening the rate of acceptance of new technologies, and reducing problems with interoperability and obsolescence
- Availability of advanced compiler technology on microprocessor products, allowing easier and maintainable programming
- Continued replacement of SSI/MSI-era system designers with VLSI/ULSI-era designers
- Eventual phased-in implementation of a procurement system oriented toward commercial buying practices and more toward commercial technology life cycles
- Further requirements for radiation-hardened (rad-hard) semiconductors in some aircraft, naval, and ground systems and in most missiles and space systems

Based on these factors, we believe that the following trends will continue or develop in the demand for semiconductors in military and aerospace electronic equipment:

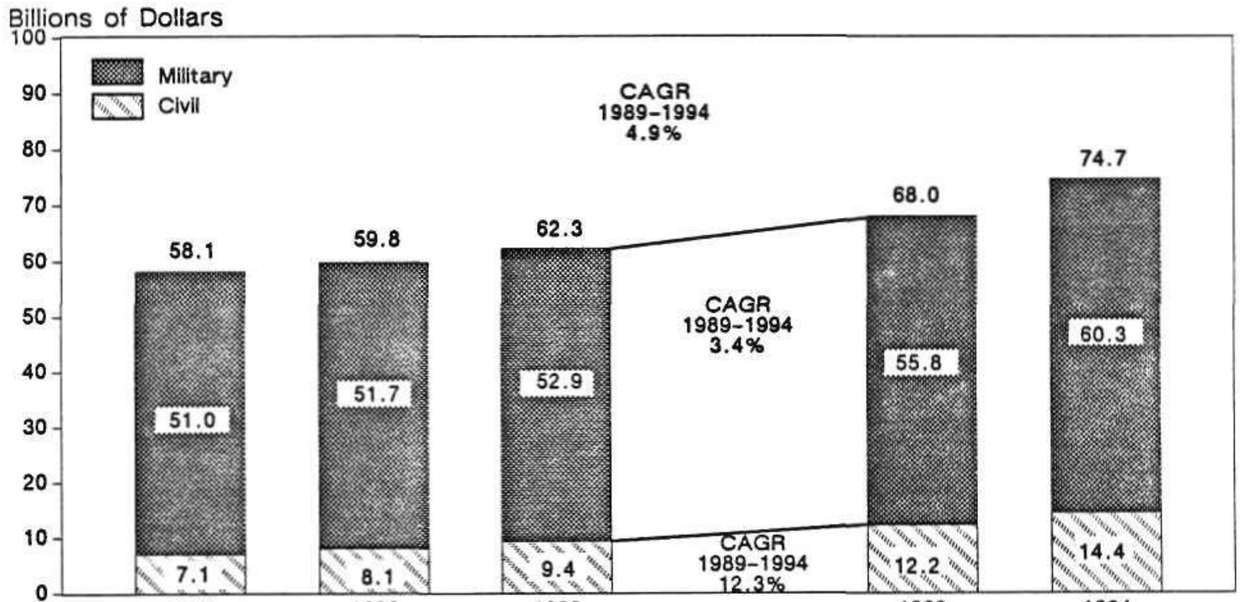
- In meeting the goals of integration and power consumption, CMOS will continue to be the technology of broad choice, but its growth will be tempered, as long system design and production cycles prevail.
- ASICs will continue to be designed-in as replacements for discrete logic and, in an increasing number of situations, as custom chip sets and processor engines.
- Microcomponents, including digital signal processing (DSP) MPUs, 16- and 32-bit MPUs, and functional chip sets, will continue gaining acceptance in areas such as electronic warfare, secure communication, integrated aircraft architectures, and intelligent weapons.
- Increasing microcomponent applications will drive new uses for volatile and nonvolatile memory products.
- Aggressive high-frequency, high-density, low-noise, and rad-hard requirements on all front-end processing will demand both gallium arsenide monolithic microwave and millimeter-wave IC (MMIC) technology and sophisticated DSP techniques.
- Smaller, cooler, more efficient power supplies, switches, and controls will drive demand for intelligent power and MOSFETs.
- Fiber-optic data conduits on aircraft and ships will demand transmitters/receivers and other optoelectronics.

ELECTRONIC EQUIPMENT PRODUCTION FORECAST

Figure 1 presents the overall North American military and aerospace electronics production forecast. A detailed forecast is presented in Table 6.

Figure 1

Estimated North American Military and Civil Aerospace Electronics Production



0006268-1

Source: Dataquest
March 1990

Table 6

Military/Aerospace Electronic Equipment Production
North America
(Millions of Dollars)

	1987	1988	1989	1990	1992	1994	CAGR 1989-1994
Total	57,862	58,179	59,876	62,329	68,073	74,751	4.5%
Military	50,932	51,063	51,727	52,918	55,845	60,299	3.1%
Radar	6,945	6,521	6,456	6,552	6,783	7,512	3.1%
Sonar	2,875	2,984	2,870	3,050	3,270	3,574	4.5%
Missile/Weapon	6,228	6,385	6,461	6,450	6,895	7,298	2.5%
Space	5,281	5,148	5,552	5,898	6,760	7,718	6.8%
Navigation	1,537	1,606	1,602	1,635	1,740	1,849	2.9%
Communications	4,616	4,791	4,944	5,118	5,409	5,736	3.0%
Electronic Warfare	3,029	3,044	3,021	3,112	3,335	3,560	3.3%
Reconnaissance	2,422	2,495	2,550	2,615	2,796	2,962	3.0%

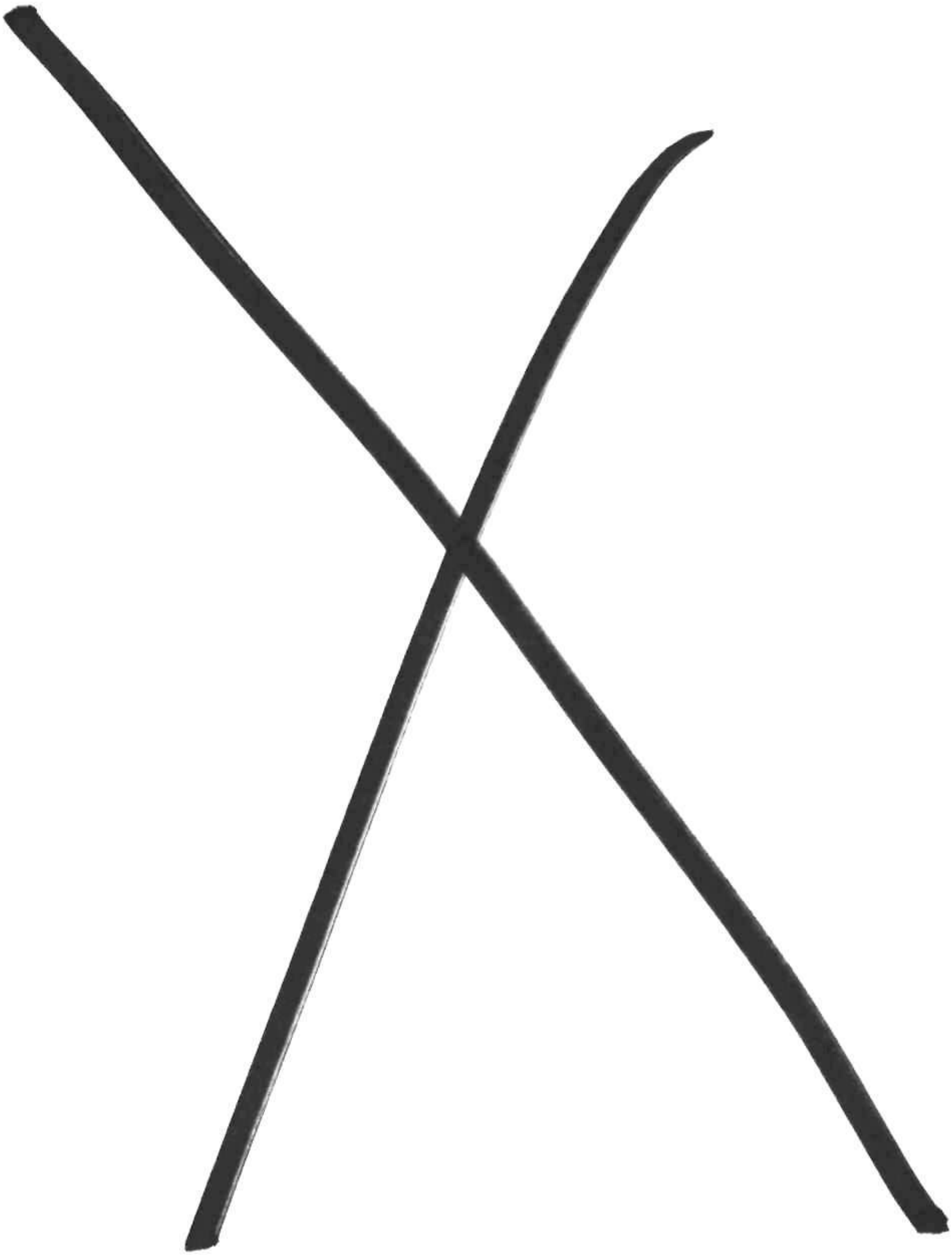
(Continued)

Table 6 (Continued)

Military/Aerospace Electronic Equipment Production
North America
(Millions of Dollars)

	1987	1988	1989	1990	1992	1994	CAGR 1989-1994
Military (Continued)							
Aircraft Systems	4,555	4,327	4,312	4,337	4,624	5,352	4.4%
Computer Systems	2,112	2,207	2,308	2,421	2,708	3,088	6.0%
Simulation	671	744	845	946	1,170	1,495	12.1%
Misc. Equip.	10,661	10,811	10,806	10,784	10,355	10,155	(1.2%)
Civilian	6,930	7,116	8,149	9,411	12,228	14,452	12.1%
Radar	1,590	1,825	2,080	2,355	2,949	3,405	10.4%
Space	2,693	2,470	2,818	3,330	4,456	5,530	14.4%
Navigation/Commun.	663	713	808	910	1,185	1,421	12.0%
Flight Systems	1,783	1,892	2,198	2,536	3,245	3,558	10.1%
Simulation	201	216	245	280	393	538	17.0%

Source: Dataquest
March 1990



Transportation

The following is a listy of material in this section:

- Semiconductor Consumption Transportation
- Trends In Automotive Electronics

NOTE: The arrow symbol indicates the latest document(s) correct location behind this subject tab.

Semiconductor Consumption—Transportation

Index of Tables

Table 1

Forecast North American Electronic Equipment Production
Transportation
(Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR (%) 1989-1990	CAGR (%) 1989-1994
Factory Revenue	10,744	11,292	11,828	12,897	13,952	14,836	15,449	4.7	6.5

Source: Dataquest (July 1990)

Table 2

Forecast North American Merchant Semiconductor Revenue
Transportation
(Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR (%) 1989-1990	CAGR (%) 1989-1994
Total Semiconductor	946	957	971	1,045	1,114	1,184	1,239	1.5	5.3
Total IC	740	752	765	828	886	945	992	1.8	5.7
Bipolar Digital	51	45	38	33	27	23	20	(14.8)	(15.2)
Bipolar Memory	20	16	12	10	7	6	4	(20.0)	(23.0)
Bipolar Logic	31	29	26	23	20	18	15	(12.0)	(12.0)
MOS	410	428	446	497	541	585	620	4.3	7.7
MOS Memory	155	157	161	181	198	214	226	2.5	7.5
MOS Micro	192	203	214	234	251	268	280	5.0	6.6
MOS Logic	63	67	72	82	92	103	114	6.5	11.1
Analog	278	279	281	299	318	337	353	0.5	4.8
Discrete	185	182	183	194	203	212	221	0.5	3.9
Opto	22	23	23	24	25	26	27	0.9	3.1

Source: Dataquest (July 1990)

Table 3

Forecast North American Merchant Semiconductor Revenue
Transportation
(Input/Output Ratios, Percentage)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	8.8	8.5	8.2	8.1	8.0	8.0	8.0
Total IC	6.9	6.7	6.5	6.4	6.4	6.4	6.4
Bipolar Digital	0.5	0.4	0.3	0.3	0.2	0.2	0.1
Bipolar Memory	0.2	0.1	0.1	0.1	0.1	0	0
Bipolar Logic	0.3	0.3	0.2	0.2	0.1	0.1	0.1
MOS	3.8	3.8	3.8	3.8	3.9	3.9	4.0
MOS Memory	1.4	1.4	1.4	1.4	1.4	1.4	1.5
MOS Micro	1.8	1.8	1.8	1.8	1.8	1.8	1.8
MOS Logic	0.6	0.6	0.6	0.6	0.7	0.7	0.7
Analog	2.6	2.5	2.4	2.3	2.3	2.3	2.3
Discrete	1.7	1.6	1.5	1.5	1.5	1.4	1.4
Opto	0.2	0.2	0.2	0.2	0.2	0.2	0.2

Source: Dataquest (July 1990)

Table 4

Forecast North American Electronic Equipment Production
Transportation
(Annual Percentage Growth)

	1989	1990	1991	1992	1993	1994
Factory Revenue	5.1	4.7	9.0	8.2	6.3	4.1

Source: Dataquest (July 1990)

Table 5

Forecast North American Merchant Semiconductor Revenue Transportation (Annual Percentage Growth)

	1989	1990	1991	1992	1993	1994
Total Semiconductor	1.1	1.5	7.6	6.6	6.2	4.7
Total IC	1.6	1.8	8.2	7.1	6.7	4.9
Bipolar Digital	(12.2)	(14.8)	(14.7)	(16.0)	(15.4)	(15.2)
Bipolar Memory	(21.3)	(20.0)	(20.2)	(25.3)	(24.3)	(25.0)
Bipolar Logic	(6.4)	(12.0)	(12.1)	(11.9)	(12.1)	(12.0)
MOS	4.3	4.3	11.2	8.9	8.2	6.0
MOS Memory	1.6	2.5	12.5	9.0	8.5	5.5
MOS Micro	5.7	5.0	9.5	7.5	6.5	4.5
MOS Logic	6.3	6.5	13.5	12.5	12.0	10.9
Analog	0.3	0.5	6.5	6.5	6.0	4.5
Discrete	(1.3)	0.5	5.6	5.0	4.5	4.0
Opto	3.2	0.9	4.4	4.2	4.0	2.3

Source: Dataquest (July 1990)

Table 6

Forecast North American Merchant Semiconductor Revenue Transportation (Percentage of Total Transportation)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total IC	78.1	78.6	78.8	79.2	79.5	79.9	80.0
Bipolar Digital	5.4	4.7	3.9	3.1	2.4	2.0	1.6
Bipolar Memory	2.1	1.6	1.3	0.9	0.7	0.5	0.3
Bipolar Logic	3.3	3.1	2.6	2.2	1.8	1.5	1.2
MOS	43.4	44.7	46.0	47.5	48.5	49.4	50.0
MOS Memory	16.3	16.4	16.6	17.3	17.7	18.1	18.3
MOS Micro	20.3	21.2	22.0	22.4	22.6	22.6	22.6
MOS Logic	6.7	7.0	7.4	7.8	8.2	8.7	9.2
Analog	29.4	29.2	28.9	28.6	28.6	28.5	28.4
Discrete	19.5	19.1	18.9	18.5	18.2	17.9	17.8
Opto	2.3	2.4	2.4	2.3	2.2	2.2	2.1

Source: Dataquest (July 1990)

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 $4.8 billion in 1989 (for modules, controls, and sensors), driving an accompanying merchant semiconductor market of $957 million. A factor that will limit electronics content as a percent of car price in the early 1990s is the anticipated drop in electronics prices as more features become standard equipment and the application of learning curve efficiencies are realized.

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 US federal government enacted policies and legislation to ensure that cars and trucks sold 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.

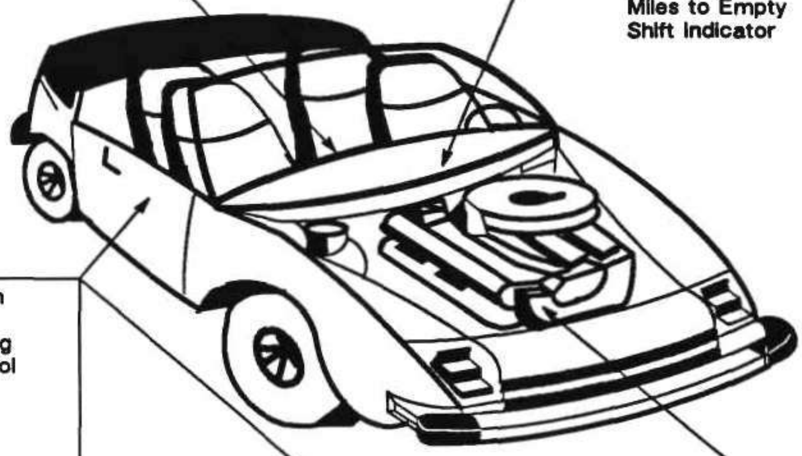
ELECTRONICS APPLICATIONS

Figure 1 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 $100 worth of electronics, whereas high-end cars such as the Cadillacs, with a full complement of options, can consume as much as $600 worth of electronics.

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

Figure 1

Electronics in Present and Future Automobiles



Source: Dataquest (August 1990)

Source: Dataquest (August 1990)

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 that operates at 1 Mbps. 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. Other proposed standards include data rates in the 10-Kbps to 100-Kbps range.

A committee from the Society of Automotive Engineers (SAE) has been 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 a 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.

The semiconductor content of a typical antilock braking system includes:

- 8- or 16-bit microcontroller
- Quad comparator
- 3- to 8-power devices
- Voltage regulator
- 64-byte EEPROM

Primarily found on high-end models and pickup trucks, ABSs are also currently in 16 percent of the units shipped in North America. It is estimated that the penetration rate will exceed 36 percent by 1992. 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, vacuum fluorescent, CRT, and electrofluorescence are just some of the technologies being employed for visual information presentation. A heads-up display was introduced by GM in 1988. In addition to microcontrollers, display-driver ICs are expected to benefit from the acceptance of advanced display technology.

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. Digital tuning utilizing 4- and 8-bit microcontrollers is the trend in most new radio designs. 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 being offered as factory-installed equipment. In 1988, GM introduced digital audio tape (DAT) players as an option. This was one of the first commitments to this technology in the US market.

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 database to augment location determination. Robert Bosch's Blaupunkt-Werke division, Honda, Plessey, 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. These advances are also partly responsible for driving down the cost of existing electronic systems.

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 (e.g., BiCMOS) 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, EPROM, EEPROM, and RAM sizes and configuration.

ASIC suppliers will continue to benefit from the demand to reduce board space and improve reliability. Some of the traditional microcontroller companies have customer codesigned cell libraries to create a new generation of 8- and 16-bit control functions.

Microcontrollers

Further penetration by 8-bit controllers into system (e.g., antilock braking) control will continue into the 1990s. Many semicustom varieties can be produced as internal CAD libraries allow low-cost lead time customization. Texas Instruments has introduced a reconfigurable 8-bit line it codeveloped with Delco. This family can be reconfigured easily with alternative memory options.

As automotive designers begin to integrate discrete control modules and need higher sampling rates/processing throughput, 16-bit controllers are expected to experience growth. Several companies have 16-bit microcontrollers targeted at the automotive market, including Hitachi, Intel, Motorola, National, Siemens, and Toshiba. Delco and Motorola have announced a 32-bit codevelopment project.

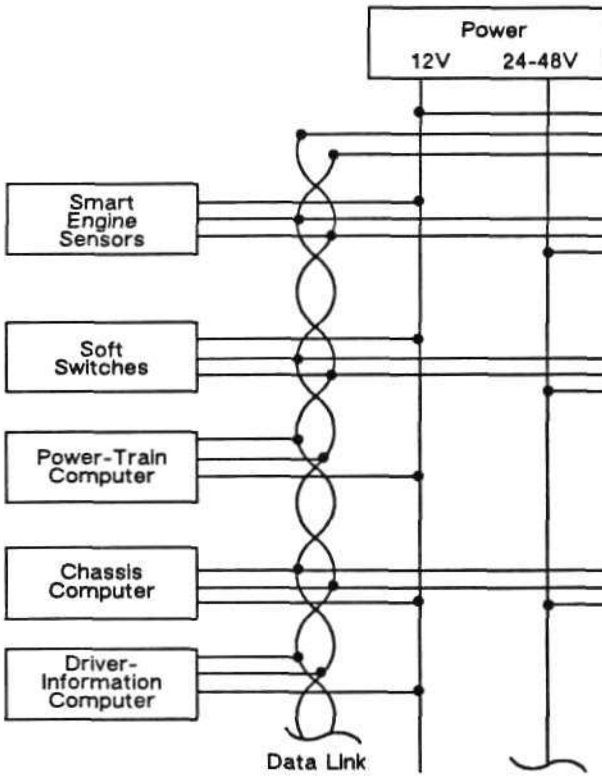
Today, each car has an average of three microcontrollers; by the early 1990s, this number is expected to double.

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 and controlled acuator. 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 2). Status information can also be fed back to the microcontroller.

Figure 2

Vehicle System Featuring Use of Smart Power Devices



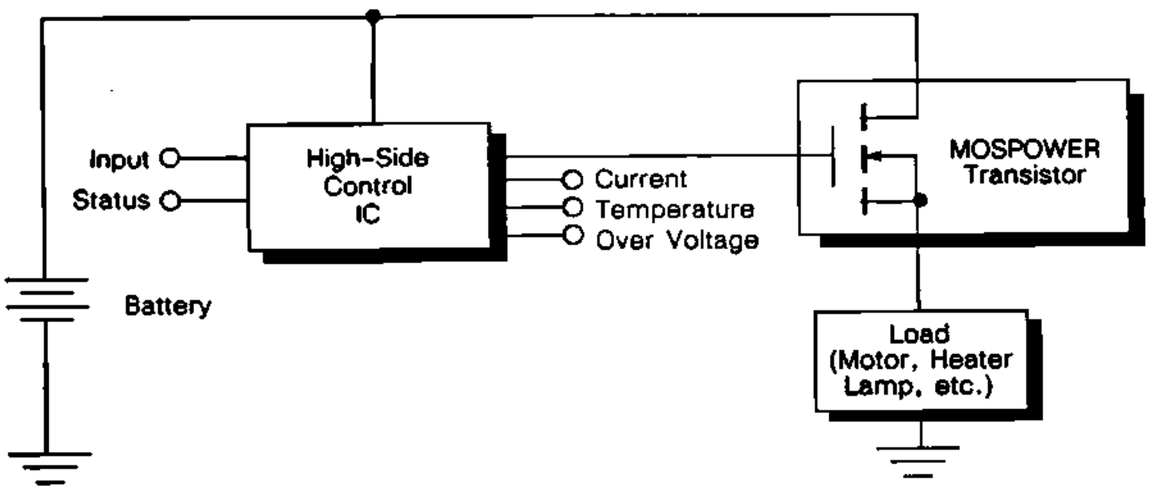
Source: Institute of Electrical and Electronics Engineers

The most prevalent use of smart power devices in automotive applications is for high-side switching (e.g., applying power to fuel injectors, air conditioners, etc.). Currently, electromechanical relays perform this function for an average of $0.70 apiece. It is believed that smart power solutions will have to reach $1.20 to $1.50 to replace these relays in earnest. Because of reliability and functionality improvements, an initial price premium with this new technology can be tolerated.

It should be noted that there is a spectrum of smart power solutions that range from the all-in-one IC to a modified discrete power MOSFET with a CMOS input (gate). International Rectifier and Motorola have MOSFET offerings with these features. Figure 3 presents a hybrid solution that utilizes an IC in conjunction with a MOSFET.

Figure 3

High-Side Power Control



Source: Siliconix

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. Because 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, their use is expected to expand along with the number of new microcontroller applications. Digital/audio applications require typically 32K to 64K densities, body and chassis applications require 16K, high-speed versions, and the engine controller can use up to 1Mb densities.

EEPROMs are finding a variety of applications for capturing or storing data that needs to be preserved when the car is not running. Applications include radio settings, odometer, and diagnostic information storage. Lower-cost flash technology is well suited for less interactive auto uses.

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

Packaging Trends

The significant trends in packaging for automotive applications are toward further use of surface mounting and higher headcount packages. Surface mounting, as in its use elsewhere, is required to reduce board size and allow more chips to be placed per square inch. For high-temperature, understood use, ceramic-leaded chip carriers are growing in popularity. The leadless varieties were found to be difficult to use because of thermal mismatch stress between the board and the IC.

Higher lead counts (greater than 44) are being required as ASICs and 16-bit microcontrollers became more prevalent. Tape-automated bonding (TAB) is becoming popular for reliability reasons, displacing wire bonding techniques.

MARKET FORECASTS

Vehicle Production

Table 1 presents the data for auto and truck production, regardless of base country. After slumping 5.3 percent in 1987, North American production was up 5.2 percent in 1988. The gain was driven principally by truck sales, which grew by 9.3 percent, while car sales grew at a more moderate 2.8 percent rate.

The production leader in 1988 was GM, but it continued its loss of share, dropping to 41.7 percent from 44.1 percent in 1988 (see Table 2). Ford's share was down to 29.1 percent; Chrysler's was flat at 16.5 percent. Honda continued to gain share, up to 3.7 percent as it expanded its resident production capabilities.

Table 1

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

	1988	1989	1990	1991	1992	1994	CAGR 1989-1994
Auto	8.52	7.97	7.77	8.58	8.27	9.00	2.5%
Truck	4.42	4.75	4.52	4.87	4.93	5.06	1.3%
Total	12.94	12.72	12.29	13.54	13.20	14.06	2.0%

Source: Dataquest (August 1990)

Table 2

North American Auto and Truck Production Share by Manufacturer

Company	1985	1986	1987	1988	1989
General Motors	53.0%	48.2%	46.4%	44.1%	41.7%
Ford	25.8%	28.9%	29.7%	30.2%	29.1%
Chrysler	16.4%	15.9%	15.8%	16.7%	16.5%
Honda	1.1%	1.9%	2.6%	3.2%	3.7%
Nissan	1.1%	1.3%	1.7%	1.6%	2.2%
Mazda	NM	NM	NM	1.2%	1.5%
Nummi	0.4%	1.6%	1.5%	1.0%	1.1%
Others	2.1%	1.7%	1.8%	1.8%	4.2%

NM = Not meaningful
Source: Dataquest (August 1990)

Table 3 presents the factory installation percentages of various vehicle electronic systems. Also noted are estimates of penetration by these systems by 1992.

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 88 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.

Table 3

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

System	1989	1994
Entertainment		
AM/FM Mono Radio	3%	<1%
AM/FM Stereo Radio	31%	26%
AM/FM Stereo Cassette	47%	49%
AM/FM Stereo Cassette, Equalizer	6%	11%
Cellular Telephone	0	<1%
Body Control		
Speed Regulator	63%	66%
Intermittent Wipers	77%	92%
Electronic Suspension	2%	13%
Electronic Steering	<1%	4%
Antitheft Device	3%	11%
Multiplexed Wiring	0	2%
Driver Information		
Digital Clock	87%	92%
Fuel/Trip Computer	7%	9%
Electronic Instrument Cluster (Nonair Core)	4%	8%
Warning Indicator/Electronic Chime	57%	88%
Integrated Diagnostic Display	11%	19%
Power Train		
Electronic Fuel Injection	65%	69%
Distributorless Ignition	9%	24%
Diagnostic System	74%	34%
Transmission Control	22%	34%
Integrated Engine Control	30%	28%
Safety and Convenience		
Antilock Braking	16%	85%
Traction Control	<1%	2%
Automatic Air Conditioning	12%	19%
Headlamp Timing	6%	15%
Keyless Locks	1%	7%
Memory Seat	1%	1%
Air Bag/Seat Belt Control	13%	85%

Source: Dataquest (August 1990)

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.

Body control features, such as electronic steering and suspension, 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. Wire multiplexing, when adopted, should experience broad application rapidly. However, it appears that it will be the mid-1990s before significant penetration takes place.

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. North American vehicle production declined 1.0 percent from 1985 to 1989. The fastest-growing area is South Korea, where production has grown at a 30.5 percent CAGR over the same time period. Western European production is up approximately 3.04 million units for the time period, the largest gain of any region.

Table 4

Geographic Vehicle Production Trends
(Millions of Units)

Country	1985	1987	1989	CAGR 1985-1989
United States	11.67	10.98	11.12	1.2%
Canada	1.94	1.56	1.94	0
Total North America	13.61	12.54	13.06	(1.0%)
Japan	12.27	12.25	13.03	1.5%
South Korea	0.39	0.98	1.13	30.5%
Australia	0.41	0.32	0.36	(3.2%)
Total Southeast Asia	0.80	1.30	1.49	16.8%
West Germany	4.44	4.61	4.85	2.2%
France	3.02	3.49	3.92	6.7%
Italy	1.57	1.91	2.22	9.0%
United Kingdom	1.31	1.34	1.63	5.6%
Spain	1.42	1.43	2.05	9.6%
Sweden	0.46	0.50	0.47	0.5%
Belgium	0.27	0.32	0.39	9.6%
Total Western Europe	12.49	13.60	15.53	5.6%
Brazil	0.97	0.90	1.01	1.0%
Mexico	0.40	0.40	0.63	12.0%
Total Latin America	1.33	1.33	1.64	5.4%
USSR	2.20	2.10	2.1	(1.2%)
Other Countries	1.99	2.56	2.65	7.4%
Worldwide Total	44.69	45.68	49.50	2.6%

Source: Dataquest (August 1990)

North American Auto and Truck Electronics Market

As Table 5 points out, it is estimated that the average vehicle manufactured in North America in 1989 contains approximately $334 worth of electronic modules, controls, and sensors. This is expected to reach $413 by 1995.

Table 5

Forecast Estimated Electronic Content of the Average North American Vehicle (Dollars)

	1988	1989	1990	1991	1992	1993	1994	CAGR 1989-1994
Auto	359	375	413	417	452	452	465	4.4%
Truck	267	266	299	302	321	321	322	3.8%
Average	327	334	371	384	405	405	413	4.3%

Source: Dataquest (August 1990)

Electronic Equipment Forecast

The forecast for North American automotive and truck electronics production is presented in the front of the transportation section and in the electronic equipment section of this binder. Included are 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 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.

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 expand. 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 disc players, and so forth) these applications still present an attractive market.

Although the growth of traditional power train controls such as ignition modules has slowed substantially, new applications like distributorless ignitions and the integrated control of engines and transmissions will continue propelling growth.

North American Semiconductor Consumption

The per-vehicle estimate of merchant plus captively produced semiconductor usage is presented in Table 6. Currently at $112 for cars and $81 for trucks, these values are expected to grow to $126 and $87, respectively, by 1994. These numbers represent a continued excellent opportunity for suppliers of semiconductors.

Table 6

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

	1988	1989	1990	1991	1992	1993	1994	CAGR 1989-1994
Auto	100	106	112	110	119	121	126	3.4%
Truck	74	76	81	79	87	86	87	2.9%
Average	91	95	101	99	107	109	112	3.4%

Source: Dataquest (August 1990)

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 21 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.

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.

AUTOMOTIVE ELECTRONICS PARTICIPANTS

Electronic System Manufacturers

The big three—GM, Ford, and Chrysler—produce an estimated 55 percent of their electronic system needs internally. This percentage is up from 45 percent in 1982. GM, which produces an estimated 60 percent of its needs internally, is benefiting from the electronics strengths found in its Hughes acquisition. It also has a large captive semiconductor operation that produces an estimated one-half of its needs.

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 Electrical and Electronic Division (EED) group at Ford also produces an estimated 40 percent of that company's needs.

The other 45 percent of the vehicle manufacturers' electronics needs come from the cadre of independent suppliers that typically specialize in various application areas. For the most part, Japanese companies import assembled electronic subsystems.

Listed in Table 7 are the primary manufacturers of vehicle electronic systems in North America. Including those serving various aspects of the aftermarket, there are an estimated 50 automotive electronic OEMs in the United States.

Table 7

Primary North American Manufacturers of Vehicle Electronic Systems

Company	Principal Electronic System(s)
Robert Bosch	Audio, ABS, engine control, ignition modules
Chrysler	Audio, engine control, displays, body control
Eaton	Engine and body control, climate control
Ford	Engine and body control
General Motors-Delco	Audio, engine and body control, ABS, suspension, displays
ITT	ABS and audio
Motorola	ABS, engine control, sensors, instruments
Rockwell International	Body control, suspension, motor control
Siemens-Bendix	Fuel injection, ABS, ignition modules
TRW	Steering, engine and body control
United Technologies	Switches, ignition systems
Wagner	Lighting control

Source: Dataquest (August 1990)

Key Semiconductor Suppliers

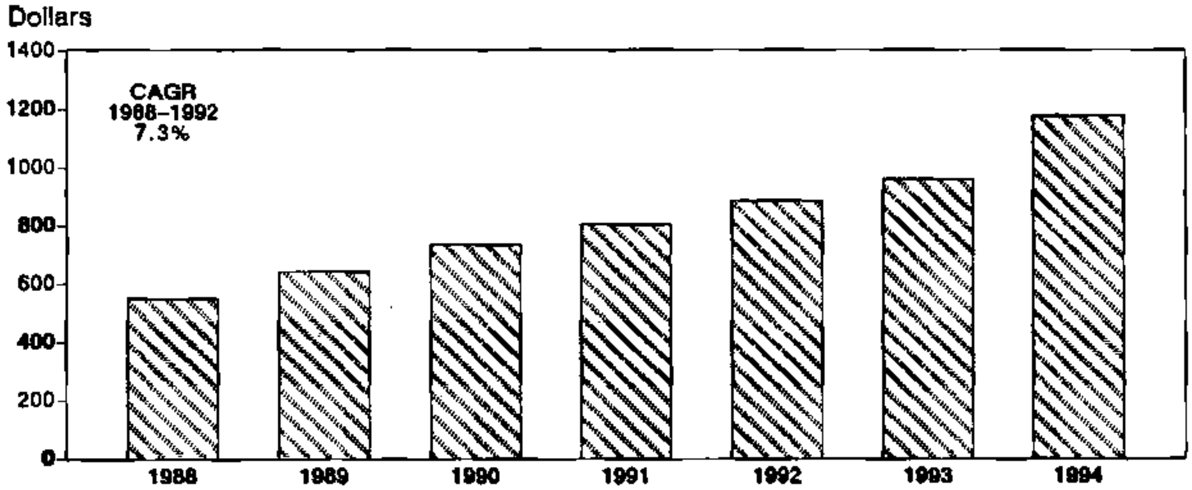
The largest merchant supplier of automotive semiconductors to North America is Motorola, with an estimated $276 million in sales (see Figure 4). The top five suppliers accounted for 66 percent of the market.

Listed in Table 8 are the key suppliers of merchant semiconductors for the North American vehicle electronics manufacturers.

Most of the successful semiconductor suppliers to the automotive business have committed completely to the strenuous requirements for service. The utilization of statistical process control data for quality assurance, ship-to-stock, and massive codesign efforts typify the nature of a new generation of supplier-OEM relationships.

Figure 4

Estimated North American Sales of Merchant Semiconductor Suppliers (Millions of Dollars)



Source: Dataquest (August 1990)

Table 8

Key Merchant Semiconductor Suppliers

Company	Principal Automotive Products
AMD/MMI	Logic devices and microcontrollers
Harris-GE	Microcontrollers, linear, discrete, and logic devices
Hitachi	Microcontrollers, linear devices, and memory
Intel	Microcontrollers and memory
International Rectifier	Power devices
ITT	Linear and discrete devices
Motorola	Microcontrollers, linear, and discrete devices
National	Microcontrollers, linear, and logic devices
NEC	Microcontrollers and optoelectronics
Oki	Microcontrollers and ASICs
Philips-Signetics	Linear and logic devices
Siemens	Microcontrollers and optoelectronics
SGS-Thomson	Linear and discrete devices
Sprague	Linear and discrete devices
Texas Instruments	Microcontrollers, linear, and logic devices
Toshiba	Microcontrollers, discrete devices, and memory

Source: Dataquest (August 1990)

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.

Real-time, microcontroller-based control and data communications have provided the automobile of the late 1980s with a stepping stone toward a truly automated status. With most of the key systems such as 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.

Trends in Automotive Electronics

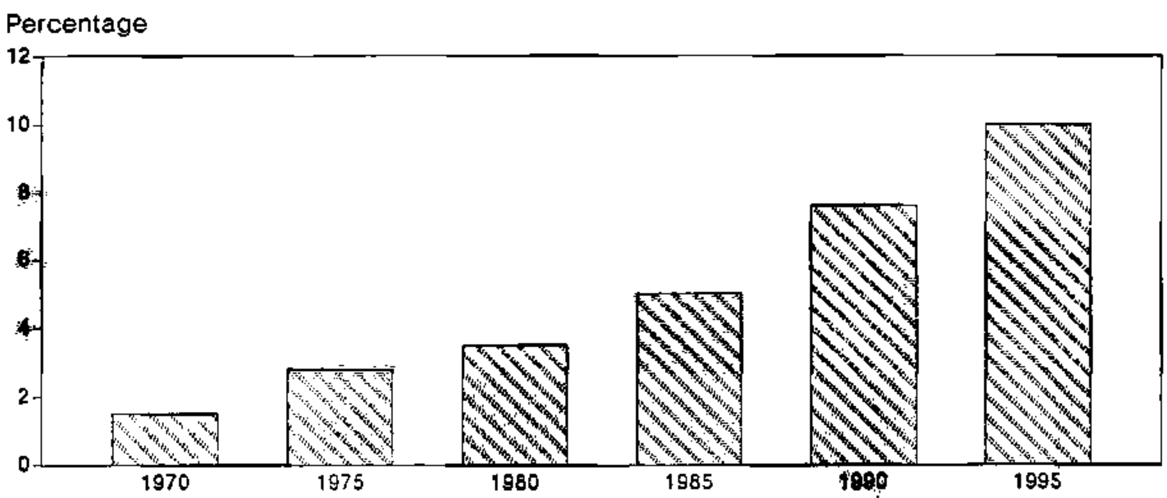
INTRODUCTION

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 $10.7 billion in 1988, driving an accompanying merchant semiconductor market of $994 million.

Figure 1 shows that, as recently as 1975, 3.0 percent of the value of the average automobile was attributable to electronics. In 1988, the electronic content is estimated to be 7.1 percent and, by 1992, 9.1 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. A factor that will limit electronics content as a percent of car price is the anticipated drop in electronics prices as more features become standard equipment and learning curve efficiencies are realized.

Figure 1

Penetration of Automobiles by Electronics (Percentage of Retail Price)



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Source: Dataquest March 1989

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.

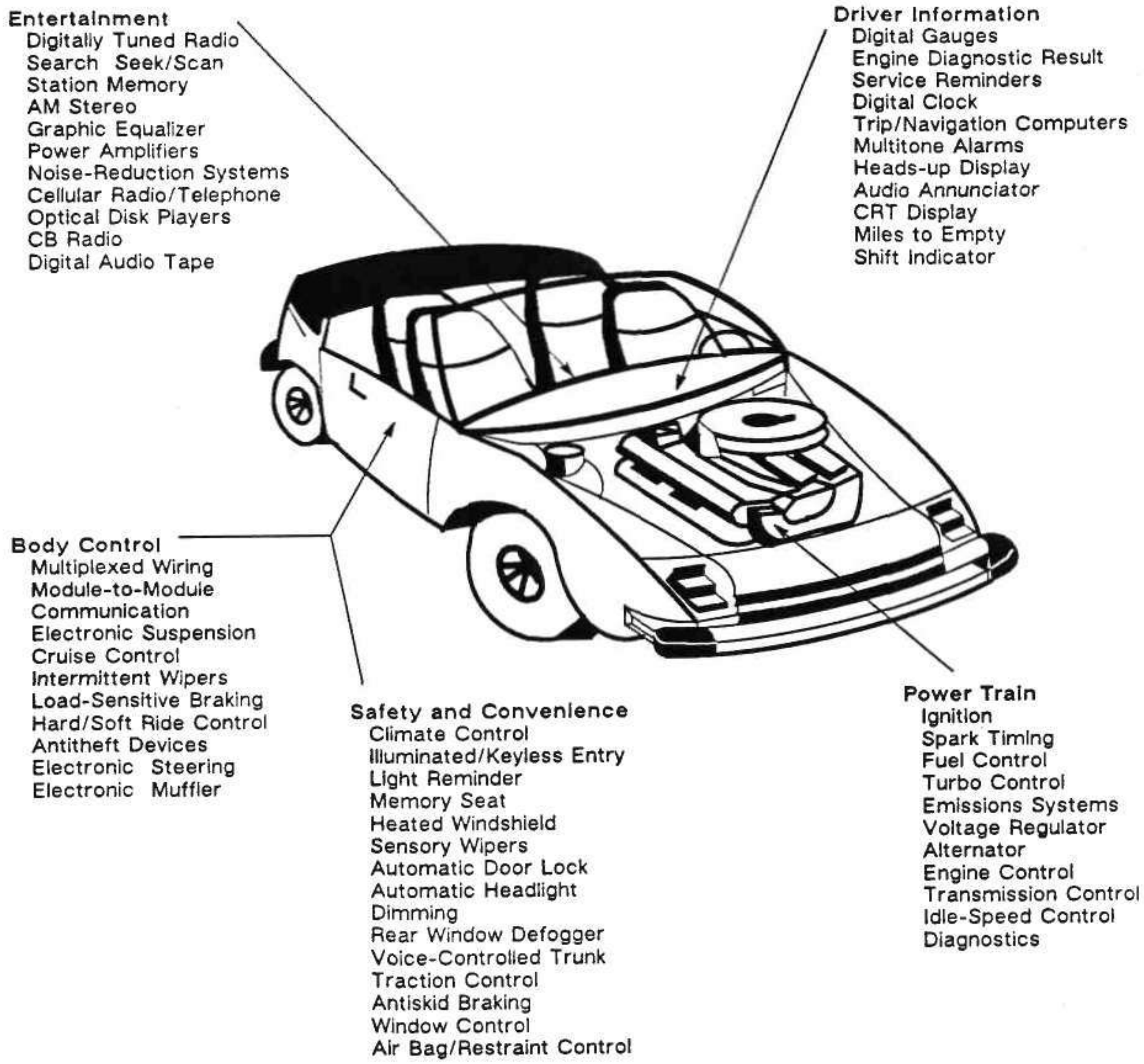
ELECTRONICS APPLICATIONS

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



0003147-2

Source: Dataquest
March 1989

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 that operates at 1 Mbps. 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. Other proposed standards include data rates in the 10-Kbps to 100-Kbps range.

A committee from the Society of Automotive Engineers (SAE) has been 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 a 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.

The semiconductor content of a typical antilock braking system includes:

- 8- or 16-bit microcontroller
- Quad comparator
- 3 to 8 power devices
- Voltage regulator
- 64-byte EEPROM

Primarily found on high-end models and pick-up trucks, ABSs are also currently in 7 percent of the units shipped in North America. It is estimated that the penetration rate will exceed 36 percent by 1992. The major manufacturers of ABSs are the following:

- Bendix
- Robert Bosch
- GM Delco
- ITT Teves
- Kelsey-Hayes
- Siemens

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. A heads-up display was introduced by GM in 1988. In addition to microcontrollers, display-driver ICs are expected to benefit from the acceptance of advanced display technology.

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. Digital tuning utilizing 4- and 8-bit microcontrollers is the trend in most new radio designs. 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. In 1988, GM introduced digital audio tape (DAT) players as an option. This was one of the first commitments to this technology in the U.S. market.

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, Plessey, 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. These advances are also partly responsible for driving down the cost of existing electronic systems.

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 (e.g., BICMOS) 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, EPROM, EEPROM, and RAM sizes and configuration.

ASIC suppliers will continue to benefit from the demand to reduce board space and improve reliability. Some of the traditional microcontroller firms have customer codesigned cell libraries to create a new generation of 8- and 16-bit control functions.

Microcontrollers

Further penetration by 8-bit controllers into system (e.g., antilock braking) control will continue into the 1990s. Many semicustom varieties can be produced as internal CAD libraries allow low-cost lead time customization. Texas Instruments has introduced a reconfigurable 8-bit line it codeveloped with Delco. This family can be reconfigured easily with alternative memory options.

As automotive designers begin to integrate discrete control modules and need higher sampling rates/processing throughput, 16-bit controllers are expected to experience growth. Several companies have 16-bit microcontrollers targeted at the automotive market, including Hitachi, Intel, Motorola, National, Siemens, and Toshiba.

Today each car has an average of three microcontrollers; by the early 1990s, this number is expected to double.

Smart Power

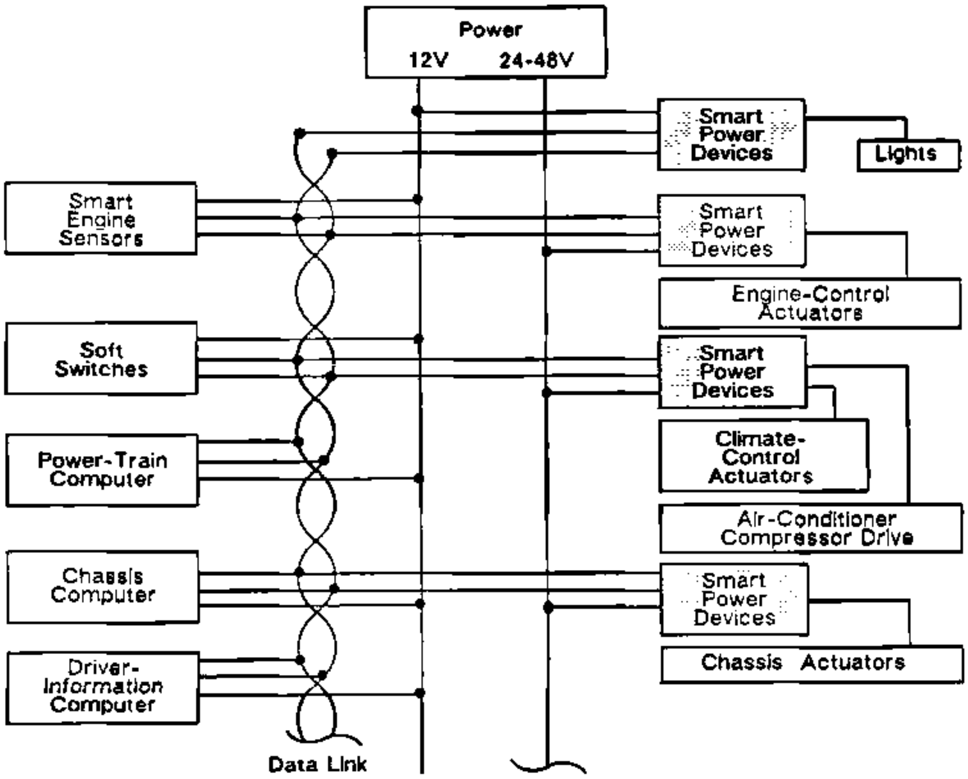
The application of smart power to the vehicle is poised for rapid growth. As high-isolation, mixed signal/transistor semiconductor processes are being perfected, and with learning curve efficiencies approaching, smart power has become a viable technology. Stimulated by the multiplexed wiring concept, 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 and controlled acuator. 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). Status information can also be fed back to the microcontroller.

The most prevalent use of smart power devices in automotive applications is for high-side switching (e.g., applying power to fuel injectors, air conditioners, etc.). Currently, electromechanical relays perform this function for an average of $0.70 a piece. It is believed that smart power solutions will have to reach $1.20 to $1.50 to replace these relays in earnest. Because of reliability and functionality improvements, an initial price premium with this new technology can be tolerated.

It should be noted that there is a spectrum of smart power solutions that range from the all-in-one IC to a modified discrete power MOSFET with a CMOS input (gate). International Rectifier and Motorola have MOSFET offerings with these features. Figure 4 presents a hybrid solution that utilizes an IC in conjunction with a MOSFET.

Figure 3

Vehicle System Featuring Use of Smart Power Devices



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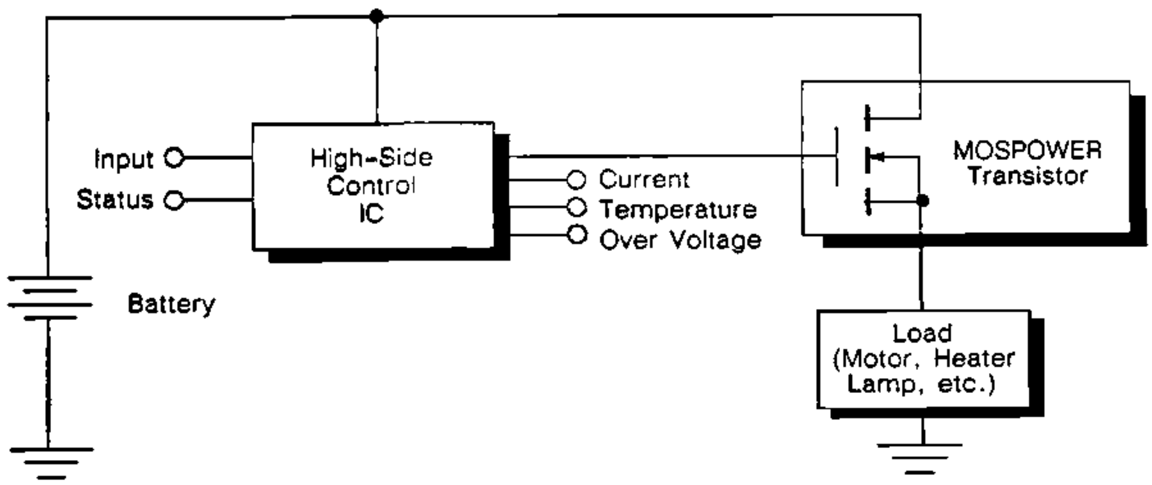
Source: Institute of Electrical and Electronics Engineers

Figure 4

High-Side Power Control



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Source: Siliconix

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, their use is expected to expand along with the number of new microcontroller applications. Digital audio applications require typically 32K to 64K densities, body and chassis applications require 16K, high speed versions, and the engine controller can use up to 1Mb densities.

EEPROMs are finding a variety of applications for capturing or storing data that needs to be preserved when the car is not running. Applications include radio settings, odometer, and diagnostic information storage. Lower-cost Flash technology is well suited for less interactive auto uses.

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

Packaging Trends

The significant trends in packaging for automotive applications are toward further use of surface mounting and higher headcount packages. Surface mounting, as in its use elsewhere, is required to reduce board size and allow more chips to be placed per square inch. For high-temperature, understood use, ceramic-leaded chip carriers are growing in popularity. The leadless varieties were found to be difficult to use because of thermal mismatch stress between the board and the IC.

Higher lead counts (greater than 44) are being required as ASICs and 16-bit microcontrollers became more prevalent. Tape automated bonding (TAB) is becoming popular for reliability reasons, displacing wire bonding techniques.

MARKET FORECASTS

Vehicle Production

Table 1 presents the data for auto and truck production, regardless of base country. After slumping 5.3 percent in 1987, North American production was up 5.2 percent in 1988. The gain was driven principally by truck sales, which grew by 9.3 percent, while car sales grew at a more moderate 2.8 percent rate.

Table 1
Estimated North American Auto and Truck Production
(Millions of Units)

	1984	1985	1986	1987	1988	1989	1992	CAGR 1988-1992
Auto	8.84	9.28	8.90	7.91	8.13	7.97	8.45	1.0%
Truck	3.96	4.33	4.34	4.63	5.06	5.18	5.44	1.8%
Total	12.80	13.61	13.24	12.54	13.19	13.15	13.89	1.3%

Source: Automotive News
Dataquest
March 1989

The production leader in 1988 was GM, but it continued its loss of share, dropping to 44.1 percent from 46.4 percent in 1987 (see Table 2). Ford's share was up to 30.2 percent; Chrysler's was up to 16.7 percent. Honda continued to gain share, up to 3.2 percent as it expanded its resident production capabilities. Nissan's share dropped as it shifted its mix to emphasize trucks. Mazda, which had just started full production in 1988, managed to produce 1.2 percent of all vehicles in North America.

Table 2

North American Auto and Truck Production Share by Manufacturer

Company	1985	1986	1987	1988
General Motors	53.0%	48.2%	46.4%	44.1%
Ford	25.8%	28.9%	29.7%	30.2%
Chrysler	16.4%	15.9%	15.8%	16.7%
Honda	1.1%	1.9%	2.6%	3.2%
Nissan	1.1%	1.3%	1.7%	1.6%
Mazda	N/A	N/A	N/A	1.2%
Nummi	0.4%	1.6%	1.5%	1.0%
Volkswagen	0.1%	0.6%	0.5%	0.3%
Others	2.1%	1.7%	1.8%	1.8%

N/A = Not Applicable

Source: Automotive News
Dataquest
March 1989

Table 3 presents the factory installation percentages of various vehicle electronic systems. Also noted are estimates of penetration by these systems by 1992.

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.

Table 3

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

System	1987	1992
Entertainment		
AM/FM Mono Radio	4%	1%
AM/FM Stereo Radio	39%	30%
AM/FM Stereo Cassette	43%	52%
AM/FM Stereo Cassette, Equalizer	7%	10%
Cellular Telephone	0	2%
Body Control		
Speed Regulator	61%	64%
Intermittent Wipers	79%	86%
Electronic Suspension	3%	12%
Electronic Steering	0	8%
Antitheft Device	4%	15%
Multiplexed Wiring	0	5%
Driver Information		
Digital Clock	87%	96%
Fuel/Trip Computer	3%	8%
Electronic Instrument Cluster	15%	32%
Warning Indicator	72%	84%
Voice Alert	1%	2%
Shift Light	12%	18%
Navigation	0	4%
Power Train		
Electronic Fuel Injection	68%	75%
Feedback Carburetor	32%	25%
Antiknock Device	21%	46%
Spark/Idle Control	87%	96%
Distributorless Ignition	12%	28%
Diagnostic System	74%	90%

(Continued)

Table 3 (Continued)

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

System	1987	1992
Safety and Convenience		
Antilock Braking	7%	35%
Traction Control	1%	21%
Automatic Air Conditioning	18%	44%
Headlamp Timing	7%	16%
Keyless Locks	2%	5%
Memory Seat	1%	5%
Day/Night Mirrors	2%	8%
Collision Avoidance	0	4%
Air Bag/Seat Belt Control	7%	25%

Source: Wards
Automotive News
Dataquest
March 1989

Penetration by factory-installed entertainment electronics is high at 93 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.

Body control features, such as electronic steering and suspension, 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. Wire multiplexing, when adopted, should experience broad application rapidly. However, it appears that it will be the mid-1990s before significant penetration takes place.

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. North American vehicle production has stayed roughly flat at 12.5 million units from 1984 to 1987. The fastest growing area is Korea, where production has grown at a 53.6 percent CAGR over the same time period. Western European production is up approximately 1.8 million units for the time period, the largest gain of any region.

Table 4

Geographic Vehicle Production Trends (Millions of Units)

Country	1984	1985	1986	1987	CAGR 1984-1987
United States	10.92	11.67	11.38	10.98	0.2%
Canada	1.88	1.94	1.86	1.56	(6.0%)
Total North America	12.80	13.61	13.24	12.54	(0.7%)
Japan	11.39	12.27	12.26	12.25	2.5%
South Korea	0.27	0.39	0.60	0.98	53.6%
Australia	0.40	0.41	0.36	0.32	(7.2%)
Total Southeast Asia	0.67	0.80	0.96	1.30	24.7%
West Germany	4.05	4.44	4.58	4.61	4.4%
France	3.06	3.02	3.19	3.49	4.5%
Italy	1.60	1.57	1.91	1.91	6.1%
United Kingdom	1.13	1.31	1.20	1.34	5.8%
Spain	1.31	1.42	1.31	1.43	3.0%
Sweden	0.43	0.46	0.48	0.50	5.2%
Belgium	0.25	0.27	0.30	0.32	8.6%
Total Western Europe	11.83	12.49	12.97	13.60	4.8%

(Continued)

Table 4 (Continued)

Geographic Vehicle Production Trends
(Millions of Units)

Country	1984	1985	1986	1987	CAGR 1984-1987
Brazil	0.86	0.97	1.06	0.90	1.5%
Mexico	0.34	0.40	0.34	0.40	5.6%
Total Latin America	1.20	1.33	1.33	1.33	3.5%
USSR	2.21	2.20	2.23	2.10	(1.7%)
Other Countries	2.06	1.99	2.18	2.56	7.5%
Worldwide Total	42.16	44.69	45.17	45.68	2.7%

Source: Automotive News
Dataquest
March 1989

North American Auto and Truck Electronics Market

As Figure 5 points out, it is estimated that the average car manufactured in North America in 1988 contains just less than $900 worth of electronic systems and components. This represents a near doubling of consumption since 1982. The estimated $1,178 worth of electronics per car by 1992 will be approximately 8 percent of the retail price. By then, electronics will represent between 13 and 18 percent of the vehicle manufacturer's cost of goods.

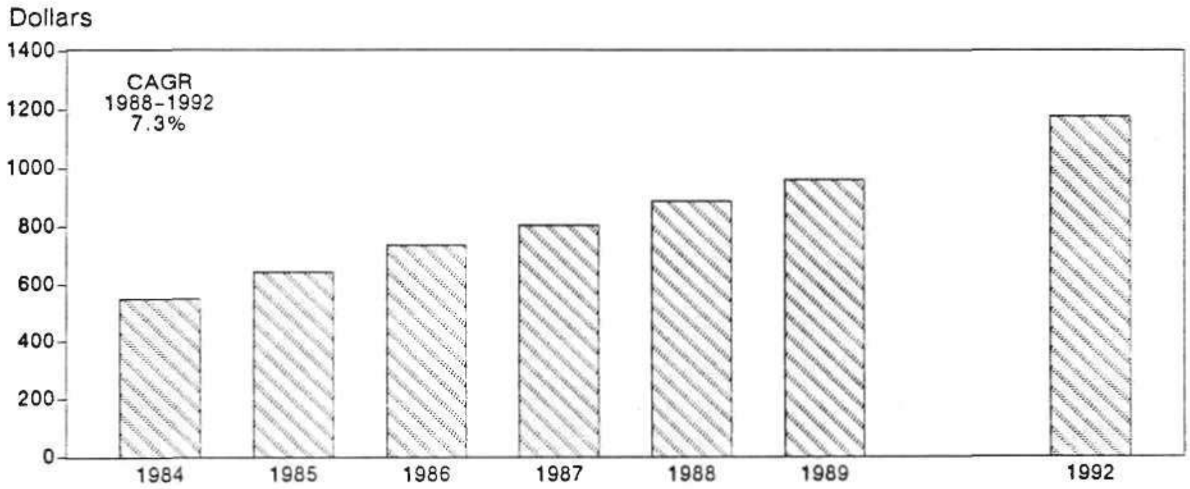
Note that the estimates for electronic systems and semiconductors found in this section represent an update from those published in the front of the "Transportation" section.

Nineteen eighty-eight was an unusual year for automotive electronics production in North America. With unit production up and pervasiveness continuing, electronics could have grown 12 to 15 percent. However, upon closer analysis, several factors tempered the potential number. One factor was that unit growth was principally from trucks, which are less electronics-intensive than cars. Second, GM, the largest and most electronics-intensive of the manufacturers, continued to lose market share. Third, Japanese transplants such as Honda for the most part import electronic subassemblies from Japan. The net result is that automotive electronics production grew only

5.4 percent in 1988. Nineteen eighty-nine is expected to grow 5.5 percent as unit production flattens overall and declines 2.0 percent for cars. A U.S. economic slowdown is expected to hit in late 1989 and continue through 1990, hurting the market for domestically produced vehicles. The 1988 to 1992 CAGR for electronics production is expected to be 8.0 percent as accelerated growth returns in 1991.

Figure 5

Electronic Content of the Average North American Car



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Source: Dataquest March 1989

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 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)

	1984	1985	1986	1987	1988	1989	1992	CAGR 1988-1992
Entertainment	$2,142	$2,380	$2,647	$ 2,780	$ 2,876	$ 2,956	$ 3,606	5.8%
Body Controls	1,060	1,261	1,513	1,640	1,772	1,923	2,713	11.2%
Driver Information	1,060	1,237	1,458	1,583	1,708	1,853	2,476	9.7%
Power Train	2,473	2,782	3,007	3,155	3,259	3,370	4,062	5.7%
Safety and Convenience	706	820	955	1,041	1,129	1,229	1,758	11.7%
Total	$7,441	$8,480	$9,580	$10,199	$10,744	$11,331	$14,615	8.0%

Source: Dataquest
March 1989

Growing at an 11.2 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 9.7 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 5.8 percent CAGR through 1992 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 5.7 percent through 1992 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 $112 for cars and $68 for trucks, these values are expected to grow to $156 and $96, respectively, by 1992. These numbers represent a continued excellent opportunity for suppliers of semiconductors.

Table 6

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

	1984	1985	1986	1987	1988	1989	1992	CAGR 1988-1992
Auto	$66	$78	$90	$101	$112	$123	$156	8.6%
Truck	$49	$54	$58	$ 63	$ 68	$ 74	$ 96	9.0%
Average	$61	$70	$80	$ 87	$ 95	$104	$133	8.6%

Source: Dataquest
March 1989

Merchant-produced semiconductors consumed for vehicle applications grew an estimated 8.2 percent in 1988 (see Table 7). The estimated CAGR through 1992 for merchant semiconductors is 10.8 percent. This is slightly faster than the electronic equipment growth rate of 8.8 percent for the same period of time. Merchant semiconductor penetration of vehicle electronics is expected to increase from 9.3 percent in 1988 to 10.3 percent in 1992. Demand for electronic devices for cars will grow at a 11.0 percent rate through 1992, whereas the less-penetrated but fertile area of trucks and buses will grow at 10.4 percent.

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 20.1 percent through 1992; body controls at 16.3 percent; and driver information at 13.6 percent. Only entertainment systems, growing at 9.4 percent through 1992, and power train equipment, at 8.6 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 69.0 percent by 1992.

Table 7

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

	1984	1985	1986	1987	1988	1989	1992	CAGR 1988-1992
Auto	$522	$583	$621	$670	$720	$ 768	$1,092	11.0%
Truck	176	205	227	249	274	298	407	10.4%
Total	$698	$788	$848	$919	$994	$1,066	$1,499	10.8%

Source: Dataquest
March 1989

Table 8

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

System	1984	1985	1986	1987	1988	1989	1992	CAGR 1988-1992
Entertainment	$129	$136	$146	$159	$170	$ 180	$ 244	9.4%
Body Controls	53	62	71	83	94	104	172	16.3%
Driver Information	60	69	79	90	99	109	165	13.6%
Power Train	421	481	508	536	571	605	793	8.6%
Safety & Convenience	35	40	44	52	60	68	125	20.1%
Total	$698	$788	$848	$919	$994	$1,066	$1,499	10.8%

Source: Dataquest
March 1989

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.

AUTOMOTIVE ELECTRONICS PARTICIPANTS

Electronic System Manufacturers

The big three—GM, Ford, and Chrysler—produce an estimated 55 percent of their electronic system needs internally. This percentage is up from 45 percent in 1982. GM, which produces an estimated 60 percent of its needs internally, is benefiting from the electronics strengths found in its Hughes acquisition. It also has a large captive semiconductor operation that produces an estimated half of its needs.

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 Electrical and Electronic Division (EED) group at Ford also produces an estimated 40 percent of that company's needs.

The other 45 percent of the vehicle manufacturers' electronics needs come from the cadre of independent suppliers that typically specialize in various application areas. For the most part, Japanese companies import assembled electronic subsystems.

Listed in Table 9 are the primary manufacturers of vehicle electronic systems in North America. Including those serving various aspects of the aftermarket, there are an estimated 50 automotive electronic OEMs in the United States.

Table 9

Primary North American Manufacturers of Vehicle Electronic Systems

Company	Principal Electronic System(s)
Robert Bosch	Audio, ABS, engine control, ignition modules
Chrysler	Audio, engine control, displays, body control
Eaton	Engine and body control, climate control
Ford	Engine and body control
General Motors-Delco	Audio, engine and body control, ABS, suspension, displays
ITT	ABS and audio
Motorola	ABS, engine control, sensors, instruments
Rockwell International	Body control, suspension, motor control
Siemens-Bendix	Fuel injection, ABS, ignition modules
TRW	Steering, engine and body control
United Technologies	Switches, ignition systems
Wagner	Lighting control

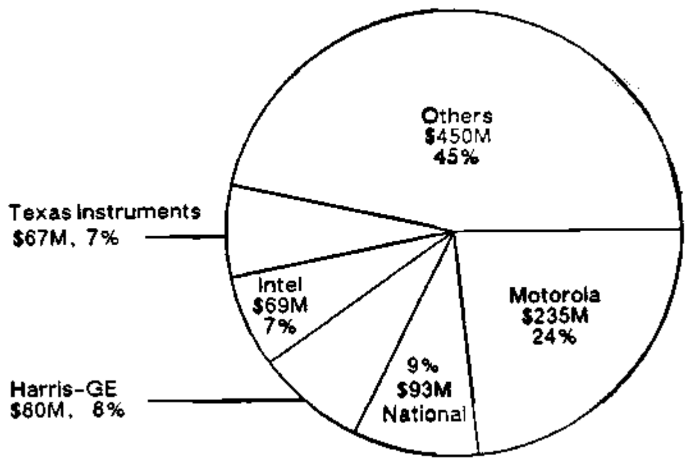
Source: Dataquest
March 1989

Key Semiconductor Suppliers

The largest merchant supplier of automotive semiconductors to North America is Motorola, with an estimated $235 million in sales (see Figure 6). The top five suppliers accounted for 55 percent of the market.

Figure 6

Estimated North American Sales
of Merchant Semiconductor Suppliers
(Millions of Dollars)



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Source: Dataquest
March 1989

Listed in Table 10 are the key suppliers of merchant semiconductors for the North American vehicle electronics manufacturers.

Most of the successful semiconductor suppliers to the automotive business have committed completely to the strenuous requirements for service. The utilization of statistical process control data for quality assurance, ship-to-stock, and massive codesign efforts typify the nature of a new generation of supplier-OEM relationships.

Table 10

Key Merchant Semiconductor Suppliers

Company	Principal Automotive Products
AMD/MMI	Logic devices and microcontrollers
Harris-GE	Microcontrollers, linear, discrete, and logic devices
Hitachi	Microcontrollers, linear devices, and memory
Intel	Microcontrollers and memory
International Rectifier	Power devices
ITT	Linear and discrete devices
Motorola	Microcontrollers, linear, and discrete devices
National	Microcontrollers, linear and logic devices
NEC	Microcontrollers and optoelectronics
Oki	Microcontrollers and ASICs
Siemens	Microcontrollers and optoelectronics
Signetics	Linear and logic devices
SGS-Thomson	Linear and discrete devices
Sprague	Linear and discrete devices
Texas Instruments	Microcontrollers, linear and logic devices
Toshiba	Microcontrollers, discrete devices, and memory

Source: Dataquest
March 1989

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.

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.

Trends in Automotive Electronics

INTRODUCTION

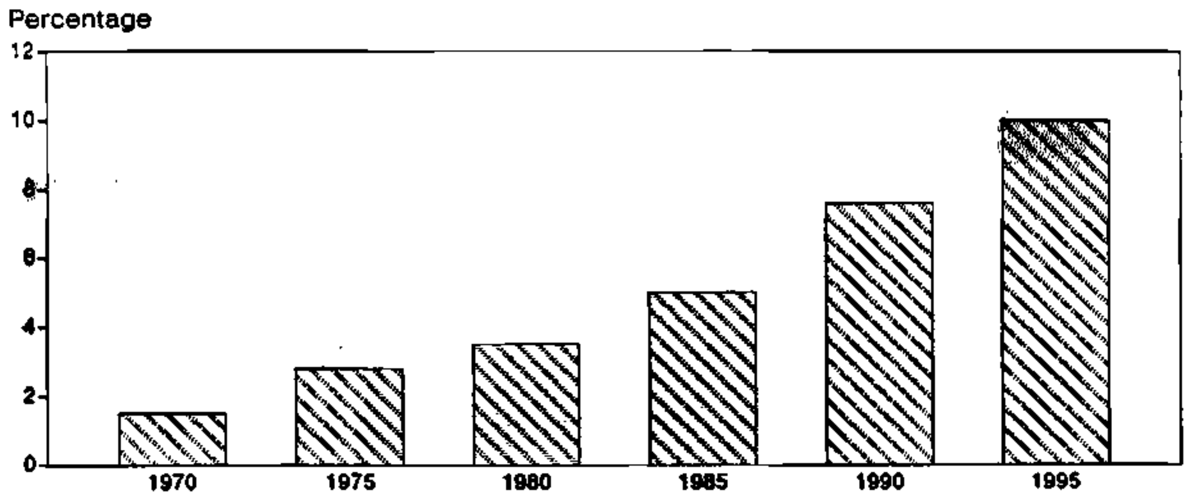
Once dependent on sleek styling and increased engine power to sell their cars, auto manufacturers have completely embraced electronics and semiconductor technology to enhance their product positions in a highly competitive world marketplace. This push by the auto industry is creating a fast-growing market 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.

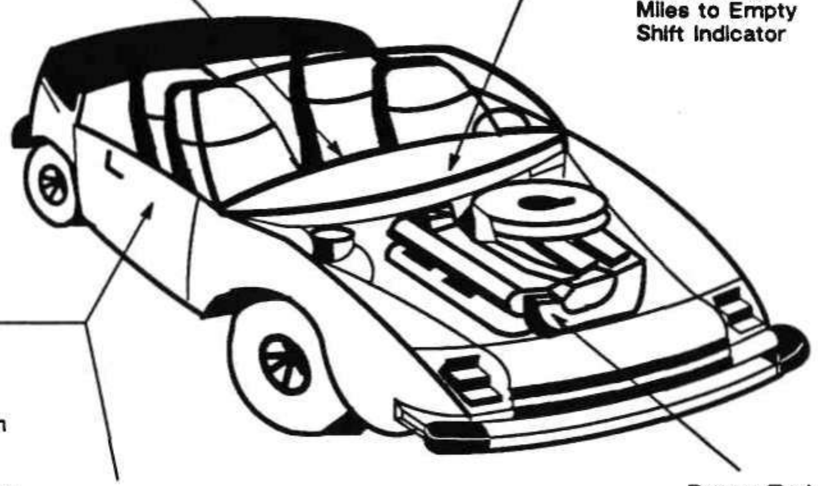
THE ROLE OF ELECTRONICS

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.

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.

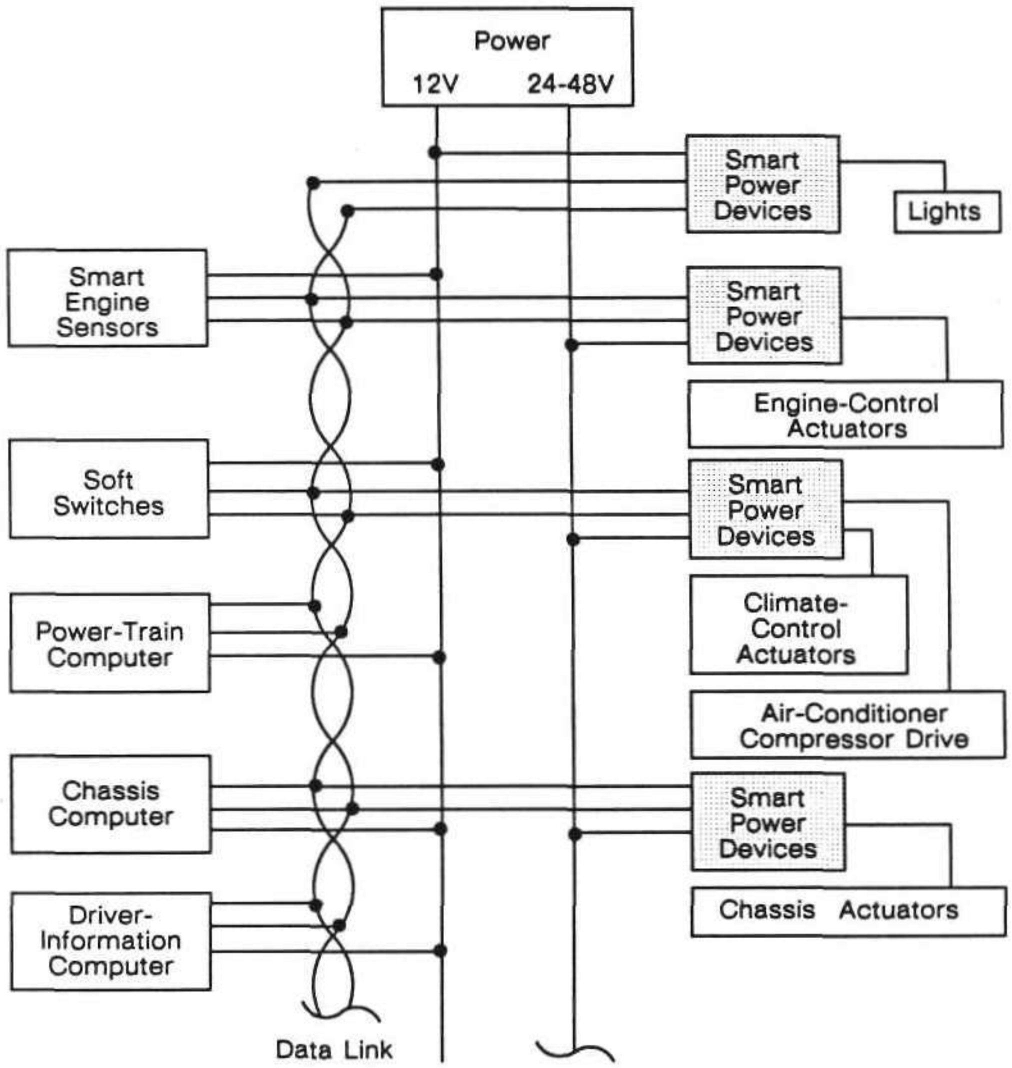
Memory

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.

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%

Source: Automotive News
Dataquest
January 1988

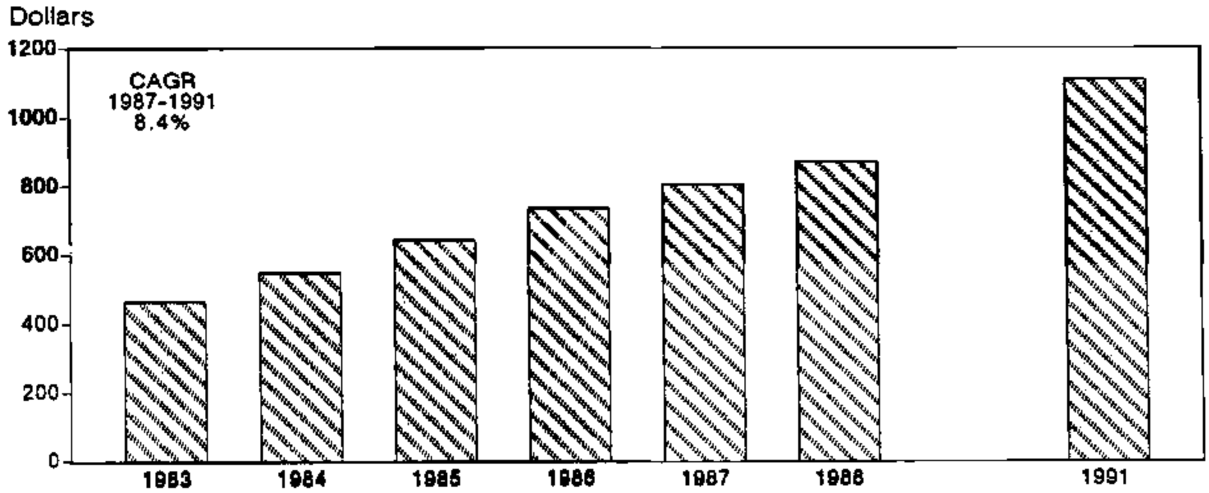
North American Auto and Truck Electronics Market

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

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
Sprague	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.

Semiconductor Consumption

INTRODUCTION

Semiconductor consumption data comprise a set of detailed tables that estimate the size of the semiconductor total available market (TAM) worldwide and for four major geographical regions for the years 1976 through 1992 and 1997. Semiconductor consumption tables contain both historical data and forecasts. Historical data begin with 1978 and end with 1987, while forecast data provide annual market size estimates for 1988 through 1992, with additional estimates for 1997. Below is a list of tables detailing the type of data, region, time period, and units of measure.

LIST OF TABLES

Table	Region Covered	Years	Units
0	Japan and Western Europe Exchange Rates	1987	Various
1a	Worldwide Consumption	1976-1981	Dollars
1b	Worldwide Consumption	1982-1987	Dollars
1c	Worldwide Consumption	1988-1992; 1997	Dollars
1d	Worldwide Consumption (CAGR)	1977-1997	Percent
2a	North American Consumption	1976-1981	Dollars
2b	North American Consumption	1982-1987	Dollars
2c	North American Consumption	1988-1992; 1997	Dollars
2d	North American Consumption	1977-1997	Percent
3a	Japanese Consumption	1976-1981	Dollars
3b	Japanese Consumption	1982-1987	Dollars
3c	Japanese Consumption	1988-1992; 1997	Dollars
3d	Japanese Consumption	1977-1997	Percent
4a	Japanese Consumption	1976-1981	Yen
4b	Japanese Consumption	1982-1987	Yen
4c	Japanese Consumption	1988-1992; 1997	Yen
4d	Japanese Consumption	1977-1997	Percent
5a	Western European Consumption	1976-1981	Dollars
5b	Western European Consumption	1982-1987	Dollars
5c	Western European Consumption	1988-1992; 1997	Dollars
5d	Western European Consumption	1977-1997	Percent
6a	Rest of World Consumption	1976-1981	Dollars
6b	Rest of World Consumption	1982-1987	Dollars
6c	Rest of World Consumption	1988-1992; 1997	Dollars
6d	Rest of World Consumption	1977-1997	Percent
7a	Worldwide Average Selling Prices	1976-1981	Dollars
7b	Worldwide Average Selling Prices	1982-1987	Dollars
7c	Worldwide Average Selling Prices	1988-1992; 1997	Dollars
7d	Worldwide Average Selling Prices	1977-1997	Percent
8a	Worldwide Consumption	1976-1981	Units
8b	Worldwide Consumption	1982-1987	Units
8c	Worldwide Consumption	1988-1992; 1997	Units
8d	Worldwide Consumption	1977-1997	Percent

Semiconductor Consumption

Each table gives estimates of semiconductor consumption listed by the major semiconductor device product categories. In these tables, semiconductor components are divided into three major product groups: integrated circuits, discrete devices, and optoelectronic devices. These groups are divided into a number of subgroups, some of which are segmented further.

DEFINITIONS AND CONVENTIONS

Dataquest uses a common manufacturer base for all data tables. This base includes all suppliers to the merchant semiconductor market. It excludes captive suppliers that manufacture devices solely for the benefit of the parent company, such as AT&T, Burroughs, Delco, and IBM. Included, however, are companies that actively market semiconductor devices to the merchant market as well as to other divisions of their own companies. For such companies, both external shipments and internal consumption are included. Devices that are used internally are valued at current market prices.

Consumption—Dataquest defines consumption as the purchase of a semiconductor device or devices. This definition must be differentiated from actual use of the device in a final product. Devices that are inventoried at the user level are considered consumption according to our definition. The terms consumption and market size are used interchangeably. Thus, a regional market includes all devices sold to or shipped to that region, i.e. the total available market (TAM) in that region.

Hybrids—In earlier consumption data, hybrid devices were included as a separate segment of integrated circuits. However, since hybrid devices are primarily a special packaging arrangement, this segment has been omitted. Hybrid devices manufactured by semiconductor companies are now included in the most appropriate product segment, usually the linear segment.

The manufacturer base product group definitions and guidelines for including value of output that we have used in our tables may differ from those used in other studies of this type. Our base is nearly the same as that used by the World Semiconductor Trade Statistics program (WSTS).

Regions—North America is defined as including both the United States and Canada. Latin America, including Mexico, is considered part of the Rest of World (ROW) category. Western Europe includes Austria, Belgium, the Federal Republic of Germany, France, Greece, Italy, Luxembourg, the Scandinavian countries (Denmark, Finland, Norway, Sweden), Spain, and the United Kingdom. The ROW region includes the Asia-Pacific (Korea, Taiwan, Hong Kong, Singapore, and China).

Semiconductor Consumption

DATA SOURCES

The information presented in the consumption data has been consolidated from a variety of sources, each of which focuses on a specific part of the market. These sources include the following:

- World Semiconductor Trade Statistics (WSTS) data, and Dataquest's estimates of regional company sales are used to determine North American consumption.
- Japanese trade statistics compiled and published by the Ministry of Finance (MOF) and the Ministry of International Trade and Industry (MITI), WSTS data, and Dataquest's estimates of regional company sales are used to determine Japanese consumption.
- For Western European markets, marketing statistics from WSTS data and Dataquest's estimates of regional company sales are used to determine consumption.
- In ROW, the major published sources used to estimate consumption are WSTS data and Dataquest's estimates of company shipments into the region.

Dataquest believes that the estimates presented here are the most accurate and meaningful generally available today. The sources of the data and the guidelines for the forecasts presented in the tables are:

- Unit sales or revenue (or both) published by major industry participants, both in the United States and abroad
- Estimates presented by knowledgeable and reliable industry spokesmen
- Government data or trade association data such as those from the Electronics Industry Association (EIA), MITI, WSTS, and the U.S. Department of Commerce
- Published product literature and price lists
- Interviews with knowledgeable manufacturers, distributors, and users
- Relevant projected world economic data

CONSISTENCY

One of the key objectives in preparing these estimates is to achieve consistency among the various data elements that constitute the forecast and the historical data base. To ensure the accuracy and consistency of the estimates, we have compared the values of directly obtained data elements with values obtained by indirect means, wherever possible. Thus, the worldwide totals in the consumption analysis are consistent with the worldwide totals of the market share analysis.

Semiconductor Consumption

ACCURACY

The tables presented here represent Dataquest estimates that we believe are reasonably accurate. Where we have no reasonable estimate, none is given. A blank space in a table indicates that a reasonably accurate estimate is unavailable, and a zero in a table represents an estimate.

VALUATION OF CONSUMPTION

Regional consumption is expressed in U.S. dollars (with Japanese consumption and shipments also expressed in yen). To make the tables in this study useful in comparing different regions, it is necessary to express all values in a common currency, and we chose the U.S. dollar for convenience.

However, the choice of the U.S. dollar (or any single currency, for that matter) as the currency basis for the tables brings with it some problems that require the readers' careful consideration in interpreting the data.

Inflation

All countries that participate significantly in international semiconductor markets suffered from an overall price inflation in the 1970s, continuing into the 1980s.

As a consequence, the dollar in a given year is not truly comparable with the dollar in any preceding year. Consumer and wholesale price indices and GNP deflators all measure price changes in various composite "market baskets" of goods. However, there is no price index that measures price changes of material, equipment, and labor inputs to the semiconductor industry. Indeed, the "mix" is changing so rapidly that what is used this year was sometimes unavailable last year, at any price. Nor is there a composite price index that measures price changes in aggregate semiconductor product. In an industry noted for its deflationary trends, this latter effect would tend to make the component purchaser's dollar worth more as time passed, in terms of purchasing ability.

We have made no adjustments in the historical data to account for these inflationary and deflationary effects. The data are expressed in current dollars (dollars that include the inflation rate and exchange rates of the given year) for all historical data; comparisons between different years must be interpreted accordingly.

Average Selling Prices

When considering the worldwide average selling prices (ASPs) for semiconductor components, one must look at the price per function of a circuit, the complexity of the circuit, and the product mix according to this increasing complexity. It is true that one characteristic of the semiconductor industry is that the price per function for integrated circuits has been dropping an average of 30 percent per year for the last 15 years. At the same time, circuits have become denser, resulting in an overall increase in the price of a device with a decreasing cost per function. Thus, Table 7 shows the worldwide ASPs increasing after many years of decreasing, due to the move toward higher-complexity devices. There are also regional differences in ASPs due to regional competition differences and the varying regional product consumption mix. The worldwide ASP is truly an aggregate measure and may differ significantly from ASPs in any specific market at any point in time.

Exchange Rates

Construction of the West European tables involves combining data from many countries, each of which has different and changing exchange rates. Dataquest uses Annual Foreign Exchange Rates for each year as published by The International Monetary Fund. As far as possible, we prepare our estimates in terms of local currencies before conversion to U.S. dollars. The exchange rates for major currencies can be found in Table 0 at the end of this introduction.

Japanese consumption is based on MITI data, originally expressed in yen. The Japanese data published in this study are expressed in both dollars (Tables 3a, 3b, and 3c) and in yen (Tables 4a, 4b, and 4c). The yen/dollar exchange rate used for each year can be found in Table 0. Because of the fluctuations in the exchange rate for the yen, the dollar values given tend to distort the growth rate of the Japanese market, but they do provide a useful basis for regional market size comparisons. However, the data in yen give a better picture of the real growth in the Japanese market.

FORECAST

As mentioned previously, historical data are expressed in current dollars or dollars that include the given year's inflation rate and exchange rates. However, the consumption forecasts use constant dollars and exchange rates, with no allowance for inflation or variations in the rates of exchange between countries. All estimates for 1988 and beyond are made as if 1988 monetary conditions will continue through 1997 and, therefore, show the absolute year-to-year growth during this period.

Table 0

Foreign Exchange Rates (In U.S. Dollars)

Year	Yrly/ Qtrly	Japan (Yen per US$)	France (US$ per Franc)	West Germany (US$ per Deutsche Mark)	United Kingdom (US$ per Pound Sterling)	European Basket ECU (1980 = 100)
1970	YR	358	$0.18	$0.27	$2.38	
1971	YR	343	$0.18	$0.29	$2.44	
1972	YR	302	$0.20	$0.31	$2.50	
1973	YR	269	$0.22	$0.37	$2.44	
1974	YR	292	$0.21	$0.39	$2.33	
1975	YR	297	$0.23	$0.41	$2.22	
1976	YR	296	$0.21	$0.40	$1.82	
1977	YR	269	$0.20	$0.43	$1.75	
1978	YR	210	$0.22	$0.50	$1.92	
1979	YR	219	$0.24	$0.55	$2.13	
1980	YR	227	$0.24	$0.55	$2.33	100
1981	YR	221	$0.18	$0.44	$2.04	124
1982	YR	248	$0.15	$0.41	$1.75	141
1983	YR	235	$0.13	$0.39	$1.52	158
1984	YR	237	$0.11	$0.35	$1.33	178
1985	YR	238	$0.11	$0.34	$1.30	185
1986	YR	167	$0.14	$0.46	$1.47	146
1987	YR	144	$0.17	$0.56	$1.64	126
1988	Q1	130	$0.18	$0.60	$1.79	117

Source: The International Monetary Fund
Dataquest
June 1988

Semiconductor Consumption

Table 1a

Worldwide Semiconductor Market
(Millions of Dollars)

	1976	1977	1978	1979	1980	1981
Total Semiconductor	$5,982	$6,968	$8,953	$11,114	$14,118	$14,828
Total IC	$3,087	$3,763	$5,230	$ 7,028	$ 9,546	$10,046
Bipolar Digital	$ 865	$ 994	$1,261	$ 1,674	$ 2,374	$ 2,337
Memory				324	572	558
Logic				1,350	1,802	1,779
MOS Digital	$1,239	$1,584	$2,332	$ 3,346	$ 4,715	$ 4,822
Memory				1,676	2,230	2,075
Micro				541	862	1,085
Logic				1,129	1,623	1,662
Linear	$ 983	$1,185	$1,637	$ 2,008	$ 2,457	$ 2,887
Total Discrete	$2,612	$2,903	$3,301	$ 3,522	$ 3,883	$ 3,985
Total Optoelectronic	$ 283	$ 302	$ 422	$ 564	$ 689	$ 797

Source: Dataquest
June 1988

Table 1b

Worldwide Semiconductor Market
(Millions of Dollars)

	1982	1983	1984	1985	1986	1987
Total Semiconductor	$15,261	$19,537	$28,903	$24,357	$29,670	$36,498
Total IC	$10,894	$14,700	$22,686	$18,555	$22,848	$28,668
Bipolar Digital	$ 2,412	$ 3,015	$ 4,771	$ 3,672	$ 4,309	$ 4,672
Memory	511	603	774	589	599	565
Logic	1,901	2,412	3,997	3,083	3,710	4,107
MOS Digital	$ 5,642	$ 7,951	$12,970	$10,122	$12,503	$16,788
Memory	2,701	3,719	6,229	3,821	4,652	6,019
Micro	1,318	1,979	3,234	2,748	3,478	4,819
Logic	1,623	2,253	3,507	3,553	4,373	5,950
Linear	$ 2,840	$ 3,734	$ 4,945	$ 4,761	$ 6,036	$ 7,208
Total Discrete	$ 3,547	$ 3,865	$ 4,987	$ 4,576	$ 5,222	$ 6,112
Total Optoelectronic	$ 820	$ 972	$ 1,230	$ 1,226	$ 1,600	$ 1,718

Source: Dataquest
June 1988

Semiconductor Consumption

Table 1c

Worldwide Semiconductor Market (Millions of Dollars)

	1988	1989	1990	1991	1992	1997
Total Semiconductor	$46,048	$50,194	$49,446	$57,152	$69,533	$120,770
Total IC	$36,806	$40,401	$39,572	$46,253	$57,203	$103,760
Bipolar Digital	$ 5,531	$ 5,901	$ 5,731	$ 6,492	$ 7,572	$ 10,760
Memory	621	636	613	578	534	310
Logic	4,910	5,265	5,118	5,914	7,038	10,450
MOS Digital	$22,621	$25,073	$24,291	$28,621	$36,179	$ 70,000
Memory	8,528	9,583	8,967	10,327	12,615	25,000
Micro	6,154	6,743	6,603	7,742	12,029	18,000
Logic	7,939	8,747	8,721	10,552	16,281	27,000
Linear	$ 8,654	$ 9,427	$ 9,550	$11,140	$13,452	$ 23,000
Total Discrete	$ 7,185	$ 7,573	$ 7,613	$ 8,339	$ 9,341	$ 12,400
Total Optoelectronic	$ 2,057	$ 2,220	$ 2,261	$ 2,560	$ 2,989	$ 4,610

Source: Dataquest
June 1988

Table 1d

Worldwide Semiconductor Market (Compound Annual Growth Rates)

	CAGR (77-82)	CAGR (82-87)	CAGR (87-92)	CAGR (92-97)	CAGR (77-87)	CAGR (87-97)
Total Semiconductor	17.0%	19.1%	13.8%	11.7%	18.0%	12.7%
Total IC	23.7%	21.4%	14.8%	12.6%	22.5%	13.7%
Bipolar Digital	19.4%	14.1%	10.1%	7.3%	16.7%	8.7%
Memory	N/A	2.0%	(1.1%)	(10.3%)	N/A	(5.8%)
Logic	N/A	16.7%	11.4%	8.2%	N/A	9.8%
MOS Digital	28.9%	24.4%	16.6%	14.1%	26.6%	15.3%
Memory	N/A	17.4%	16.0%	14.7%	N/A	15.3%
Micro	N/A	29.6%	20.1%	8.4%	N/A	14.1%
Logic	N/A	29.7%	22.3%	10.6%	N/A	16.3%
Linear	19.1%	20.5%	13.3%	11.3%	19.8%	12.3%
Total Discrete	4.1%	11.5%	6.7%	5.8%	7.7%	7.3%
Total Optoelectronic	22.1%	15.9%	11.7%	9.1%	19.0%	10.4%

Source: Dataquest
June 1988

Table 2a

North American Semiconductor Market
(Millions of Dollars)

	1976	1977	1978	1979	1980	1981
Total Semiconductor	$2,423	$2,876	$3,506	$4,538	$6,053	$6,529
Total IC	$1,490	$1,811	$2,335	$3,179	$4,562	$4,867
Bipolar Digital	$ 470	$ 537	$ 666	$ 901	$1,411	$1,339
Memory				185	396	375
Logic				716	1,015	964
MOS Digital	$ 640	$ 830	$1,099	$1,703	$2,442	$2,595
Memory				1,028	1,230	1,107
Micro				186	377	489
Logic				489	835	999
Linear	$ 380	$ 444	$ 570	$ 575	$ 709	$ 933
Total Discrete	$ 789	$ 940	$1,005	$1,161	$1,269	$1,378
Total Optoelectronic	$ 144	$ 125	$ 166	$ 198	$ 222	$ 284

Source: Dataquest
June 1988

Table 2b

North American Semiconductor Market
(Millions of Dollars)

	1982	1983	1984	1985	1986	1987
Total Semiconductor	$6,970	$9,002	$13,006	$9,420	$9.968	$11,869
Total IC	$5,466	$7,301	$11,089	$7,757	$8,202	$ 9,991
Bipolar Digital	$1,367	$1,664	$ 2,818	$1,926	$1,990	$ 2,072
Memory	320	373	441	288	292	279
Logic	1,047	1,291	2,377	1,638	1,698	1,793
MOS Digital	$3,183	$4,326	$ 6,503	$4,322	$4,538	$ 6,128
Memory	1,592	2,051	3,426	1,753	1,831	2,347
Micro	641	1,034	1,634	1,258	1,285	1,817
Logic	950	1,241	1,443	1,311	1,422	1,964
Linear	$ 916	$1,311	$ 1,768	$1,509	$1,674	$ 1,791
Total Discrete	$1,201	$1,353	$ 1,503	$1,295	$1,352	$ 1,442
Total Optoelectronic	$ 303	$ 348	$ 414	$ 368	$ 414	$ 436

Source: Dataquest
June 1988

Table 2c

North American Semiconductor Market
(Millions of Dollars)

	1988	1989	1990	1991	1992	1997
Total Semiconductor	$14,720	$15,576	$15,236	$17,993	$22,355	$37,010
Total IC	$12,682	$13,494	$13,079	$15,655	$19,762	$33,650
Bipolar Digital	$ 2,269	$ 2,375	$ 2,245	$ 2,528	$ 2,924	$ 3,750
Memory	297	301	291	275	265	150
Logic	1,972	2,074	1,954	2,253	2,659	3,600
MOS Digital	$ 8,424	$ 9,038	$ 8,664	$10,582	$13,794	$25,000
Memory	3,485	3,721	3,499	4,287	5,936	9,800
Micro	2,349	2,500	2,375	2,890	3,558	6,800
Logic	2,590	2,817	2,790	3,405	4,300	8,400
Linear	$ 1,989	$ 2,081	$ 2,170	$ 2,545	$ 3,044	$ 4,900
Total Discrete	$ 1,573	$ 1,587	$ 1,642	$ 1,753	$ 1,904	$ 2,400
Total Optoelectronic	$ 465	$ 495	$ 515	$ 585	$ 689	$ 960

Source: Dataquest
June 1988

Table 2d

North American Semiconductor Market
(Compound Annual Growth Rates)

	CAGR (77-82)	CAGR (82-87)	CAGR (87-92)	CAGR (92-97)	CAGR (77-87)	CAGR (87-97)
Total Semiconductor	19.4%	11.2%	13.5%	10.6%	15.2%	12.0%
Total IC	24.7%	12.8%	14.6%	11.2%	18.6%	12.9%
Bipolar Digital	20.5%	8.7%	7.1%	5.1%	14.5%	6.1%
Memory	N/A	(2.7%)	(1.0%)	(10.8%)	N/A	(6.0%)
Logic	N/A	11.4%	8.2%	6.2%	N/A	7.2%
MOS Digital	30.8%	14.0%	17.6%	12.6%	22.1%	15.1%
Memory	N/A	8.1%	20.4%	10.5%	N/A	15.4%
Micro	N/A	23.2%	14.4%	13.8%	N/A	14.1%
Logic	N/A	15.6%	17.0%	14.3%	N/A	15.6%
Linear	15.6%	14.4%	11.2%	10.0%	15.0%	10.6%
Total Discrete	5.0%	3.7%	5.8%	4.7%	4.4%	5.2%
Total Optoelectronic	19.4%	7.5%	8.2%	6.9%	13.3%	8.2%

Source: Dataquest
June 1988

Table 3a

Japanese Semiconductor Market
(Millions of Dollars)

	1976	1977	1978	1979	1980	1981
Total Semiconductor	$1,632	$1,723	$2,448	$2,768	$3,383	$4,295
Total IC	$ 787	$ 864	$1,399	$1,738	$2,201	$2,793
Bipolar Digital	$ 174	$ 190	$ 259	$ 304	$ 345	$ 438
Memory				52	57	77
Logic				252	288	361
MOS Digital	$ 306	$ 314	$ 588	$ 762	$ 991	$1,174
Memory				256	423	491
Micro				213	269	404
Logic				293	299	279
Linear	$ 307	$ 360	$ 552	$ 672	$ 865	$1,181
Total Discrete	$ 801	$ 792	$ 946	$ 889	$ 986	$1,237
Total Optoelectronic	$ 44	$ 67	$ 103	$ 141	$ 196	$ 265

Source: Dataquest
June 1988

Table 3b

Japanese Semiconductor Market
(Millions of Dollars)

	1982	1983	1984	1985	1986	1987
Total Semiconductor	$4,082	$5,722	$8,774	$8,149	$11,852	$14,329
Total IC	$2,855	$4,167	$6,517	$5,985	$ 8,879	$11,006
Bipolar Digital	$ 498	$ 706	$ 955	$ 824	$ 1,328	$ 1,491
Memory	87	109	163	136	170	183
Logic	411	597	792	688	1,158	1,308
MOS Digital	$1,263	$1,948	$3,621	$3,232	$ 4,798	$ 6,327
Memory	534	893	1,579	1,185	1,755	2,311
Micro	446	594	979	884	1,371	1,732
Logic	283	461	1,063	1,163	1,672	2,284
Linear	$1,094	$1,513	$1,941	$1,929	$ 2,753	$ 3,188
Total Discrete	$ 970	$1,217	$1,756	$ 1,621	$ 2,164	$ 2,424
Total Optoelectronic	$ 257	$ 338	$ 501	$ 543	$ 809	$ 899

Source: Dataquest
June 1988

Table 3c

Japanese Semiconductor Market
(Millions of Dollars)

	1988	1989	1990	1991	1992	1997
Total Semiconductor	$18,217	$19,845	$18,788	$21,071	$25,404	$45,300
Total IC	$14,062	$15,359	$14,487	$16,261	$19,844	$37,300
Bipolar Digital	$ 1,919	$ 2,056	$ 1,963	$ 2,230	$ 2,620	$ 4,300
Memory	215	223	213	200	170	100
Logic	1,704	1,833	1,750	2,030	2,450	4,200
MOS Digital	$ 8,296	$ 9,105	$ 8,469	$ 9,408	$11,676	$24,000
Memory	3,047	3,421	2,989	3,088	4,027	8,000
Micro	2,114	2,299	2,230	2,520	3,049	6,200
Logic	3,135	3,385	3,250	3,800	4,600	9,800
Linear	$ 3,847	$ 4,198	$ 4,055	$ 4,623	$ 5,548	$ 9,000
Total Discrete	$ 3,019	$ 3,234	$ 3,066	$ 3,403	$ 3,914	$ 5,300
Total Optoelectronic	$ 1,136	$ 1,252	$ 1,235	$ 1,407	$ 1,646	$ 2,700

Source: Dataquest
June 1988

Table 3d

Japanese Semiconductor Market
(Compound Annual Growth Rate Based on U.S. Dollars)

	CAGR (77-82)	CAGR (82-87)	CAGR (87-92)	CAGR (92-97)	CAGR (77-87)	CAGR (87-97)
Total Semiconductor	18.8%	28.5%	12.1%	12.3%	23.6%	12.2%
Total IC	27.0%	31.0%	12.5%	13.5%	29.0%	13.0%
Bipolar Digital	21.3%	24.5%	11.9%	10.4%	22.9%	11.2%
Memory	N/A	16.0%	(1.5%)	(10.1%)	N/A	(5.9%)
Logic	N/A	26.1%	13.4%	11.4%	N/A	12.4%
MOS Digital	32.1%	38.0%	13.0%	15.5%	35.0%	14.3%
Memory	N/A	34.0%	11.7%	14.7%	N/A	13.2%
Micro	N/A	31.2%	12.0%	15.3%	N/A	13.6%
Logic	N/A	51.8%	15.0%	16.3%	N/A	15.7%
Linear	24.9%	23.9%	11.7%	10.2%	24.4%	10.9%
Total Discrete	4.1%	20.1%	7.3%	6.3%	11.8%	8.1%
Total Optoelectronic	30.8%	28.5%	12.3%	10.4%	29.6%	11.6%

Source: Dataquest
June 1988

Table 4a

Japanese Semiconductor Market
(Billions of Yen)

	1976	1977	1978	1979	1980	1981
Total Semiconductor	¥483	¥463	¥514	¥607	¥768	¥949
Total IC	¥233	¥232	¥294	¥381	¥500	¥617
Bipolar Digital	¥ 52	¥ 51	¥ 54	¥ 67	¥ 78	¥ 97
Memory				11	13	17
Logic				55	65	80
MOS Digital	¥ 91	¥ 84	¥123	¥167	¥225	¥259
Memory				56	96	109
Micro				47	61	89
Logic				64	68	62
Linear	¥ 91	¥ 97	¥116	¥147	¥196	¥261
Total Discrete	¥237	¥213	¥199	¥195	¥224	¥273
Total Optoelectronic	¥ 13	¥ 18	¥ 22	¥ 31	¥ 44	¥ 59

Source: Dataquest
June 1988

Table 4b

Japanese Semiconductor Market
(Billions of Yen)

	1982	1983	1984	1985	1986	1987
Total Semiconductor	¥1,012	¥1,344	¥2,080	¥1,939	¥1,979	¥2,064
Total IC	¥ 708	¥ 979	¥1,545	¥1,424	¥1,483	¥1,585
Bipolar Digital	¥ 124	¥ 166	¥ 226	¥ 196	¥ 222	¥ 215
Memory	22	26	39	32	28	26
Logic	102	140	188	164	193	188
MOS Digital	¥ 313	¥ 458	¥ 858	¥ 769	¥ 801	¥ 911
Memory	132	210	374	282	293	333
Micro	111	140	232	210	229	249
Logic	70	108	252	277	279	329
Linear	¥ 271	¥ 356	¥ 460	¥ 459	¥ 460	¥ 459
Total Discrete	¥ 241	¥ 286	¥ 416	¥ 386	¥ 361	¥ 349
Total Optoelectronic	¥ 64	¥ 79	¥ 119	¥ 129	¥ 135	¥ 129

Source: Dataquest
June 1988

Table 4c

Japanese Semiconductor Market
(Billions of Yen)

	1988	1989	1990	1991	1992	1997
Total Semiconductor	¥2,368	¥2,580	¥2,442	¥2,739	¥3,303	¥5,889
Total IC	¥1,828	¥1,997	¥1,883	¥2,114	¥2,580	¥4,849
Bipolar Digital	¥ 249	¥ 267	¥ 255	¥ 290	¥ 341	¥ 559
Memory	28	29	28	26	22	13
Logic	222	238	228	264	319	546
MOS Digital	¥1,078	¥1,184	¥1,101	¥1,223	¥1,518	¥3,120
Memory	396	445	389	401	524	1,040
Micro	275	299	290	328	396	806
Logic	408	440	423	494	598	1,274
Linear	¥ 500	¥ 546	¥ 527	¥ 601	¥ 721	¥1,170
Total Discrete	¥ 392	¥ 420	¥ 399	¥ 442	¥ 509	¥ 689
Total Optoelectronic	¥ 148	¥ 163	¥ 161	¥ 183	¥ 214	¥ 351

Source: Dataquest
June 1988

Table 4d

Japanese Semiconductor Market
(Compound Annual Growth Rate Based on Yen)

	CAGR (77-82)	CAGR (82-87)	CAGR (87-92)	CAGR (92-97)	CAGR (77-87)	CAGR (87-97)
Total Semiconductor	16.9%	15.3%	9.9%	12.3%	16.1%	11.1%
Total IC	25.0%	17.5%	10.2%	13.5%	21.2%	11.8%
Bipolar Digital	19.3%	11.7%	9.7%	10.4%	15.4%	10.0%
Memory	N/A	4.1%	(3.5%)	(10.1%)	N/A	(6.8%)
Logic	N/A	13.1%	11.1%	11.4%	N/A	11.2%
MOS Digital	30.0%	23.8%	10.7%	15.5%	26.8%	13.1%
Memory	N/A	20.2%	9.5%	14.7%	N/A	12.1%
Micro	N/A	17.7%	9.7%	15.3%	N/A	12.4%
Logic	N/A	36.2%	12.7%	16.3%	N/A	14.5%
Linear	22.9%	11.1%	9.5%	10.2%	16.8%	9.8%
Total Discrete	2.5%	7.7%	7.3%	6.3%	5.1%	7.0%
Total Optoelectronic	28.7%	15.2%	12.3%	10.4%	21.8%	10.5%

Source: Dataquest
June 1988

Table 5a

Western European Semiconductor Market
(Millions of Dollars)

	1976	1977	1978	1979	1980	1981
Total Semiconductor	$1,594	$1,886	$2,339	$3,018	$3,686	$3,041
Total IC	$ 676	$ 904	$1,238	$1,747	$2,333	$1,892
Bipolar Digital	$ 186	$ 228	$ 291	$ 390	$ 510	$ 454
Memory				85	116	103
Logic				305	394	351
MOS Digital	$ 226	$ 352	$ 535	$ 781	$1,139	$ 882
Memory				367	543	426
Micro				125	189	149
Logic				289	407	307
Linear	$ 264	$ 324	$ 412	$ 576	$ 684	$ 556
Total Discrete	$ 851	$ 914	$1,004	$1,138	$1,192	$ 995
Total Optoelectronic	$ 67	$ 68	$ 97	$ 133	$ 161	$ 154

Source: Dataquest
June 1988

Table 5b

Western European Semiconductor Market
(Millions of Dollars)

	1982	1983	1984	1985	1986	1987
Total Semiconductor	$3,167	$3,370	$4,907	$4,839	$5,485	$6,355
Total IC	$1,988	$2,323	$3,752	$3,634	$4,041	$4,693
Bipolar Digital	$ 434	$ 483	$ 741	$ 719	$ 735	$ 725
Memory	100	107	144	150	125	85
Logic	334	376	597	569	610	640
MOS Digital	$ 948	$1,227	$2,146	$1,952	$2,280	$2,753
Memory	469	581	990	749	822	838
Micro	168	239	476	489	578	794
Logic	311	407	680	714	880	1,121
Linear	$ 606	$ 613	$ 865	$ 963	$1,026	$1,215
Total Discrete	$1,011	$ 866	$ 955	$ 981	$1,153	$1,384
Total Optoelectronic	$ 168	$ 181	$ 200	$ 224	$ 291	$ 278

Source: Dataquest
June 1988

Table 5c

Western European Semiconductor Market
(Millions of Dollars)

	1988	1989	1990	1991	1992	1997
Total Semiconductor	$7,642	$8,130	$8,325	$9,180	$10,398	$16,150
Total IC	$5,789	$6,192	$6,248	$6,982	$ 8,027	$13,250
Bipolar Digital	$ 832	$ 864	$ 865	$ 897	$ 944	$ 1,150
Memory	91	93	91	86	84	50
Logic	741	771	774	811	860	1,100
MOS Digital	$3,575	$3,910	$4,013	$4,608	$ 5,464	$10,000
Memory	1,133	1,278	1,257	1,442	1,745	3,200
Micro	1,015	1,105	1,124	1,265	1,447	2,400
Logic	1,427	1,527	1,632	1,901	2,272	4,400
Linear	$1,382	$1,418	$1,370	$1,477	$ 1,619	$ 2,100
Total Discrete	$1,531	$1,599	$1,715	$1,811	$ 1,940	$ 2,300
Total Optoelectronic	$ 322	$ 339	$ 362	$ 387	$ 431	$ 600

Source: Dataquest
June 1988

Table 5d

Western European Semiconductor Market
(Compound Annual Growth Rates)

	CAGR (77-82)	CAGR (82-87)	CAGR (87-92)	CAGR (92-97)	CAGR (77-87)	CAGR (87-97)
Total Semiconductor	10.9%	14.9%	10.3%	9.2%	12.9%	9.8%
Total IC	17.1%	18.7%	11.3%	10.5%	17.9%	10.9%
Bipolar Digital	13.7%	10.8%	5.4%	4.0%	12.3%	4.7%
Memory	N/A	(3.2%)	(0.2%)	(9.9%)	N/A	(5.2%)
Logic	N/A	13.9%	6.1%	5.0%	N/A	5.6%
MOS Digital	21.9%	23.8%	14.7%	12.8%	22.8%	13.8%
Memory	N/A	12.3%	15.8%	12.9%	N/A	14.3%
Micro	N/A	36.4%	12.8%	10.6%	N/A	11.7%
Logic	N/A	29.2%	15.2%	14.1%	N/A	14.7%
Linear	13.3%	14.9%	5.9%	5.3%	14.1%	5.6%
Total Discrete	2.0%	6.5%	4.0%	3.5%	4.2%	5.2%
Total Optoelectronic	19.8%	10.6%	6.7%	6.8%	15.1%	8.0%

Source: Dataquest
June 1988

Table 6a

Rest of World Semiconductor Market (Millions of Dollars)

	1976	1977	1978	1979	1980	1981
Total Semiconductor	$333	$483	$660	$790	$996	$963
Total IC	$134	$184	$258	$364	$450	$494
Bipolar Digital	$ 35	$ 39	$ 45	$ 79	$108	$106
Memory				2	3	3
Logic				77	105	103
MOS Digital	$ 67	$ 88	$110	$100	$143	$171
Memory				25	34	51
Micro				17	27	43
Logic				58	82	77
Linear	$ 32	$ 57	$103	$185	$199	$217
Total Discrete	$171	$257	$346	$334	$436	$375
Total Optoelectronic	$ 28	$ 42	$ 56	$ 92	$110	$ 94

Source: Dataquest
June 1988

Table 6b

Rest of World Semiconductor Market
(Millions of Dollars)

	1982	1983	1984	1985	1986	1987
Total Semiconductor	$1,042	$1,443	$2,216	$1,949	$2,365	$3,945
Total IC	$ 585	$ 909	$1,328	$1,179	$1,726	$2,978
Bipolar Digital	$ 113	$ 162	$ 257	$ 203	$ 256	$ 384
Memory	4	14	26	15	12	18
Logic	109	148	231	188	244	366
MOS Digital	$ 248	$ 450	$ 700	$ 616	$ 887	$1,580
Memory	106	194	234	134	244	523
Micro	63	112	145	117	244	476
Logic	79	144	321	365	399	581
Linear	$ 224	$ 297	$ 371	$ 360	$ 583	$1,014
Total Discrete	$ 365	$ 429	$ 773	$ 679	$ 553	$ 862
Total Optoelectronic	$ 92	$ 105	$ 115	$ 91	$ 86	$ 105

Source: Dataquest
June 1988

Table 6c

Rest of World Semiconductor Market
(Millions of Dollars)

	1988	1989	1990	1991	1992	1997
Total Semiconductor	$5,469	$6,643	$7,097	$8,908	$11,376	$22,310
Total IC	$4,273	$5,356	$5,758	$7,355	$ 9,570	$19,560
Bipolar Digital	$ 511	$ 606	$ 658	$ 837	$ 1,084	$ 1,560
Memory	18	19	18	17	15	10
Logic	493	587	640	820	1,069	1,550
MOS Digital	$2,326	$3,020	$3,145	$4,023	$ 5,245	$11,000
Memory	863	1,163	1,222	1,510	1,900	4,000
Micro	676	839	874	1,067	1,328	2,600
Logic	787	1,018	1,049	1,446	2,017	4,400
Linear	$1,436	$1,730	$1,955	$2,495	$ 3,241	$ 7,000
Total Discrete	$1,062	$1,153	$1,190	$1,372	$ 1,583	$ 2,400
Total Optoelectronic	$ 134	$ 134	$ 149	$ 181	$ 223	$ 350

Source: Dataquest
June 1988

Table 6d

Rest of World Semiconductor Market
(Compound Annual Growth Rates)

	CAGR (77-82)	CAGR (82-87)	CAGR (87-92)	CAGR (92-97)	CAGR (77-87)	CAGR (87-97)
Total Semiconductor	16.6%	30.5%	23.6%	14.4%	23.4%	18.9%
Total IC	26.0%	38.5%	26.3%	15.4%	32.1%	20.7%
Bipolar Digital	23.7%	27.7%	23.1%	7.6%	25.7%	15.0%
Memory	N/A	35.1%	(3.6%)	(7.8%)	N/A	(5.7%)
Logic	N/A	27.4%	23.9%	7.7%	N/A	15.5%
MOS Digital	23.0%	44.8%	27.1%	16.0%	33.5%	21.4%
Memory	N/A	37.6%	29.4%	16.1%	N/A	22.6%
Micro	N/A	49.8%	22.8%	14.4%	N/A	18.5%
Logic	N/A	49.0%	28.3%	16.9%	N/A	22.4%
Linear	31.5%	35.3%	26.2%	16.6%	33.4%	21.3%
Total Discrete	7.3%	18.8%	9.7%	8.7%	12.9%	10.8%
Total Optoelectronic	17.0%	2.7%	11.4%	9.4%	9.6%	12.8%

Source: Dataquest
June 1988

Table 7a

Worldwide Average Selling Prices
(Dollars)

	1976	1977	1978	1979	1980	1981
Total Semiconductor	$0.29	$0.28	$0.28	$0.29	$0.33	$0.31
Total IC	$1.00	$1.02	$1.01	$0.97	$1.07	$1.02
Bipolar Digital	$0.61	$0.66	$0.63	$0.57	$0.70	$0.70
Memory						
Logic						
MOS Digital	$2.39	$2.06	$1.91	$1.93	$1.81	$1.66
Memory				5.15	4.90	3.17
Micro				3.96	3.61	3.40
Logic				0.89	0.85	0.86
Linear	$0.85	$0.83	$0.84	$0.78	$0.83	$0.81
Total Discrete	$0.15	$0.14	$0.13	$0.12	$0.12	$0.11
Total Optoelectronic	$0.67	$0.45	$0.47	$0.51	$0.44	$0.39

Source: Dataquest
June 1988

Table 7b

Worldwide Average Selling Prices
(Dollars)

	1982	1983	1984	1985	1986	1987
Total Semiconductor	$0.34	$0.33	$0.37	$0.34	$0.36	$0.38
Total IC	$1.01	$1.04	$1.11	$1.06	$1.12	$1.19
Bipolar Digital	$0.62	$0.65	$0.65	$0.71	$0.71	$0.69
Memory						
Logic						
MOS Digital	$1.71	$1.73	$2.01	$1.69	$1.73	$1.97
Memory	3.06	3.21	3.90	2.59	2.45	2.91
Micro	3.34	3.40	4.41	3.91	3.90	4.30
Logic	0.80	0.79	0.85	0.93	0.99	1.12
Linear	$0.79	$0.76	$0.75	$0.76	$0.84	$0.82
Total Discrete	$0.11	$0.09	$0.09	$0.09	$0.09	$0.09
Total Optoelectronic	$0.38	$0.37	$0.36	$0.33	$0.36	$0.34

Source: Dataquest
June 1988

Table 7c

Worldwide Average Selling Prices
(Dollars)

	1988	1989	1990	1991	1992	1997
Total Semiconductor	$0.43	$0.42	$0.43	$0.46	$0.49	$0.60
Total IC	$1.26	$1.25	$1.28	$1.34	$1.33	$1.63
Bipolar Digital	$0.70	$0.70	$0.73	$0.76	$0.78	$0.85
Memory						
Logic						
MOS Digital	$2.11	$2.05	$2.08	$2.22	$2.05	$2.74
Memory	3.15	2.90	3.05	3.10	3.30	3.80
Micro	4.46	4.15	4.15	4.35	4.85	4.50
Logic	1.20	1.20	1.22	1.36	1.43	1.80
Linear	$0.82	$0.81	$0.83	$0.85	$0.86	$0.90
Total Discrete	$0.10	$0.10	$0.10	$0.10	$0.10	$0.10
Total Optoelectronic	$0.33	$0.31	$0.32	$0.34	$0.35	$0.37

Source: Dataquest
June 1988

Table 7d

Worldwide Average Selling Prices
(Compound Annual Growth Rates Based on U.S. Dollars)

	CAGR (77-82)	CAGR (82-87)	CAGR (87-92)	CAGR (92-97)	CAGR (77-87)	CAGR (87-97)
Total Semiconductor	4.0%	2.5%	5.2%	4.2%	3.2%	4.7%
Total IC	(0.1%)	3.4%	2.2%	4.1%	1.6%	3.2%
Bipolar Digital	(1.2%)	2.2%	2.5%	1.7%	0.4%	2.1%
Memory	N/A	N/A	N/A	N/A	N/A	N/A
Logic	N/A	N/A	N/A	N/A	N/A	N/A
MOS Digital	(3.7%)	3.0%	0.7%	6.0%	(0.4%)	3.3%
Memory	N/A	(1.0%)	2.5%	2.9%	N/A	2.7%
Micro	N/A	5.2%	2.4%	(1.5%)	N/A	0.5%
Logic	N/A	7.0%	5.0%	4.7%	N/A	4.9%
Linear	(1.0%)	0.7%	1.0%	0.9%	(0.1%)	0.9%
Total Discrete	(4.7%)	(3.5%)	2.5%	(0.8%)	(4.1%)	0.8%
Total Optoelectronic	(3.3%)	(2.2%)	0.6%	1.1%	(2.8%)	0.8%

Source: Dataquest
June 1988

Table 8a

Worldwide Semiconductor Market
(Millions of Units)

	1976	1977	1978	1979	1980	1981
Total Semiconductor	$20,929	$25,110	$31,461	$37,703	$42,870	$48,081
Total IC	$ 3,093	$ 3,703	$ 5,171	$ 7,242	$ 8,955	$ 9,809
Bipolar Digital	$ 1,418	$ 1,506	$ 2,002	$ 2,937	$ 3,391	$ 3,339
Memory						
Logic						
MOS Digital	$ 518	$ 769	$ 1,221	$ 1,731	$ 2,603	$ 2,906
Memory				325	455	655
Micro				137	239	319
Logic				1,269	1,909	1,933
Linear	$ 1,156	$ 1,428	$ 1,949	$ 2,574	$ 2,960	$ 3,564
Total Discrete	$17,413	$20,736	$25,392	$29,350	$32,358	$36,227
Total Optoelectronic	$ 422	$ 671	$ 898	$ 1,111	$ 1,557	$ 2,045

Source: Dataquest
June 1988

Table 8b

Worldwide Semiconductor Market
(Millions of Units)

	1982	1983	1984	1985	1986	1987
Total Semiconductor	$45,195	$59,717	$79,180	$71,961	$81,667	$95,551
Total IC	$10,791	$14,144	$20,390	$17,435	$20,462	$24,063
Bipolar Digital	$ 3,890	$ 4,638	$ 7,340	$ 5,172	$ 6,069	$ 6,771
Memory						
Logic						
MOS Digital	$ 3,306	$ 4,593	$ 6,456	$ 5,999	$ 7,208	$ 8,502
Memory	883	1,159	1,597	1,475	1,899	2,068
Micro	395	582	733	703	892	1,121
Logic	2,029	2,852	4,126	3,820	4,417	5,313
Linear	$ 3,595	$ 4,913	$ 6,593	$ 6,264	$ 7,186	$ 8,790
Total Discrete	$32,245	$42,944	$55,411	$50,844	$56,761	$66,435
Total Optoelectronic	$ 2,159	$ 2,629	$ 3,379	$ 3,682	$ 4,444	$ 5,053

Source: Dataquest
June 1988

Table 8c

Worldwide Semiconductor Market
(Millions of Units)

	1988	1989	1990	1991	1992	1997
Total Semiconductor	$107,337	$118,334	$115,785	$123,802	$141,395	$200,252
Total IC	$ 29,158	$ 32,287	$ 31,036	$ 34,518	$ 43,038	$ 63,793
Bipolar Digital	$ 7,901	$ 8,430	$ 7,851	$ 8,542	$ 9,708	$ 12,659
Memory						
Logic						
MOS Digital	$ 10,703	$ 12,218	$ 11,679	$ 12,870	$ 17,688	$ 25,579
Memory	2,707	3,304	2,940	3,331	3,823	6,579
Micro	1,380	1,625	1,591	1,780	2,480	4,000
Logic	6,616	7,289	7,148	7,759	11,385	$ 15,000
Linear	$ 10,554	$ 11,638	$ 11,506	$ 13,106	$ 15,642	$ 25,556
Total Discrete	$ 71,850	$ 78,885	$ 77,684	$ 81,755	$ 89,817	$124,000
Total Optoelectronic	$ 6,329	$ 7,161	$ 7,066	$ 7,529	$ 8,540	$ 12,459

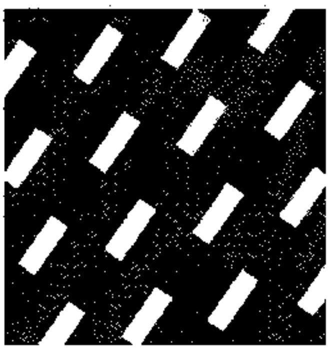
Source: Dataquest
June 1988

Table 8d

Worldwide Semiconductor Market
(Compound Annual Growth Rates Based on Millions of Units)

	CAGR (77-82)	CAGR (82-87)	CAGR (87-92)	CAGR (92-97)	CAGR (77-87)	CAGR (87-97)
Total Semiconductor	12.5%	16.2%	8.2%	7.2%	14.3%	7.7%
Total IC	23.9%	17.4%	12.3%	8.2%	20.6%	10.2%
Bipolar Digital	20.9%	11.7%	7.5%	5.5%	16.2%	6.5%
Memory	N/A	N/A	N/A	N/A	N/A	N/A
Logic	N/A	N/A	N/A	N/A	N/A	N/A
MOS Digital	33.9%	20.8%	15.8%	7.7%	27.2%	11.6%
Memory	N/A	18.6%	13.1%	11.5%	N/A	12.3%
Micro	N/A	23.2%	17.2%	10.0%	N/A	13.6%
Logic	N/A	21.2%	16.5%	5.7%	N/A	10.9%
Linear	20.3%	19.6%	12.2%	10.3%	19.9%	11.3%
Total Discrete	9.2%	15.6%	6.2%	6.7%	12.3%	6.4%
Total Optoelectronic	26.3%	18.5%	11.1%	7.8%	22.4%	9.4%

Source: Dataquest
June 1988



Economic Outlook 1988–1989

Dataquest

a company of
The Dun & Bradstreet Corporation

Published by Dataquest Incorporated

Executive Preface

Why You Should Take an Hour to Read This Report

We are entering an era of global markets. The electronics industry is a primary force in the creation of this era, and this is the same industry that stands to profit the most from it. Successful businesspeople in this era will add two new skills to the traditional set:

- They will understand the appropriate uses of technology in their field.
- They will anticipate opportunities and competitive moves on an international basis.

Every business and every individual will be influenced by global economic events, willingly or not. Some effects will be more obvious or dynamic than others. Regardless of whether the decision is where to design system software or where to open the next sales office, an understanding of economic factors is fundamental to the specific business skills needed for success.

This report is written for Dataquest clients. About 60 percent of the material concerns the United States, and 40 percent relates to major U.S. trading partners and markets. The report summarizes events leading to the current position of the United States in the world economy. For the future, economic trends and forces are described that will directly affect both global and domestic markets for electronics industry products in 1988-1989.

The most significant forecasts in this document are as follows:

- United States real economic growth in 1988 will be similar to 1987 at 2.8 percent; but 1989 will be slower, particularly in the second half. Consumer and government spending will continue to weaken, but export trade growth will compensate for a large part of these declines.
- 1989 federal tax increases and congressional legislation will have little real effect in reducing the federal budget deficit.
- Structural shifts in the United States economy will tend to stabilize wage and employment rates. The largest contribution to inflation in the United States will come in the form of consumer spending for imported goods.
- The focus of international trade for the United States will sharpen on the Pacific region, which accounts for 60 percent of its trade deficit and only 20 percent of its export markets.
- The most positive domestic prospects for 1988-1989 among major U.S. trading partners belong to Japan, Canada, the United Kingdom, and Italy.

Much of the macroeconomic data presented in this report is used by Dataquest analysts to put together specific industry market forecasts. As informed Dataquest clients, your understanding of this material will enhance the information value of every Dataquest service.

Contents

Introduction

As the end of the 1980s approaches, a new economic era is dawning. Global markets are becoming a reality, with electronics, steel, and automotive products leading the way and providing new opportunities on an unprecedented scale. Yet these developments are also making the economic relationships between nations, industries, and markets increasingly complex. As a result, there is a rapidly growing need for accurate insights and sources of information to improve marketing, planning, and decision-making within the electronic industry.

Change is rarely painless, since it requires doing things differently from the way they were done in the past. In particular, the structural economic changes of the 1980s are increasingly forcing analysts and managers to focus their research more on current conditions, since historical trends have become less meaningful. Evidence of this can be clearly seen in the daily newspapers. The most closely watched indicators of economic activity today are the dollar exchange rates, interest rates, international stock and commodity markets, and consumer spending and sentiment. The one characteristic these variables all share is their short-term volatility.

Given this constantly changing environment, one way to achieve a clearer U.S. perspective is to focus on the realities of the marketplace as viewed by the actual participants—businesspeople in large and small companies across the country. Dun & Bradstreet, Dataquest's parent company, makes important contributions toward understanding current trends with its quarterly surveys of business expectations.

For example, D&B post-stock market crash surveys of sales expectations for 1988 showed levels of optimism equal to the high levels of 1985 through 1987. In another D&B post-crash survey of corporate buyers, roughly 75 percent of the respondents said that their capital spending plans were not affected by the October stock market slump. A third year-end survey of 1,500 plant managers showed an immediate but small reduction in 1988 production plans.

In formulating Dataquest forecasts, we utilize many of the D&B business surveys. The perceptions of Main Street are substantially more important than those of Wall Street. Given the insights provided in part by these survey results, our economic forecast for 1988 of 2.8 percent growth expected in the inflation-adjusted gross national product (GNP) reflects a pace of activity that is similar to 1987. Looking further ahead, we expect U.S. economic growth in 1989 to be about 2.2 percent, with the first half of the year showing more strength than the second half.

Growth in 1988 will be driven by significantly different factors from those of recent years. A brief overview of these factors and the circumstances leading to their emergence is presented in the next section. For reference, key economic statistics appear later in this document.

The 1980s in Review

To a great degree, the economic events of 1987 represent the culmination of a number of trends that have been developing throughout this decade.

Inflation was undoubtedly the most dominant issue in terms of shaping the U.S. economy in the early 1980s. Oil prices and high wages forced double-digit increases in the consumer price index in the beginning of the decade, reflecting problems created in the late 1970s. High real and nominal interest rates were exacerbated by a large dose of Federal Reserve tightening, which sharply limited the supply of loanable funds in the economy. The recessions in 1980 and 1982 were the price that was paid to end this wage-price spiral.

During the early 1980s, three key events occurred that played major roles in shaping today's economic environment:

- First, President Reagan's massive individual tax cuts took effect. The average tax rate on taxable personal income fell from 13.2 percent in 1981 to 11.1 percent in 1984. With only a minor slowdown in federal spending, the federal budget deficit, which had been almost nil in 1979, exploded to 5.2 percent of GNP in 1983 and now hovers in the 3.4 percent range.

- Second, the pattern of financial deregulation that started in the late 1970s began to influence money and equity markets in significant ways. New financial institutions and instruments began to offer individuals and firms a wide range of competitive investment choices.
- Third, technology began to have a profound impact on business information processing and communication during this period. Through the application of information technology, financial institutions expanded through the scope and sophistication of their analyses to interpret and evaluate vast amounts of macroeconomic and microeconomic data. Stock markets began to react in unison to global economic events. The more aggressive businesses began to apply technology to sharpen their control of "mission-critical" sales, manufacturing, and customer service activities.

The tax cuts served as the starting gun that set the U.S. economic expansion off and running. America rapidly emerged as the engine of economic growth for the industrialized world. The United States, with its relatively high interest rates, strong domestic markets, and sophisticated financial infrastructure, became a magnet for foreign investors. As a result, the dollar exchange rate soared and prices of imported goods in the United States fell.

In response, U.S. consumers flexed their increased disposable income muscles, courtesy of the Reagan tax cuts, and voraciously bought these low-priced imported goods. Unfortunately, this was not what was intended. The tax cuts were designed to stimulate the U.S. economy by increasing disposable income and, hence, demand for *domestically* produced goods. However, consumers found better value in imports, and the dollars flowed both into the U.S. economy and abroad. At the same time, savings as a percentage of disposable income fell from 7.5 percent in 1981 to about 3.6 percent in 1987, due to new and convenient ways to borrow. By comparison, the Japanese savings rate is 17.5 percent, and most Europeans average about 14.0 percent.

In capital markets, savings must necessarily match investment. Given the shortage of domestic savings and an excess demand for capital by both consumers and government, foreign capital filled the void. In September 1985, this instability was formally recognized by the finance ministers of the G-7 industrialized countries (Canada, Germany, the United Kingdom, France, Italy, Japan, and the United States), and efforts were initiated to systematically devalue the dollar.

The goals of the devaluation were to discourage U.S. consumption of imports by raising imported prices, and to make U.S.-produced goods more competitive abroad.

This devaluation has succeeded in stimulating U.S. exports. In terms of volume, the U.S. trade deficit has started to improve slightly, but a turnaround has yet to occur in terms of current dollars, because import price increases have compensated for the decline in demand. Meanwhile, U.S. export prices have been flat, indicating that current export markets are both highly competitive and somewhat weak. U.S. exports on a constant-dollar basis increased 17.5 percent in 1987, while imports were up only 3.1 percent. Which U.S. industries led the export surge? Many of the same ones that had suffered earlier—textiles, paper, and agricultural products. Others are also the most visible beneficiaries of American productivity and quality improvements—metals, chemicals, aircraft, machinery, instruments, and computer equipment.

However, the earlier import wave has left the United States in 1988 in the position of a debtor nation after 50 years of creditor status. American assets owned by foreigners exceed the value of foreign assets owned by Americans.

Other factors make a shift in the U.S. balance of trade an uphill battle. For example, goods from newly industrialized countries (NICs), such as Taiwan and South Korea, are increasingly being substituted for other import sources, such as Japan. The dollar has fallen relatively little against the currencies of many of these countries. In other cases, such as Mexico, the dollar has appreciated. As a result, NIC products are still a bargain when priced in dollars. So, while the mix of trading partners has changed, the U.S. trade deficit has not yet been substantially reduced. The Japanese have held onto a major piece of the action by setting up plants in Taiwan and Singapore, for example, and by building their products with low-cost components from these countries.

In recognition of this shift in manufacturing sources, the United States has increased pressure on NICs to revalue their currencies. However, NIC revaluations constitute a two-edged sword. Although imports would indeed become more costly in the United States, many of the current international sources of inexpensive goods and labor would also be eliminated. The result would be increased inflationary pressures on the U.S. economy.

To summarize, the 1980s to date have been characterized by consumption-driven growth of the U.S. GNP. Though trade improvements contributed to final demand early in the decade, by 1983 the swelling trade deficit began to have a negative impact on U.S. economic growth, an impact that was overshadowed only by the exuberant levels of consumer spending. Nevertheless, the current expansion is now 64 months old and continuing, the second longest expansion in the post-war period.

Figure 1 shows the shift in factors that contribute to U.S. economic growth. This illustration clearly shows that growth in the mid-1980s was exceptional, despite the tremendous drag from the trade deficit. The Dun & Bradstreet forecast for 1988-1989 has real GNP growing annually at a lower rate compared with the initial phases of the current expansion. Consumption growth also is expected to be lower in the years ahead, but will remain on par with growth in the '60s and '70s. Meanwhile, contributions to GNP from improvements in trade will help to offset a large part of this reduction in consumer-spending growth.

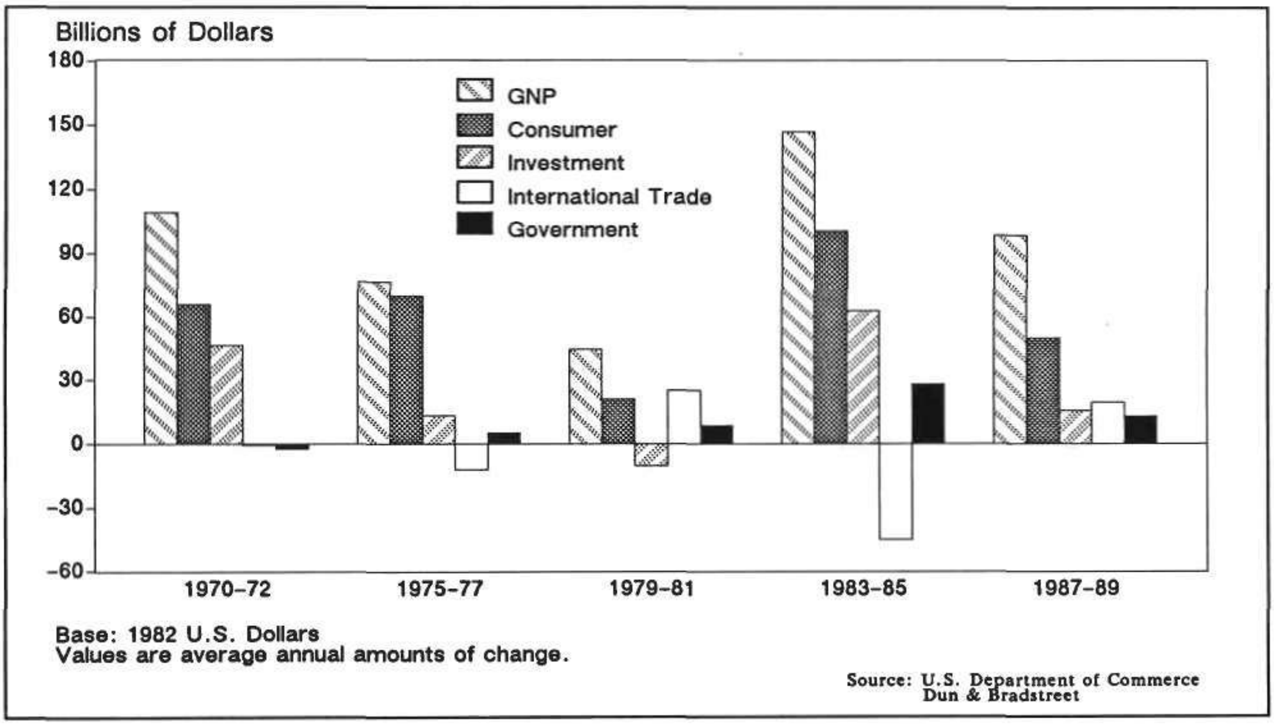


Figure 1. Components of U.S. Real GNP Growth

Key Factors in the U.S. Economy of the 1990s

The key issues for the future are the trade and federal budget deficits, and the steps that will be taken to reduce them. Reducing the federal deficit will, in the long run, reduce U.S. demand for capital, thereby relieving upward pressure on interest rates. However, for the near term, measures to reduce the federal deficit will hurt industries and individuals directly dependent upon the federal government.

Cutting the trade deficit will be more difficult. Basically, the deficit can be reduced by increasing exports or decreasing imports, with export growth having far more beneficial side effects. Currently, 90 percent of all American manufacturers concentrate exclusively on the domestic market. To enlarge their horizons and expand exports, of course, it is essential for U.S. manufacturers to develop export markets. Overseas market development requires development of the fundamental skills, with an international accent:

- Thorough market research
- Products designed with the features to appeal to those markets
- Professional sales and service organizations
- The capability of delivering those products on time at the right price

U.S. manufacturers can hope to be the beneficiaries of any further erosion of the dollar's value, or they can pursue a more aggressive strategy of improving their industrial productivity, and so reduce unit costs.

Productivity gains require that capital spending must increase, and that other input costs, such as labor and scrapped material, must decrease as a percentage of the total. Federal policies must be put into place to stimulate investment and induce individuals to save rather than to spend. This is crucial if the United States is to increase domestic sources of investment funds. In addition, some of this reduced consumption would inevitably lower the volume of imported goods, further helping the trade deficit. The forecast is for very modest increases in personal savings rates, from a 1987 level of 3.7 percent of disposable income to about 4.0 percent in 1988-1989.

To the extent that U.S. domestic spending is curtailed, many production-oriented businesses must find growth opportunities outside the United States. There are many emerging opportunities in Asia, Europe, and the Americas, but U.S. companies will have to adapt their products and sales strategies to compete effectively outside the familiar domestic arena.

Demographic shifts will also occur in the '90s as they have in each decade in the postwar period. Household formation will slacken as baby-boomers reach their thirties and forties. The demand for starter housing will ebb, being replaced by a market for step-up homes. Dual income households will increasingly dominate spending trends, especially for upscale consumer items and time-saving services.

Capital investments in manufacturing automation will continue to be extended and upgraded. The shakeout of firms that have not chosen—or cannot afford—to improve productivity and quality by modernizing will continue in a bigger way. Dispersal and subcontracting of production, where smaller firms produce components for larger firms, will increase. Thus, the current trend in which new small businesses provide much of the employment growth will continue.

Dataquest's View of the U.S. Economy

In recent years, most economic analysts have compiled rather poor records in forecasting important economic developments. All a good economist can do is to assimilate as much information as possible, and interpret it with the maximum amount of skill. However, the major structural changes occurring in the U.S. economy in conjunction with international events make it difficult to foresee major developments and dangerous to rely too much on historical patterns. Dataquest expects the U.S. economy to continue its evolution in ways that bear little resemblance to the past. Hence, analyses of historical relationships are of limited value.

Under these conditions, information directly from business decision makers and major participants in the economic system is especially valuable. It is important to grasp how business people perceive the environment and to recognize how the status of their order books directly affects their business plans.

For example, a Dun's 5000 survey at the end of 1987 asked businesses whether the October decline in the stock market and the subsequent turmoil in the capital markets affected their 1988 capital spending plans. Capital spending is a good proxy for the general health of the economy. Firms invest when they wish to increase capacity or enhance productivity, and both situations require confidence in future economic conditions.

About 75 percent of the respondents said their capital spending plans for 1988 were not affected by the October 1987 crash. The remaining respondents were unsure or said their spending plans were negatively impacted. The responses were uniform across most industries and firm sizes. The two exceptions were among the smallest firms (1 to 19 employees) and among construction companies, for reasons one might expect. Small firms typically pull back during periods of uncertainty to avoid risking their limited financial resources, and construction firms routinely turn pessimistic when interest rates appear to be heading upward. Both types of companies are the most flexible about spending plans and become conservative during periods of economic uncertainty.

The quarterly Dun & Bradstreet Business Expectations survey (See Figure 2), querying about 1,400 business people, asked executives

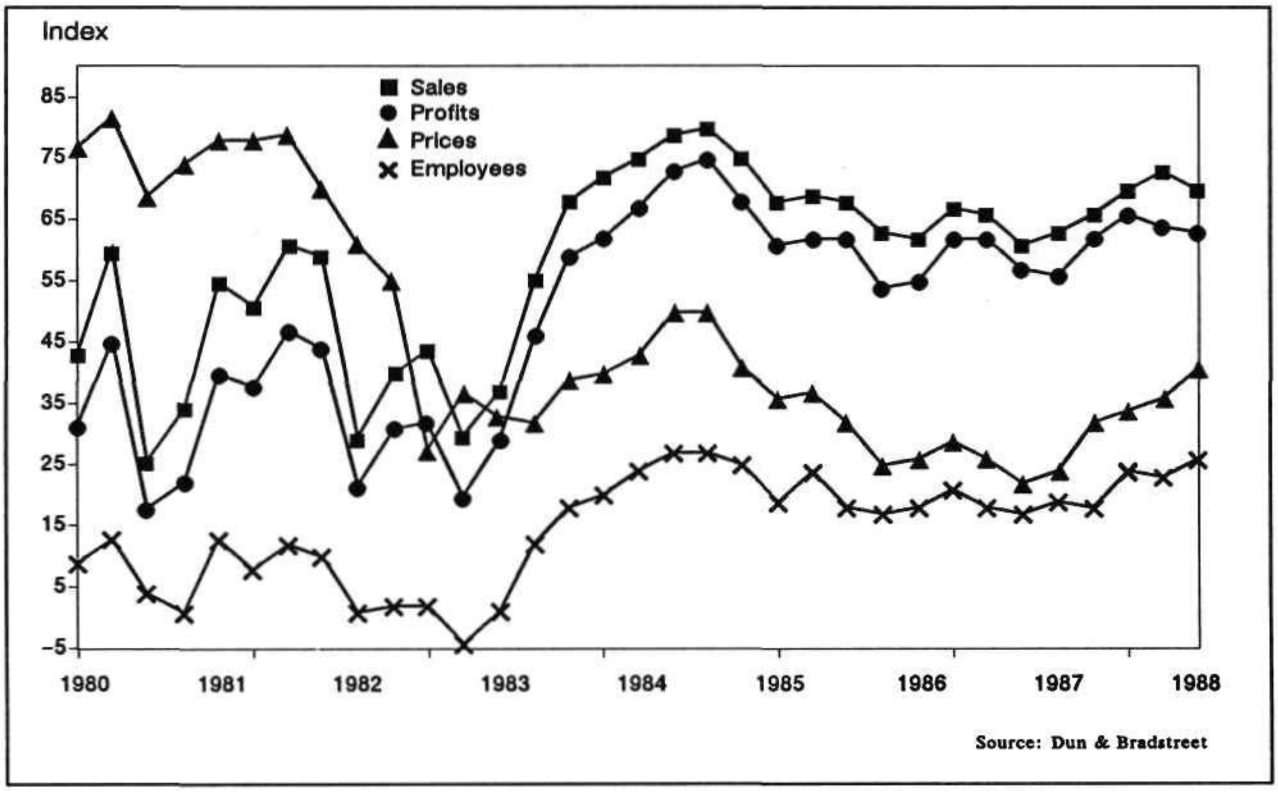


Figure 2. Dun & Bradstreet Business Expectations Survey

about their outlook for their businesses in the first quarter of 1988. The results showed that the outlook for sales and profits was down only slightly compared with their expectations for the fourth quarter of 1987, measured prior to the crash. What is more remarkable is that hiring plans for the first quarter of 1988 actually increased compared with plans in the fourth quarter of 1987.

The survey also showed an increase in the number of executives anticipating price increases in the beginning of 1988. Several inferences may be made from this. First, prices usually increase during periods of economic strength, not weakness, so comparatively few of the respondents expect a recession soon. Second, these anticipated price increases could be related to expectations of a continued decline in the dollar or concerns over an expansionary trend in monetary policy, both of which could increase inflation down the road. Lastly, given the recent rise in prices of many imported goods, some firms will seek to exploit this reduced competition by raising their own prices.

Dun & Bradstreet's statistical series on business starts and failures are two other key sources of insight into U.S. economic trends. Regional and industry breakdowns provide information on the business environment that is not easily available from other sources.

Business starts through November 1987 decreased 7.6 percent compared with the same period in 1986. Despite this decline, the overall level remains high, given that the current economic expansion is more than five years old. Stronger regions include the Northeast and the Pacific Coast, both of which have been strong for some time. The Midwest, with its large industrial sector, is benefiting from the surge in exports and is an emerging area of strength.

D&B data on business failures shows that the growth in bankruptcies, which had continued unabated for eight years, finally leveled off in 1987. Similar to business starts, the decrease in failures occurred in all industry sectors except agriculture and services. The increase in agriculture failures was related to tax law changes and the introduction of Chapter 12 reorganization for farmers, giving them the opportunity to reorganize rather than liquidate. Business failures in the service sector of the economy reflect the entrepreneurial quality of growth in the past few years. Overall, we conclude that the business sector is healthy and optimistic about prospects for 1988. We now will examine the factors that have shaped this outlook.

Factors Affecting the Economic Environment in 1988-1989

As noted earlier, the outlook for 1988 is for continued moderate growth of 2.8 percent. However, this growth will come more from improvements in trade and capital spending than from consumers. Consumer spending will be as weak this year as it was in 1987, while government spending growth will be impeded somewhat by Gramm-Rudman-Hollings expenditure cuts.

Nineteen eighty-nine growth will be a bit weaker than 1988, with the first half of 1989 stronger than the second half. Trade gains will be waning and higher interest rates will inhibit capital purchases later in the year. Consumer and government spending will remain weak. While 1989 will not be a recessionary year, the absence of any sparkling growth sectors will hold GNP expansion to about 2.2 percent in 1989.

Figure 3 shows the quarterly pattern of growth during 1986-1987. Two measures of growth are illustrated: real GNP and real final sales to domestic purchasers. Real GNP is the total of all goods and services produced in the economy. GNP includes items produced but not sold in this country. In contrast, final sales to domestic purchasers excludes unsold inventory and exports to foreign markets, while including imported goods in the total.

While GNP measures all economic activity, final sales to domestic purchasers measures only the portion of GNP that is actually spent within the

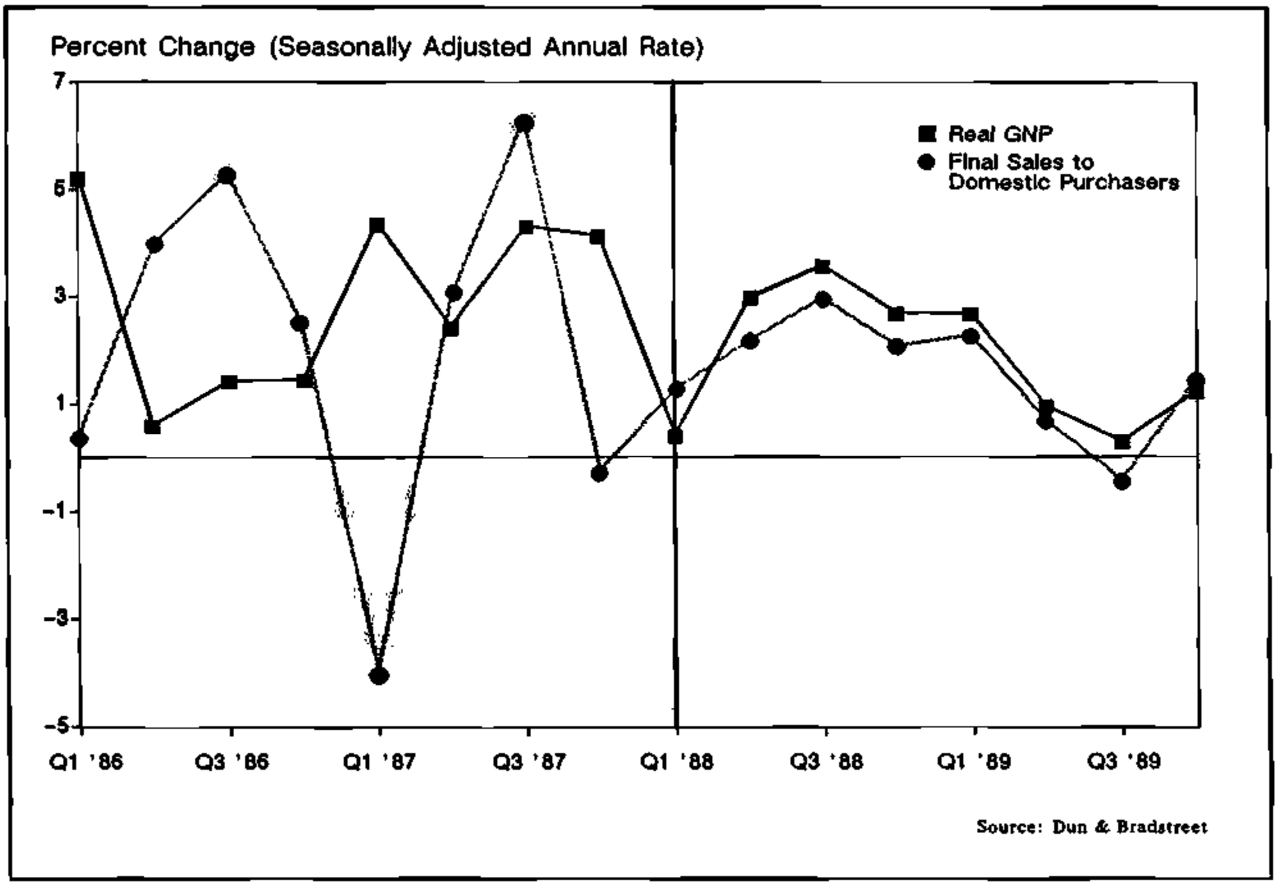


Figure 3. Forecast of U.S. Economic Growth (Seasonally Adjusted)

United States. The higher final sales measure in 1986 indicates that GNP was reduced by a degradation of the real trade balance. That is, the volume of imports into the United States exceeded the volume of exports.

The wide discrepancies between the two measures in several quarters are caused by massive inventory swings, particularly for consumer electronics, apparel, and automobiles, toward the end of 1987. When a car is built but not sold, it counts as part of GNP but not as part of final sales. The carmakers' incentive programs in the third quarters of 1986 and 1987 increased car purchases and, hence, final sales. But these cars were built earlier in each year, particularly in the first quarters, adding to GNP at that time. The important fact is that both measures of output should be used to properly gauge the direction of the economy.

The Trade Deficit and the Dollar

The trade deficit and the dollar will be among the most closely watched indicators in the next two years. Since last year's stock market plunge, the trade-weighted value of the dollar has fallen by an additional 10 percent, in addition to the more than 40 percent it had already dropped from its peak in March 1985. The dollar value now is about the same as in the fourth quarter of 1980. This stimulated export sales of price-sensitive U.S. goods and commodities, such as chemicals, lumber, and pharmaceuticals, then broadened into more durable goods and equipment.

It is important to remember that what happens in the United States as a result of a lower dollar occurs in reverse in the countries against whose currencies the dollar falls. A lower dollar means eventual improvements in the U.S. trade balance, but leads to trade deterioration abroad. In addition, a lower dollar leads to increases in domestic inflation and interest rates. Countries whose currencies have appreciated against the dollar experience deflationary effects from cheaper imports. These countries can also reduce their interest rates because of the lower inflation.

Typically, these inflation and interest rate hikes that follow a drop in the dollar take place only after a period of several months to two years. In other words, the aftershocks of recent falls in the dollar will probably occur after the 1988 election.

In the meantime, the Federal Reserve System can either support the dollar or fix interest rates at some antirecessionary level. These objectives are contradictory because interest rates are used as a tool to attract foreign funds into this country, ultimately affecting the dollar exchange rates. Immediately after the stock market crash, the Federal Reserve Board allowed the dollar to drop, preferring to encourage lower interest rates to ward off adverse effects of the crash. In pursuing this policy, bank reserves were increased to make certain that the stock market crash did not result in a liquidity crunch.

Because of the dichotomous monetary policy goals of the Federal Reserve Board, Dataquest assumes the Fed will walk a tightrope, trying its best to avoid a recession while also attempting to achieve stable dollar exchange rates. As a result, the best the Fed can do is to achieve partial success on both fronts. Interest rates will slowly edge upward, while the dollar will continue to decline, albeit at a much slower pace, bottoming out in the second half of 1989.

This policy can succeed only with international support and coordination. If other countries such as Japan or West Germany reduce their interest rates, this also reduces upward pressure on U.S. interest rates. This eases the Fed's balancing act. Such economic stimulation from abroad can help solve the U.S. trade imbalance by increasing worldwide demand. The key point, however, is that U.S. producers *must* capture the lion's share of any new demand. The current U.S. share of world markets is about 13 percent. To eliminate the U.S. trade deficit solely by increasing exports would require this share to double. Some U.S. import restrictions would seem to be inevitable.

On the import side, the dollar's 50 percent drop over the last three years will eventually channel U.S. demand away from imports and toward domestic goods as the price advantages of U.S. producers become more pronounced. Figure 4 illustrates a forecast of 7.9 percent and 8.6 percent increases in the average prices of imported goods in 1988 and 1989, stemming from continued erosion in dollar exchange rates. Government policies that encourage increased levels of saving and investment can go far to reduce import demand.

Clearly, many economic and political events have to occur to achieve improvements in the U.S. balance of trade. However, U.S. businesses must take upon themselves the responsibility for changes to their own internal cultures and attitudes in order to be successful internationally. Attention and effort must be directed toward selling a higher percentage of U.S. production abroad rather than domestically, even in circumstances when demand in the U.S. market is strong. American industry would do well to follow the example of U.S. computer and semiconductor manufacturers, and seek ways to pool commercial R&D resources in cooperative efforts to perfect manufacturing technology and regain a competitive edge.

The free trade agreement signed January 2 by President Reagan and Prime Minister Mulroney is intended to gradually phase out all trade barriers and investment restrictions between the United States and Canada, the world's largest trading relationship. The agreement is currently being converted to legislation for review and ratification by Congress and the Canadian Parliament. Although some industries and regions on both sides of the border will have to make adjustments, the agreement has a 10-year implementation period for that purpose. The net result will be significant bilateral market development, particularly for Canadian lumber and apparel and U.S. investors.

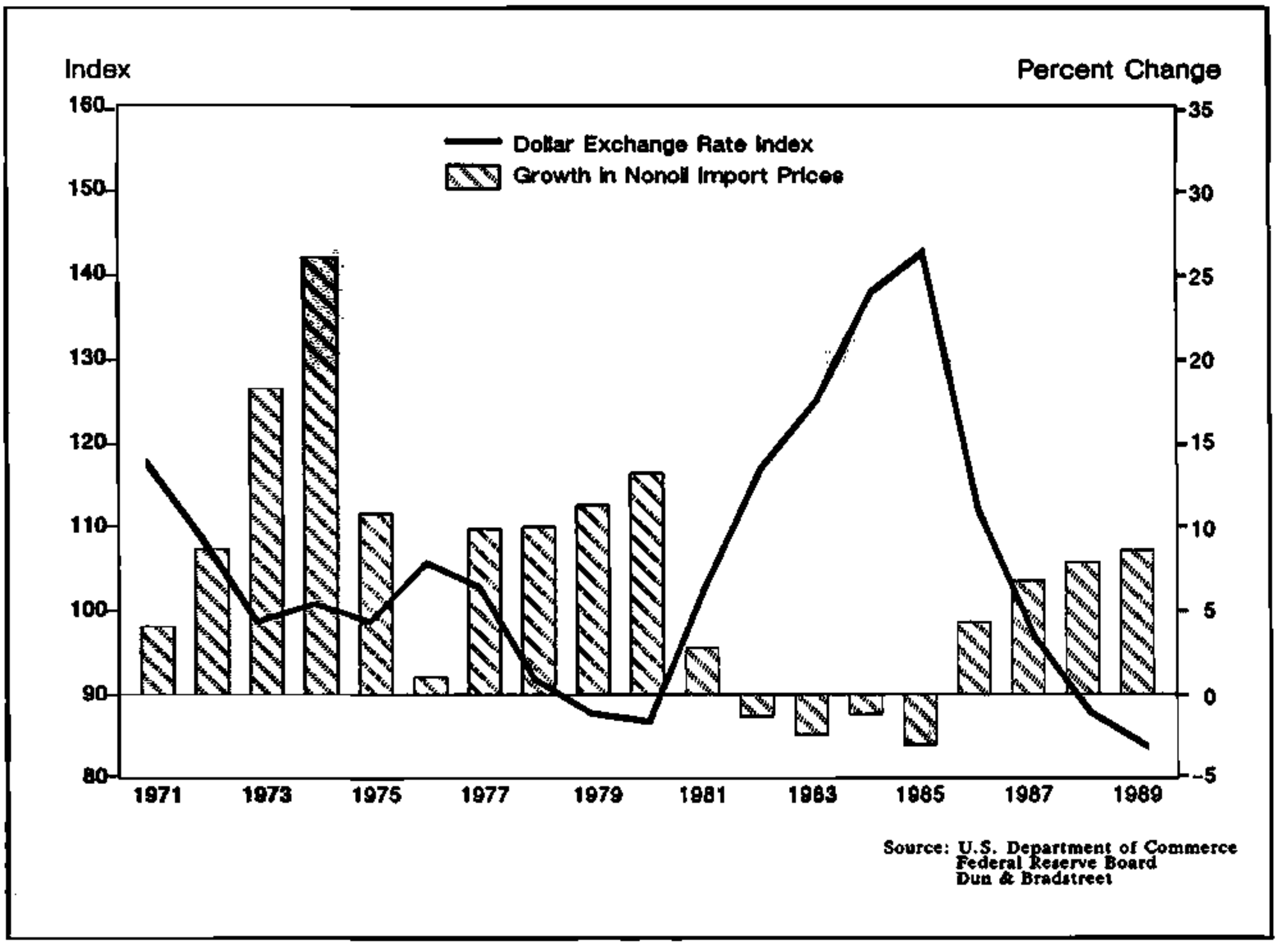


Figure 4. Imported Inflation and the Dollar

It is interesting to speculate on the free trade agreement and the prospect for an eventual North American common market encompassing Canada, the U.S., and Mexico. Figure 5 shows the 1987 U.S. balance of trade with Canada and Mexico. The elimination of import tariffs on goods traveling between the three countries would most directly benefit Canada and Mexico, which ship 80 percent and 75 percent of their respective exports to the United States. By comparison, the United States sells 25 percent of its exports to its bordering neighbors. The primary benefits to the United States would be freer commercial investment opportunities, a favorable climate for development of lower-cost manufacturing operations close to home, and preferential pricing on Canadian and Mexican petroleum.

Interest Rates, Bonds, and the Stock Market

The large federal deficit has created a global market of considerable size in U.S. Treasury securities, a market which recently has more movement and effect on monetary policy than the Federal Reserve Board. Government bond rates rose beyond 10 percent in early October, responding to a booming global economy, and helped to trigger the stock market meltdown. Bond prices dipped and then recovered immediately after the crash, as the Federal Reserve's flood of liquidity pushed interest rates down again.

While the long-term relationship between bonds and stocks is tenuous, the two instruments currently interact closely. As money flows from

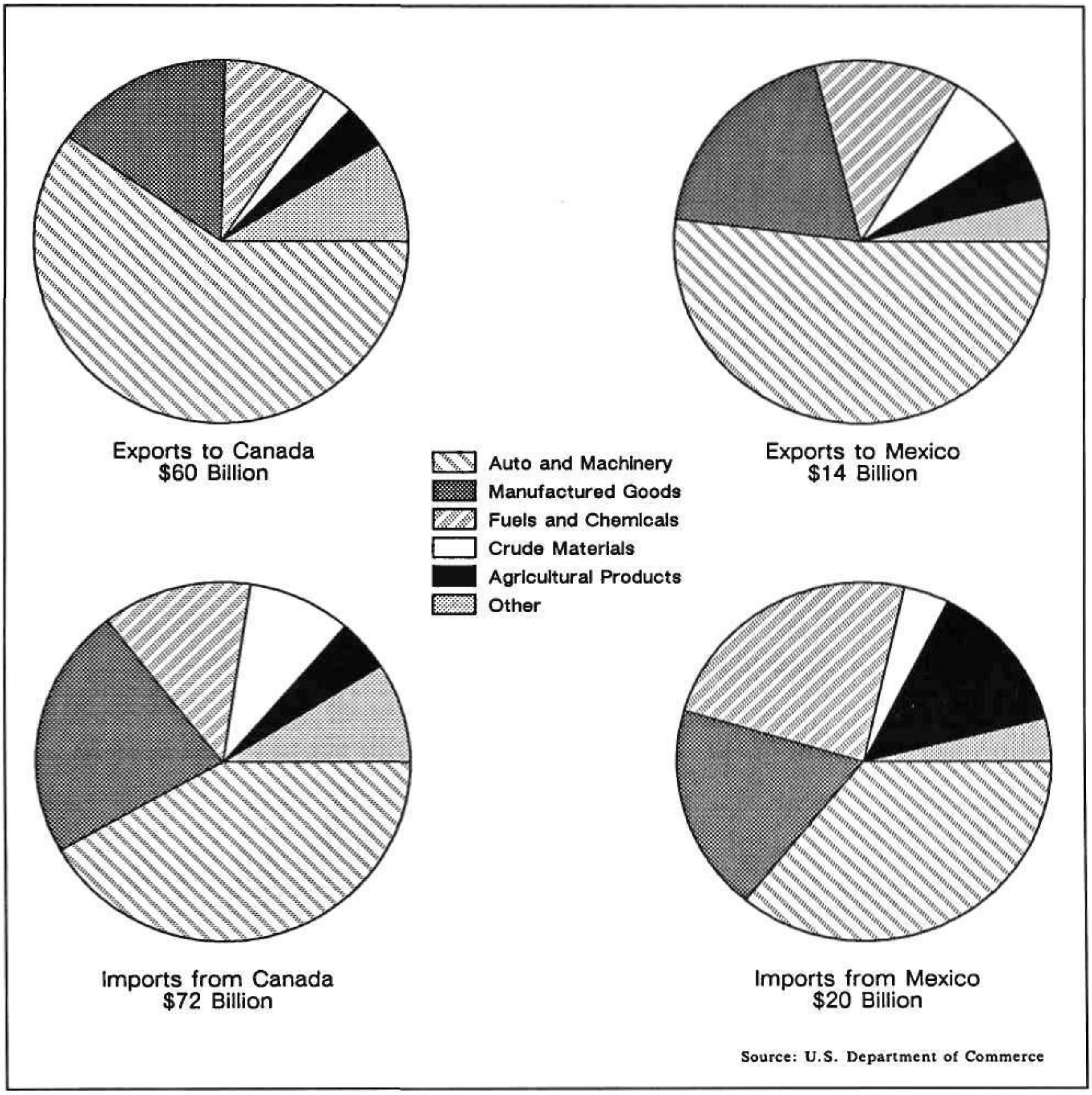


Figure 5. U.S. Merchandise Trade with Canada and Mexico—1987

stock markets into bonds, the price of stocks fall, raising the price of bonds and lowering bond yields, i.e., interest rates. Psychological factors play a big role in this relationship, too. If negative expectations about the economy form, then downward expectations about interest rates and stock prices follow, and the demand for bonds increases.

Thus, the bond market also serves as a handy economic buffer. When the total market value of the U.S. stock market fell by about $1 trillion from an original total of $3 trillion in last year's fourth quarter, the value of bonds increased about $700 billion, representing a 10 percent gain on a $7 trillion base. This may help explain why businesses and consumers remained relatively calm in the weeks after the crash.

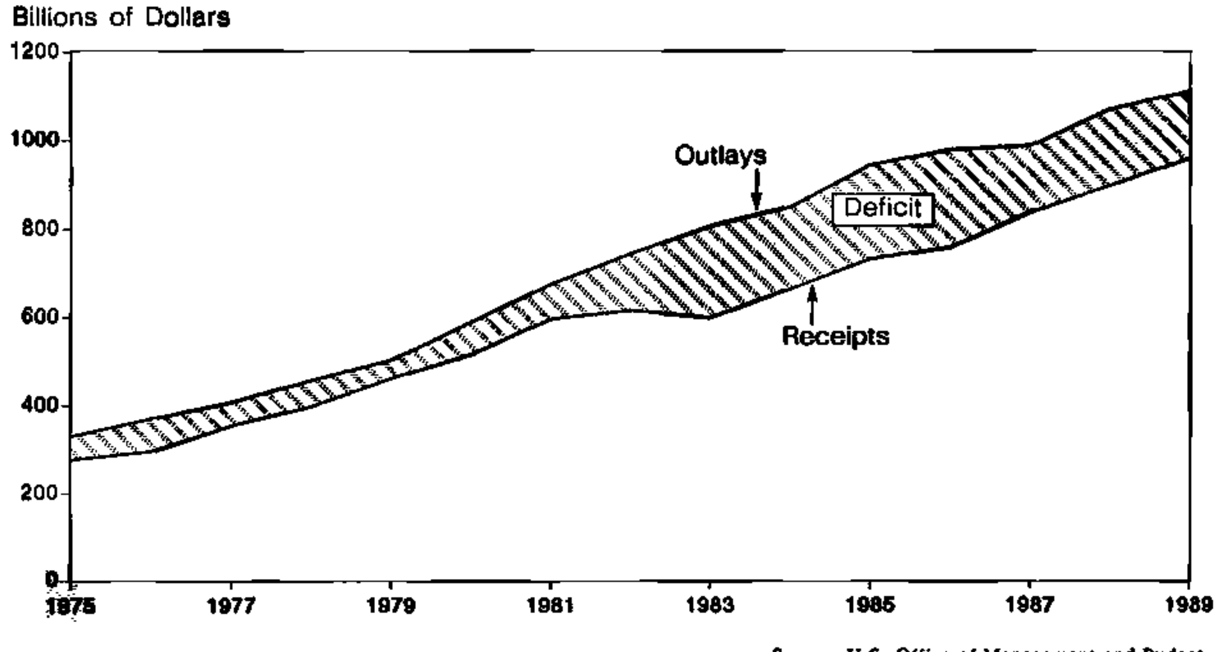
Expectations for continued declines in the dollar and a subsequent increase in inflation suggest interest rates will rise over the next two years. Long-term bonds, which currently yield just over 9.0 percent, should yield between 9.5 and 10.0 percent by the end of the year, and between 10.0 and 10.5 percent by the end of 1989. Risk factors that might increase rates beyond these ranges include higher inflation rates or a rebound in the stock market, which could drain liquidity from bonds. About the only source of downward pressure on interest rates is a recession or "growth pause" in final demand, reducing the demand for loanable funds.

The Federal Sector: The 1988 Election and the Budget Deficit

Given the lagging consequences of actions taken in 1986 and 1987, the direction of the economy in 1989 depends very little on who occupies the White House and Congress, especially considering the start-up period of several months required before a new administration can begin to implement its own policies.

Gramm-Rudman-Hollings restrictions on federal spending will also hinder the implementation of new policy initiatives. The distribution of the Gramm-Rudman-Hollings cuts, or of any avoidance measures, may vary depending on the party or person in power. However, any cuts will probably net out to elaborate accounting maneuvers rather than real spending reductions.

The Gramm-Rudman-Hollings budget cuts will also mean little to the macroeconomy, and very little to capital markets. The recently passed legislation calls for $30 billion in deficit reduction in fiscal 1988, and an additional $46 billion in fiscal 1989. With these cuts, the federal deficit is still likely to exceed $170 billion in 1988 and $150 billion in 1989, compared with $149 billion in fiscal 1987. The deficit reductions mean even less compared with the $2.4 trillion cumulative federal budget debt. Figure 6 illustrates the enormous bulge since 1981 in federal deficit spending.



Source: U.S. Office of Management and Budget
Dataquest
April 1988

Figure 6. Federal Budget Receipts and Outlays—1975 to 1989

Since a portion of these cuts merely transfers the demand for capital from the government to the private sector, the cuts will have little impact on reducing the U.S. demand for capital and, hence, little impact on interest rates. For example, private acquisition of federal assets to be sold in the deficit reduction plan requires private financing, merely replacing federal debt with individual or corporate debt.

Difficult budget decisions have been postponed to the future. Eventually, elected officials will have to address out of balance national entitlement programs such as Medicare and Social Security that consume 9.5 percent of the GNP.

Thus, any economic fallout from the federal sector will probably be psychological. Until the 1988 presidential election is decided, and the winner's policies become clear, there will be a cloud of uncertainty surrounding the outlook for the economy. To the degree any leading presidential candidates propose a peculiar or uncertain economic or political agenda, this uncertainty may add a downbeat note to the economy.

The Consumer

In the measurement of U.S. GNP, consumer spending accounts for about two-thirds of the total. The economic realities of the late 1980s are affecting three primary factors that have a direct impact on the consumer—personal income, debt, and psychology.

The first and most obvious factor is household income. The best measure of this is *real disposable income*, which necessarily takes inflation and taxes into account. When the second part of the 1986 tax reform act's tax cut took effect on January 1, 1988, tax liabilities of individuals were reduced by about 4 percent. Offsetting a large part of this increase was a substantial increase in social security tax payments. On balance, tax payments will be reduced in 1988, but because of the change in the Oval Office in 1989, taxes can be expected to increase thereafter.

Also affecting disposable income, of course, are wage rates. Slight increases in compensation are expected over the next two years because of gradually tightening labor markets in some regions and industry sectors. In addition, inflation is expected to rise slightly in 1988-1989, offsetting much of the buying power of these gains. Therefore, real disposable income is expected to remain largely unchanged from 1987.

Another factor that affects the consumer is *debt*. Consumer debt-to-disposable-income ratios are currently high, but can be explained in part by the increased use of credit cards over the past five years. The use of credit cards is a convenience rather than a debt purchase if the credit card bill is paid off in full each month. However, as far as the credit accounts are concerned, debt is debt, even though consumers may not regard it as such.

The explosion of home equity loans and adjustable rate mortgages have in the past provided consumers with reduced interest rates for debt payments of all types. However, this debt involves flexible rather than fixed interest rates, and so ties debt payments more closely to current interest rates. Thus, if interest rates increase, more current income would be required to pay off old debt, reducing consumption growth.

The net effect of consumer debt on expenditures remains a complex issue. Compounding the problem of analysis is the third factor affecting consumption decisions: *consumer psychology*. What is certain is that consumers are less likely to incur debts if they have doubts about their future prosperity.

If consumers fear a recession is coming, they will withhold spending in favor of increasing savings as a hedge against bad times. Because the economy is in a period of notable transition, there is a great deal of uncertainty. The University of Michigan conducts regular surveys of consumer attitudes, and the results provide some insight into spending plans. Figure 7 shows historical values for consumer sentiment and spending, with projections for 1988 and 1989. The survey's consumer sentiment index took a large dip immediately after the October crash,

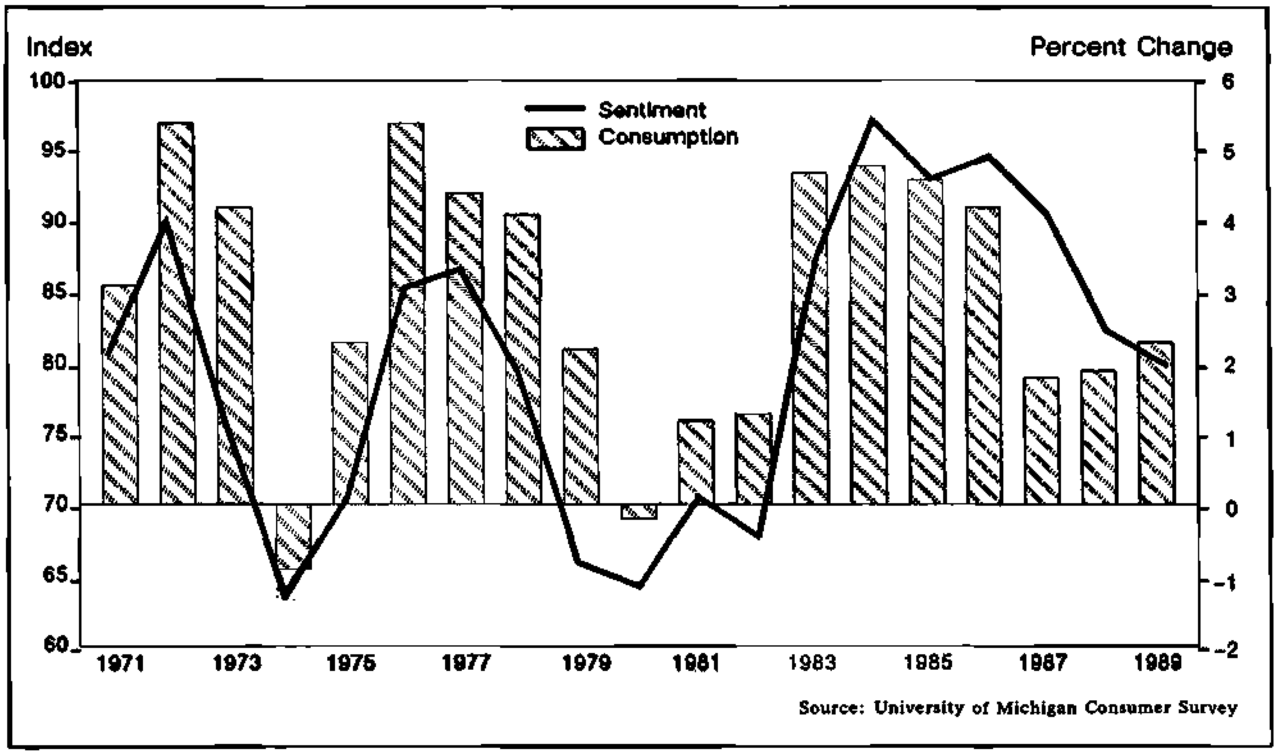


Figure 7. U.S. Consumer Sentiment and Consumption

stabilized in November, and then rose modestly in December. The resiliency evident in consumer sentiment makes it likely that changes would occur only after sustained stress or sustained improvement in the general economy.

The outlook for consumer spending is weak, but not weak enough to cause a recession. While GNP is expected to grow 2.8 percent in 1988, consumption is anticipated to grow only 2.0 percent. Dataquest views this as a favorable trend for two reasons:

- Roughly 21 percent of U.S. *merchandise imports* in 1987 were consumer goods, and another 21 percent were automobiles and auto parts. Therefore, a cutback in consumer spending would clearly help reduce the U.S. trade deficit.
- Because income must be either spent or saved, a reduction in consumer spending means an increase in savings, which flow back into capital investments in plant and equipment. Capital investments will be necessary to expand production capacity for export.

Consumer spending reductions will help hold prices and inflation down, and will restrict further excesses in the level of American personal debt.

The Household Balance Sheet

An analysis of consumer spending requires a brief examination of the health of the consumer. A look at the balance sheet of households—total assets and liabilities—can provide insight into the longer-term trends of consumer behavior.

This is especially important today because much has been written about the so-called "wealth effects" of the stock market decline killing off personal spending. Scant empirical evidence is available to support the view that wealth effects are important, and there are many arguments against this type of forecast:

- If wealth effects indeed exist, there would have been a surge in spending when the stock market was on the way up during the first nine months of last year. Consumption expenditures were flat during this period.
- The period in which wealth effects are measured is likely to be quite long. It is doubtful that individuals would make consumption decisions on potentially fleeting paper profits.
- Only 20 percent of individuals own stock. Many of these individuals are either long-term investors who ignore short-term fluctuations, or simply are well enough off to withstand the stock market's bearish intervals.
- Much of the lost wealth in the value of stocks was made up by the gains in the bond markets.

These arguments imply that the long-term health of the consumer is dependent on all of the net assets of the household, not just on income flows. As a result, it is necessary to look at all sources of household wealth and all liabilities supported by this wealth.

Using an accountant's point of view, the ratio of household liabilities to assets has generally been stable at around 20 to 24 percent since 1960. In 1986, this ratio reached a 24 percent cyclical peak. Increases in mortgage and installment debt exceeded increases in wealth, including stocks. And in 1986, economists were forecasting a mild consumer retrenchment for 1987, which in fact occurred.

In 1987, the household liability/asset ratio dropped to 22 percent, signaling an increase in the long-term solvency of the consumer. The most pessimistic projections of lost wealth in the fourth quarter from the stock market crash would raise the liability/asset ratio from 22 percent back to the 1986 level of 24 percent.

Two conclusions can be reached from this analysis. First, based on calculations from the aggregate household balance sheet, 1988 and 1989 will see a continuation of weak spending growth, much like 1987. Second, the economy, at this time, can survive mild consumer retrenchments and still avoid a recession.

Inflation and Unemployment

Near-term inflation will be the resultant combination of three forces: oil prices, wage rates, and import prices.

Oil prices should decrease relative to the general inflation rate in 1988. This is due to OPEC's failure to reduce its overall production quotas below 17.5 million barrels per day, the lack of success in controlling unofficial discounting by OPEC members, widespread non-OPEC third-world production increases, and very small increases in worldwide demand. OPEC oil prices should average $17 per barrel in 1988, and rise gradually to about $18 per barrel by the end of 1989.

In the labor market, it would appear that the currently low unemployment rate would suggest future labor shortages if the economy expands any further, causing large future increases in wages. However, outside the Northeast, this simply is not so. With the unemployment rate at 5.8 percent, there is still room for further expansion without generating wage pressures. Since the last time the unemployment rate fell this low was in 1979, the average age of the labor force has increased. With this maturation, fewer people are changing jobs, and this job stability is reflected in the unemployment rate.

The gradual shift in the U.S. economy from manufacturing toward service industries and the trimming of corporate payrolls have reduced many potential downside effects. In addition, the focus of labor contracts has shifted from wage increases to job stability. Average annual wage increases in negotiated labor contracts are running between 2 and 3 percent. Also, new entrepreneurial activity is responsible for many new jobs in smaller businesses, which generally pay less than their large business counterparts and offer fewer direct employee benefits. Therefore, unemployment and inflation rate comparisons with the past are not necessarily valid. We see the unemployment rate bottoming out at 5.6 percent by the end of 1988 and rising from 5.8 percent to 6.0 percent in 1989.

A major source of inflation comes from abroad. With a decreasing dollar value, foreign goods cost more. To the extent that U.S. markets see higher prices for foreign goods, U.S. competitors may also choose to raise their prices. Imports other than oil represent about 10.0 percent of GNP, so if prices for these goods increase by 8.0 percent, and if prices of substitute domestic goods increase by about 6.0 percent, this can add about one percentage point to current inflation rates. Overall, Dataquest expects inflation rates to rise through 1988 to the 4.5 to 5.0 percent range, until peaking at about 5.4 percent in mid-1989.

Capital Spending

The projected growth in capital spending is an important factor in our forecast of 2.8 percent real GNP growth for 1988 and 2.2 percent in 1989. Although the outlook for purchases of plant and equipment is influenced by many of the same considerations as consumer spending, two additional factors will make this sector a major source of growth. First, U.S. production facilities are currently running at an average 82.0 percent of capacity. The export boom, if sustained, will strain industrial capacity in many export-oriented industries and thus force expansion. Second, corporate profits in 1987 were quite strong, providing funds for investment in 1988. Much of this investment will go into equipment rather than construction because of the shorter payback period.

The pivot point in this forecast concerns interest rates. Since firms usually plan major capital expenditures many months in advance, it is unlikely that any minor uptick in interest rates would adversely affect corporate spending in 1988. The recent Dun's 5000 Survey on 1988 capital expenditure plans confirms this. In 1989, investment expenditures for larger firms would still be interest-rate insensitive up to a point. In other words, larger businesses generally pay more attention to the sales prospects for their products than to interest rates when planning their capital spending.

Financial Industries

With the declines in the stock markets, the financial sector is one of the weakest in the economy. The banking industry must deal with a weak portfolio, including large amounts of nonperforming third world debt, plus weak loans in the agricultural, energy, and real estate sectors. Higher interest rates can exacerbate these problems by raising the cost of obtaining new funds. The good news for bankers is that they are not working for Wall Street brokerage houses, which instituted 10 percent personnel cutbacks after meteoric expansion over the past several years. At the same time, many of these same firms express commitments to continue purchases of communications and data processing equipment in 1988, in order to retain their competitive position.

The risk of a potential banking crisis appears to have passed. However, because of the general economic sluggishness ahead, any turnaround will be slow. While government regulatory agencies appear to consider most bank and brokerage house problems under control, the situation remains precarious.

One additional factor to consider in this sector may come from repeal of regulatory restrictions preventing banks, brokers, and insurance companies from engaging in each other's activities. With new markets open to these institutions, an expansion followed by a shakeout of the new megabanks will occur. The end result may be a stronger industry, but the route to this end is likely to be painful.

Tables 1 and 2 contain key statistics concerning the U.S. economic outlook and GNP components.

Table 1. U.S. Economic Outlook (Billions of U.S. Dollars)

	1987	1988				1989			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Nominal GNP	$4,486	$4,641	$4,723	$4,818	$4,904	$4,989	$5,060	$5,123	$5,197
% Change SAAR	7.2%	3.8%	7.2%	8.3%	7.4%	7.1%	5.8%	5.1%	5.9%
% Change Year Ago	5.9%	6.0%	6.2%	6.5%	6.7%	7.5%	7.1%	6.3%	6.0%
Real GNP	$3,820	$3,880	$3,909	$3,944	$3,970	$3,997	$4,006	$4,009	$4,022
% Change SAAR	3.6%	0.5%	3.0%	3.6%	2.7%	2.7%	1.0%	0.3%	1.3%
% Change Year Ago	2.8%	2.9%	3.0%	2.8%	2.4%	3.0%	2.5%	1.7%	1.3%
GNP Deflator	117.5	119.6	120.8	122.2	123.5	124.8	126.3	127.8	129.2
% Change SAAR	3.5%	3.2%	4.1%	4.5%	4.5%	4.3%	4.8%	4.7%	4.6%
% Change Year Ago	3.0%	3.0%	3.2%	3.6%	4.1%	4.4%	4.5%	4.6%	4.6%
Industrial Production	129.8	134.0	134.6	135.8	136.9	137.8	138.6	139.1	139.5
% Change SAAR	5.0%	3.0%	2.0%	3.6%	3.2%	2.8%	2.1%	1.6%	1.2%
% Change Year Ago	3.6%	5.6%	5.0%	3.7%	3.0%	2.9%	2.9%	2.4%	1.9%
Capacity Utilization (%)	81.0%	83.1%	83.6%	83.6%	83.7%	83.7%	83.4%	83.0%	82.7%
Unemployment Rate (%)	6.1%	5.8%	5.8%	5.7%	5.6%	5.8%	5.9%	6.0%	6.0%
Number Employed (M)	102.1	103.2	103.7	104.9	106.6	106.8	105.9	104.0	104.4
% Change Year Ago	2.5%	2.1%	2.0%	2.5%	3.2%	3.5%	2.1%	(0.9%)	(2.1%)
Real Final Sales	$3,785	$3,827	$3,848	$3,877	$3,897	$3,920	$3,927	$3,923	$3,938
% Change SAAR		1.3%	2.2%	3.0%	2.1%	2.3%	0.7%	(0.4%)	1.5%

Notes: Nominal GNP = GNP measured in current dollars
Real GNP = GNP measured in constant dollars from 1982 base year
SAAR = Seasonally adjusted annual rate
Industrial Production = Base 100 in 1977.

Source: Dun & Bradstreet

Table 2. U.S. GNP Components (SAAR*, 1982 Billions of U.S. Dollars)

	1987	1988				1989			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Consumer Spending	$2,495	$2,514	$2,531	$2,556	$2,569	$2,586	$2,596	$2,608	$2,611
Nonresidential Fixed Invest	447	467	473	481	490	502	507	509	506
Residential Fixed Invest	196	195	197	196	196	193	189	185	185
Government Purchases	773	784	781	789	796	792	788	796	800
Inventory Change	42	29	24	20	16	11	14	0	4
Net Foreign Trade	(134)	(109)	(97)	(98)	(97)	(87)	(88)	(89)	(84)
GNP	$3,819	$3,880	$3,909	$3,944	$3,970	$3,997	$4,006	$4,009	$4,022

*Seasonally adjusted annual rate

Source: Dun & Bradstreet

Conclusion—the U.S. Economy

The next two years are expected to be about as strong as 1987, but the economy will rely on different sources to achieve similar levels of growth.

On the downside, there are several realistic scenarios in which a recession could develop as early as this summer. Such possibilities include a massive divestment of dollars by foreign investors, a drop in consumer confidence, or a jump in oil prices from extraordinary military developments in the Persian Gulf.

Positive risks include larger-than-expected export gains or increased international coordination to reduce interest rates, which could bring about a capital spending and housing boom.

In any event, careful planning will be required to keep pace with the evolving economy. The nature and location of markets for all firms will be changing in the next two years. Profitability will depend on the ability to exploit these changes to their fullest advantage.

1988-1989 Outlook for Major U.S. Trading Partners

Figure 8 shows the volume and composition of U.S. international transactions in goods and services during 1987, illustrating the large share attributable to imported consumer goods (15.5 percent), even excluding automobiles. The bar graphs in Figures 9 and 10 rank U.S. trading partners in descending order by value of imported goods into the United States. Three conclusions are particularly worth noting:

- Japan accounts for 36 percent of the 1987 U.S. merchandise trade deficit, and the NICs of the Pacific region account for a rapidly growing 23 percent.

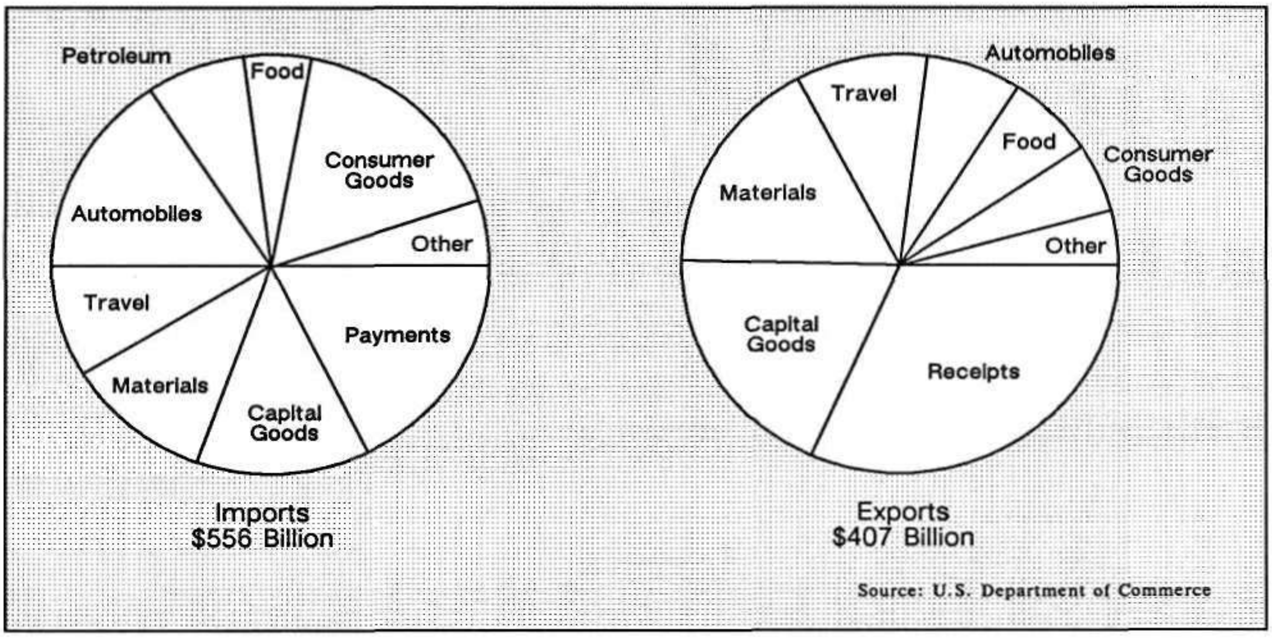


Figure 8. U.S. International Transactions—1987 ($ Billions)

- The negative aspect of the 1987 U.S. trade results, while weighted so heavily by Pacific area countries, still permeates almost all U.S. trading relationships. In scanning the list, the reader will note that the U.S. balance is negative until reaching the nineteenth area, Australia and New Zealand.
- The first- and third-ranking country-markets for U.S. exports are its bordering neighbors, Canada and New Mexico. Many of the U.S. exports to these countries are related to automotive and electronic assembly operations, the products of which are reimported into the United States.

Japan

As international markets shift toward new equilibrium points, the Japanese are reshaping their economy with increased emphasis on domestic demand as the primary driving force, and less dependence on exports. The years of 20 percent-plus export growth in the 1960s and early 1970s, which made Japan the world's largest creditor nation, are dampening to a steady 3.50 percent. Meanwhile, total domestic demand grew at 4.00 percent rates in 1986 and 1987, and is expected to continue at this rate through 1988 before slowing to 3.25 percent in 1989. This is in comparison with a healthy 3.50 percent to 3.00 percent real GNP growth in 1988 and 1989. The primary components of domestic spending are as follows:

- Sharp spending increases in 1987 by central and local governments on airport and railway construction projects, telecommunications facilities, conference centers, highways, and electric power generation and distribution networks will continue through 1988-1989. The U.S. government is seeking rights for American companies to bid on parts of the $17 billion construction and expansion program.
- Corporate capital spending plans for 1988 are moderate overall. Sizable spending in industries closely related to domestic markets, such as construction, banking, insurance, and food, will be counterbalanced by decreases in the shipbuilding, steel, mining, and automobile industries.

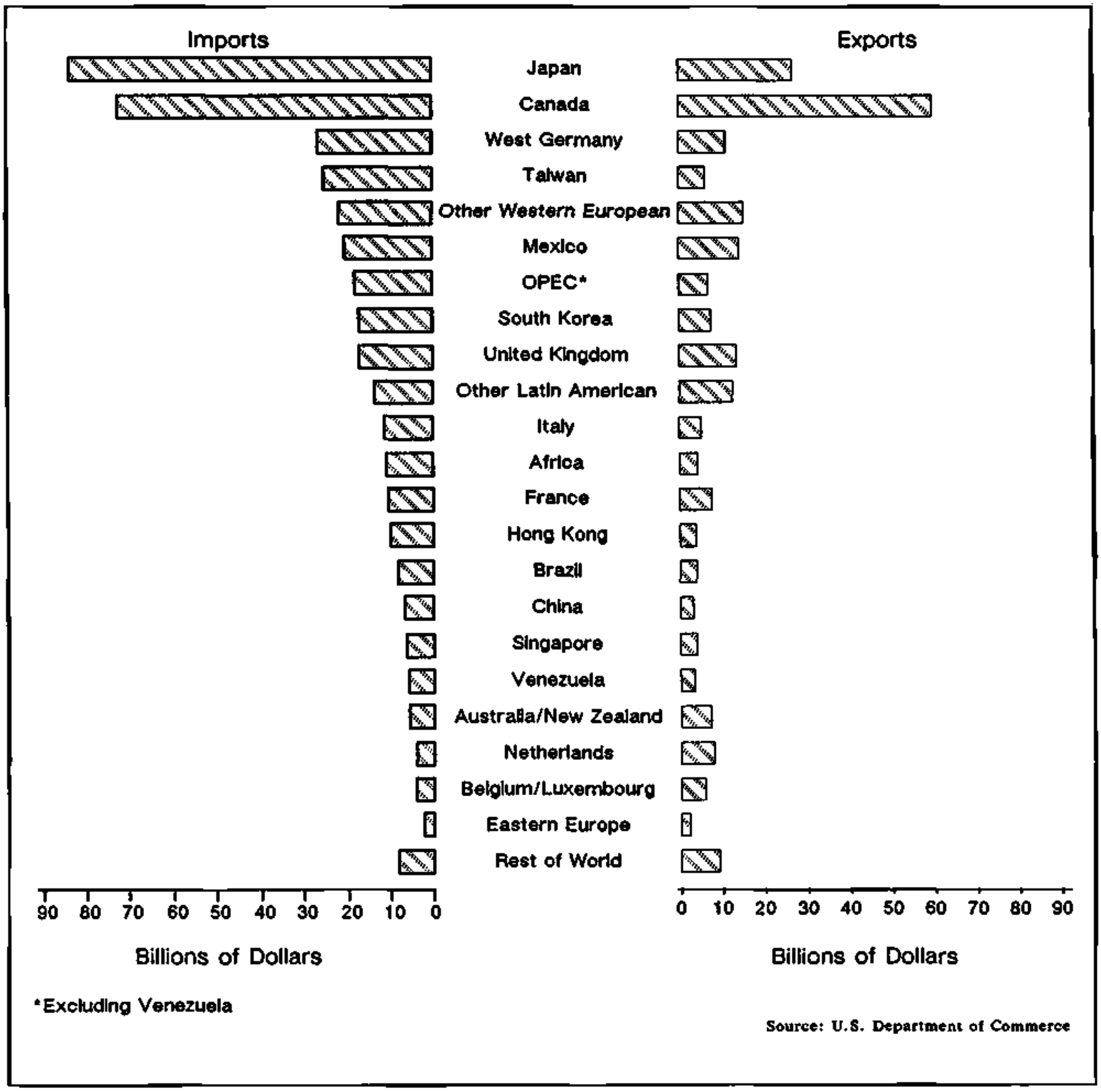


Figure 9. U.S. Merchandise Trade—1987 ($ Value, Billions)

- Modest wage increases, stable consumer prices, and historically low interest rates combined to spur Japanese consumption 3.75 percent in 1987. Consumer spending will continue to increase 5.00 percent per year through 1988-1989, primarily for housing and household goods, automobiles, and travel. To date, the benefits of yen appreciation on imported goods have been retained as profits within the complex multilayered Japanese distribution network, and have not been passed through to the ultimate consumer.

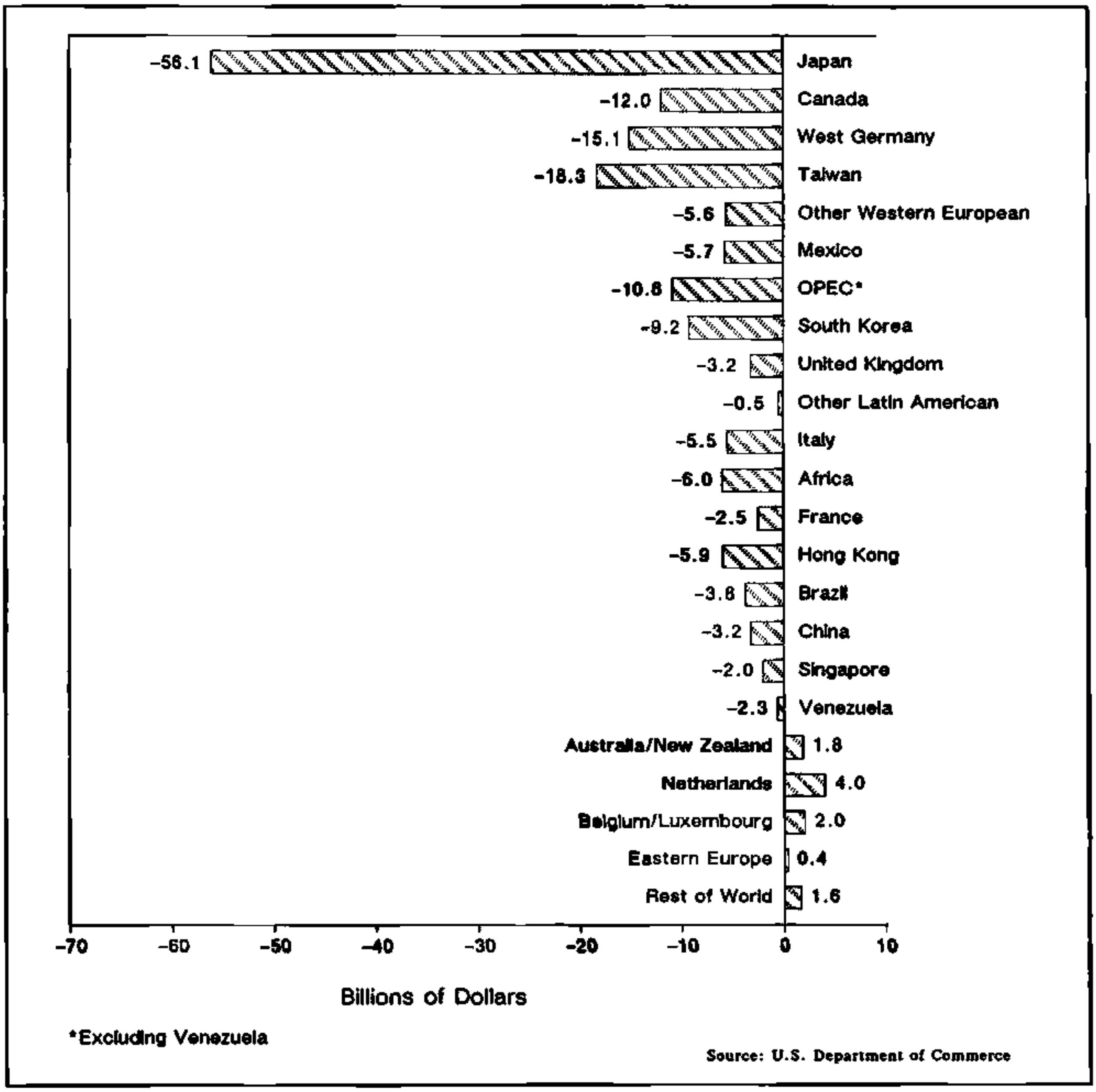


Figure 10. U.S. Merchandise Balance of Trade—1987 ($ Value, Billions)

As developing countries emulate the Japanese industrial success model, and the strong yen is a major factor in international trade balances, the Japanese face a number of pressing domestic issues.

The Japanese baby-boom generation of 1947 through 1949 numbers 10 million, about 20.0 percent greater in size than the generations just before and after. These workers, hired in the mid-1960s period of rapid expansion, are now competing for a limited number of promotions. Japan's rigid labor market still regards job-hopping as disloyalty, and pay systems are based heavily on seniority. The national unemployment rate has been steady at 2.8 percent.

Consequently, there is growing corporate pressure on the over-50 generation to take early retirements. By 2010, the ratio of adults over 65 to working adults will exceed 0.4 and put increasing stress on government and family health care budgets.

Japanese agricultural import restrictions and controls have kept domestic food prices at much higher levels than in many other countries. The most prominent example is rice, which is regarded as a strategic national resource and supported at a price four times the U.S. price. The magnitude of all agricultural subsidies is such that they would add 1 percent to the Japanese GNP if redirected.

Japan's post-war development has concentrated a disproportionate share of political, industrial, and financial power in the Kanto region surrounding Tokyo. Tokyo's population now strains the limits of municipal services. The Kansai region to the west, with its major cities of Kyoto, Osaka, and Kobe, has thus been eclipsed economically. Indeed, foreign companies seeking entry to Japanese markets would do well to investigate the more receptive Kansai.

Service industry employment now accounts for 60 percent of the total work force, as the Japanese domestic economy tracks the global trend. However, large portions of the work force remain in export-oriented manufacturing and subsidized agriculture, and are more vulnerable to fluctuations in foreign exchange rates, trade restrictions, and government budget constraints.

Japanese manufacturers have opened many foreign production subsidiaries, to move closer to ultimate markets and cope with exchange rates and trade barriers. This trend is accelerating, particularly regarding U.S. locations. Public concerns and debates about "exporting jobs" continue, as in the United States. As a perspective, Dataquest estimates the cumulative Japanese overseas manufacturing investment at $23.6 billion at year-end 1987, compared with an estimated U.S. figure of $110 billion.

West Germany

West Germany, another beneficiary of the U.S. import shopping spree, has experienced a decrease to zero real growth in exports of goods and services in the last two years. Germany was able to sustain a significant positive trade balance with the United States through the mid-1980s, second only to that of Japan. The effective appreciation of the deutsche mark has hindered exports of machinery and automobiles, slowing industrial production and creating some upward pressure on unemployment figures. The German economy in 1987 was generally weak and erratic across many sectors, but was rescued from a chill by a notable rise in consumer spending during the second half of the year.

Dataquest expects West German exports to show a modest recovery to 1.0 percent real growth in 1988 and 1989, accompanied by a 3.5 percent per year rise in the value of imported goods. The result will be a contraction of the German foreign trade balance by about negative 1.0 percent annually. More attention will be focused on sales efforts in European and newly industrialized world markets for German exports, where the deutsche mark has appreciated less than against the dollar. In the battle to retain its competitive export position, Dataquest also expects German industry to be a leader in making substantial investments in shop floor control systems, factory networks, and design automation.

The Germans have done the best job among major industrial countries in managing central government budgets, averaging less than a 1.4 percent annual deficit since 1980. Domestic demand will grow at about 2.0 percent per year. Family disposable income will grow at 3.5 percent, and consumer spending is projected to increase at 4.0 percent per year, with imported goods getting a considerable share. Automobiles, electronics, and household goods will be high on German shopping lists. Given the above, GNP is expected to grow at 1.3 percent per year. In addition to recent and pending tax reform legislation, these projections are based on assumptions of continued low rates of inflation, interest, and wage increases.

France

The French economy is a vessel with her sails luffed in the wind. Real GDP growth was 1.5 percent in 1987, and Dataquest projects the same 1.5 percent growth in 1988, before slowing further to 1.3 percent in 1989. French GDP growth has ranked as the lowest of the major Western European economies since 1983. The rate of unemployment is currently the highest in Western Europe, at 10.8 percent of the French labor force. Inflation and average annual wage increases were both a little more than 3.0 percent in 1987.

In a time of shifting international trade balances, France's $2 billion trade deficit in 1986 slid to a negative $10 billion in 1987, or 1.3 percent of GDP, and will continue in this direction by about a negative $1 billion per year through 1989. The problem is not as much the increasing value of imports, as it is the flat export growth rate. Between 1969 and 1974, the value of French exports grew an average of 13.4 percent per year, second only to the 14.9 percent annual growth in Japanese exports. However, a large proportion of French exports went to oil-exporting and developing countries, both sensitive to dollar exchange rates and growing more slowly than the average. As the franc appreciated against the dollar in the early 1980s, the price competitiveness of French exports declined. Finally, the total value of exports slipped below the value of imports in 1982.

The government began to take stringent measures to improve the economic picture in early 1986 by deregulating many sectors of the economy, and by privatizing a number of large state-owned companies. The privatization process has been successful in liberalizing and stimulating some industries, though the program is far from complete. Whether it will be continued depends upon the socialist-conservative composition of the government after the May 1988 election, and the market value of companies under consideration.

Private and corporate disposable incomes will improve when the government reduces income and corporate tax rates by 3.0 percent and 4.0 percent, respectively, in 1988. French value-added tax rates will be reduced progressively through 1992, to align with the internal European community. Corporate investment and private consumption spending should show modest increases as a result. Over time, the value-added tax reductions could add 0.5 percent per year to French GDP growth.

Generally, the French have been slower than the Germans and quicker than the English to make investments in manufacturing automation, and have been slow to adapt their products and distribution organizations to match changing market demands. Both domestic and international market share have been lost, and it is unlikely that near-term reversals in the trade deficit trend will occur. U.S. computer companies now control more than 60 percent of the French market, with only a 24 percent share going to French companies.

Domestically, the government has moved to improve employment figures by offering retraining, tax, and various subsidy incentives to new employers, including foreign firms. In view of the labor market and prospects for moderate wage increases through 1990, U.S. firms should seize the opportunity to open new offices and production facilities in France.

Italy

The Italian economy is a dramatic play of extremes. With 2.8 percent GDP growth in 1987, Italy pulled past Britain and France to rank as the fourth largest capitalist economy, behind the United States, Japan, and West Germany. The fastest annual growth rate over the last decade among major European countries has generated much talk of an Italian economic miracle. Inflation has dropped to 5.0 percent, down from 21.0 percent in 1980. Thousands of new small businesses have sprung from the fertile ground of a high household savings rate, 23.0 percent of disposable income, and plenty of individual entrepreneurial drive. Dispersion of production to networks of these small businesses is common, enabling the smaller subcontractors to contribute substantial added value to the finished products of big firms.

But beneath the gleam of GDP growth lie economic fault lines. As in the United States, the two largest problems are the balance of trade and the government budget deficit.

The Italian international trade balance, which popped into a surplus condition in 1986, dropped back to the deficit side in 1987. Imports of manufactured goods, energy, and food shot up 6.3 percent, occupying an increasing share of the domestic market. At the same time, Italian exports were weak, declining 1.0 percent in aggregate value shipped. Domestic demand will grow in 1988 and 1989 at a faster rate than GDP because imports will continue to outpace exports and detract from the total GDP figure. Unemployment seems destined to climb from the 1987 level of 10.8 percent to 11.5 percent within the next two years.

A disproportionate share of Italian exports are low-technology manufactured goods. For example, 14 percent of the 1987 total was clothing and textiles, which will become increasingly vulnerable to future competition from newly developing countries. In the high-technology sector, Olivetti is the largest Italian data processing equipment company and tenth largest worldwide, but is the only Italian company within the industry's top 100 firms. Funds for high-technology investment within the economy are limited, and R&D spending is half that of other major industrial economies, as a percentage of GDP. Much of the effective progress in technology advancement has come through acquisitions and strategic partnerships with foreign firms. Higher relative unit labor costs and slow productivity growth in the 1980s continue to hamper the competitive position of manufacturers. Given the foregoing, Dataquest projects that the Italian trade deficit will continue to widen through 1988 and 1989, due to heavy import traffic and only modest export growth.

In the United States, where credit cards are quite common, many consumers know firsthand how difficult it can be to recover from a large accumulated debt. Monthly payments to reduce the debt and cover interest must be squeezed from cash that otherwise would go to normal monthly activities. The debt to income ratio determines the degree of constraint in selecting options. On a national scale, Americans can easily see the problems posed by the U.S. budget deficit.

By comparison, Italy has a GDP one-sixth the size of the U.S. GNP, but had a 1987 budget deficit two-thirds the size of the U.S. deficit. The accumulated Italian government debt is equal to 93 percent of the annual GDP. By another measure, the debt is equivalent to $628 billion, or one-fourth the size of the huge U.S. public debt.

The tightly regulated Italian financial system, which severely restricts competition for financial assets, has thus far enabled government securities to sell very well in the domestic economy. However, as a member of the EEC, Italy must bring its banking and financial systems into accord with the other nations by 1992. The pending liberalization of capital flows means the government must ultimately increase the yield on its securities and come to grips with the deficit size. The most realistic hope for progress lies in a series of reductions in government spending. For fiscal 1988, a series of budget cutbacks and increases in direct taxes are expected to compress the Italian deficit to 12 percent of the GDP.

United Kingdom

The United Kingdom can boast the highest average rate of real GNP/GDP growth (3.6 percent) over the last three years among the major industrialized countries. This has been fueled chiefly by very strong private consumption and healthy exports. Industrial employment, which had dropped 25.0 percent in the United Kingdom since 1979, finally rose slightly in 1987 in conjunction with the growth in industrial output. Previous declines in manufacturing jobs have been partially countered by employment growth in the services sector since 1982. Total unemployment, which had risen to a 1986 peak of 11.6 percent of the work force, dropped below 10.0 percent by the end of 1987.

The above factors have enabled the British government to do an outstanding job of budget management in the 1980s, turning in a revenue-expense performance against plan second only to the record of the German government. Government spending will decrease slightly as a percentage of GDP in 1988, as will the small government budget deficit. The strength of the economy has also translated to good tax revenues, and the prospects are excellent for more supply-side incentives in the form of 1988 tax rate reductions.

Real GDP is forecast to increase by 2.8 percent in 1988, slowing to 1.8 percent in 1989. Economic growth will be led by continued expansion of consumer spending, in anticipation of tax cuts, moderate 3.5 percent to 4.0 percent inflation rates and further small decreases in the unemployment rate. Good order backlogs have caused business sentiment to remain very bullish regarding domestic markets, and many companies expect to make substantial investments in equipment and real estate to increase manufacturing capacity.

The primary drag on future economic growth will be from a deterioration in the United Kingdom's international competitive position, and decreasing demand from the United States, which in recent years has taken 14.0 to 16.0 percent of the United Kingdom's exports. A strong pound, declining North Sea oil production and recent weakening world oil prices will contribute negatively to the trade deficit in the near term. Exports are expected to show real growth of 2.0 percent in 1988, declining to 1.5 percent in 1989. A 4.0 to 4.5 percent growth in the value of imports will result in a growth in negative trade balance of approximately 0.8 percent of GDP per year.

Canada

Nineteen eighty-seven brought more good economic news for the United States' largest trading partner. The Canadian economy continued very robust growth in 1987, chalking up a real 3.6 percent increase. A glance at the table at the end of this section, which contains the 1983 through 1989 GNP/GDP growth, shows the Canadian average of 3.7 percent to be the highest average growth rate among the seven countries.

Fuel for the 1988-1989 economic engine will be provided by strong domestic investment in capital equipment and plant construction. Exports will continue to grow at 3.5 percent in 1988, with 78 percent of Canadian merchandise exports going into the United States. The Canada-U.S. free trade agreement, signed last year and officially taking effect in 1989, will begin having a substantial positive impact in 1988 in anticipation of the phased elimination of all tariffs and most other constraints on trade and investments. Canada's international trade balance is positive, with Can$125 billion in merchandise leaving the country and Can$114 coming in during 1987. U.S. manufacturers supply fully 70 percent of Canada's import purchases. Of the incoming goods from the U.S. in 1987, about 36 percent was automobiles and parts, 14 percent was industrial machinery and equipment, and 9 percent was communications and electronics equipment.

The Canadian economy is based around forestry, automobile manufacturing, petroleum, and mining. While smaller by comparison, the dynamic Canadian electronics industry is a major U.S. export market and a worldwide supplier of sophisticated products for telecommunications, geophysical exploration, natural resource processing and refining, and defense electronics. Many of the leading Canadian electronics companies are subsidiaries of U.S. or British firms, but there are an increasing number of examples in the opposite direction, such as Northern Telecom and Mitel Corporation.

With the exception of oil-related industries, Canadian manufacturers will continue to make heavy investments in capital equipment to sustain their growth, and U.S. exporters will continue to have the lion's share of that market. Many Canadian companies are actively seeking joint-venture manufacturing or sales partnerships with U.S. companies, and probably constitute the best learning opportunity for U.S. companies looking to expand into international markets.

Nineteen eighty-eight will see the lowering and restructuring of Canadian corporate and personal tax rates, as part of the government's long-range tax reform program. The general plan includes the probability of a national sales tax in 1990, replacing the current sales tax on manufacturers. If the government can keep spending relatively controlled, the federal budget deficit should improve to the range of 2.4 to 3.0 percent of GDP in 1988 and 1989.

As always, the big swing factor affecting prospects for Canadian economic growth is the health of U.S. markets. The good news/bad news about having such a good customer for exports on your southern border is that the United States accounts for so much of Canada's international business. Since a great part of the Canadian export industry centers on automobiles and lumber, it is especially sensitive to levels of U.S. consumer spending and residential construction. When the North American economies are moving along well, the Canadians generally do very well. Historically, the effects of slowdowns also tend to be more pronounced on Canada, and the economy underperforms that of the United States. Most current indications are cause for optimism, however, and the prospects for business activity in Canada remain good.

Newly Industrializing Countries

Figure 11 charts the 1987 gross domestic product data for five newly industrializing countries. Each country has its unique problems and unique strategies for long-range industrial success. The role of import-export trade in relation to total GDP should be especially noted. The most prominent trade example is Singapore, where import and export trade volumes were $37 billion in 1987, while GDP was $17 billion.

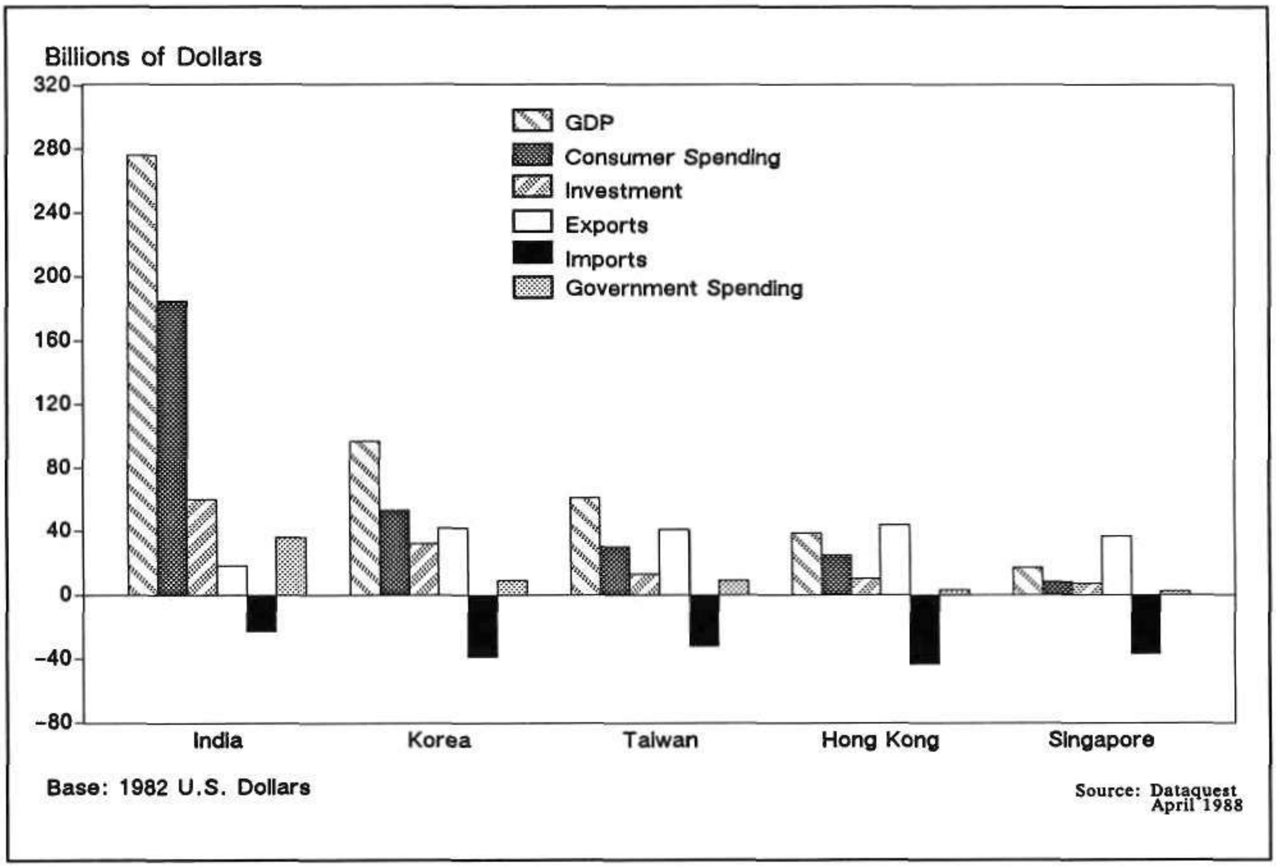


Figure 11. Newly Industrializing Countries' Components of 1987 GDP

Asian NICs continue to take advantage of the manufacturing opportunities and export markets opened by a weak dollar and strong yen. The countries of choice for United States and Japanese manufacturing investment have grown beyond the basic industry stage in many sectors, and have begun to successfully challenge for international market share. In particular, Taiwan and South Korea posted record levels of exports to the United States in 1987, ranking fourth and eighth on the list of U.S. suppliers. The most striking aspect in this can be seen in Figure 10, where the 1987 $18.3 billion U.S. trade deficit with Taiwan is second only to Japan, and has increased $3.6 billion over 1986. The U.S.-Korea deficit at $9.2 billion is half the Taiwan deficit size, but is growing at a faster rate. The pending U.S. removal of Taiwan, Korea, Hong Kong, and Singapore from the U.S. Generalized System of Preferences recognizes the U.S. status as 40 to 50 percent of their export markets, the relative restriction of their own domestic markets, and the consequent contribution to the U.S. trade deficit.

Korea, along with Taiwan, has been the major beneficiary of the yen's appreciation against the U.S. dollar, the Korean won, and the Taiwanese dollar. Trade surpluses, a drop in oil prices, and lower international interest rates have enabled the Korean government to halt foreign borrowing and begin to repay existing debts. Real GDP growth in 1987 was 12.5 percent, repeating 1986. Korean industry has been heavily dependent on imported Japanese capital equipment to continue manufacturing expansion, and this has been the source of a growing trade deficit with Japan, as well as an added stimulus in the Korean competitive attitude toward Japan. In efforts to reduce the trade deficit with Japan and the surplus in U.S. trade, the Korean government is pressuring manufacturers to shift part of their export sales efforts to Japan and away from the United States. Real GDP growth is expected to continue at a 9.0 percent rate through 1988-1989.

Taiwan has a far more decentralized industrial base than Korea, and as a percent of GDP, spends one-third less overall than the Koreans on fixed investments and capital equipment. The Taiwanese rate of growth in industrial production is, not surprisingly, 85 percent of the Korean rate, and is more concentrated in textiles and other light manufactured products, which are more vulnerable to foreign trade legislation. In programs to assist the capitalization and expansion of Taiwanese industry, the government is sponsoring centralized industrial parks and technology research institutions, with some notable successes. The administration of these programs is very active in promoting strategic alliances with Taiwanese and foreign companies for joint R&D, manufacturing, and East Asian market development.

Singapore is a recognized base for multinational manufacturing, and electronics and is becoming the central theme in the economy. More than 180 foreign companies have now established plants in the city-state, responding to a series of generous government incentives. In an aggressive move to accelerate this process, the Singaporean government will cover 74 percent of the construction costs for a $40 million wafer-fabrication plant to be built this year, in conjunction with National Semiconductor and Sierra Semiconductor, who have 9 and 17 percent shares, respectively.

Hong Kong, like Singapore, is a reexporting economy. A record 14.8 percent GDP growth in 1987 followed 11.0 percent the previous year, and is expected to continue at 9.0 percent through 1989. Textiles and apparel make up more than 40.0 percent of Hong Kong's exports and the bulk of shipments to the United States. Exports to the United States were up by 14.0 percent, while the Hong Kong-U.S. trade surplus increased by $119 million, or 2.0 percent. Strong domestic demand and increased trade with China will be major contributors to 1988 growth.

Hong Kong exporters have benefited from the Hong Kong dollar's stability against the U.S. dollar since 1985, in comparison with the Korean and Taiwanese currencies, which have appreciated 15 percent and 30 percent, respectively. The domestic economy has not suffered unduly, primarily because 45 percent of Hong Kong's consumer goods and food comes from the People's Republic of China

(PRC), and the Chinese reminbi has dropped 20 percent in value relative to the dollar. A revaluation of the Hong Kong dollar in the near term is unlikely.

India's 1987 4 percent growth in real GDP will continue through 1988 and 1989. International trade runs a $5 billion per year deficit. The government's past constraints on competition have effectively protected most of the domestic market, but the lack of stimulation has produced little technological innovation. This is beginning to change. The government has begun loosening restrictions on imports of systems, peripherals, and components. Efforts to encourage hardware assembly, especially software development in joint partnerships with foreign companies, have seen some modest successes. Indians believe that the most promising opportunities lie in matching their large pool of technically trained, English-speaking manpower with the worldwide demand for software. If the weighty Indian bureaucracy and start-up productivity levels can be overcome, Indian software technology will become a world force.

The reference statistics in Table 3 comprise GNP/GDP growth rates for the United States and its trading partners that were discussed in this document.

Table 3. Reference Statistics
(Percentage Changes from Previous Period, SAAR*)

	1983	1984	1985	1986	1987	1988	1989
Growth of Real GNP/GDP							
United States	3.6	6.8	3.0	2.9	2.8	2.8	2.2
Japan	3.2	5.1	4.7	2.4	3.5	3.5	3.0
West Germany	1.9	3.3	2.0	2.5	1.5	1.3	1.3
France	0.7	1.4	1.7	2.0	1.5	1.5	1.3
United Kingdom	3.3	2.7	3.6	3.3	3.8	2.8	1.8
Italy	0.5	3.5	2.7	2.7	2.8	2.0	1.8
Canada	3.2	6.3	4.3	3.3	3.6	2.8	2.3
Growth of Private Consumption							
United States	4.6	4.8	4.6	4.2	1.9	2.0	2.3
Japan	3.2	2.7	2.6	2.7	3.3	3.3	3.0
West Germany	1.7	1.5	1.8	4.3	2.5	2.8	2.3
France	0.9	1.0	2.4	3.3	1.8	1.5	1.0
United Kingdom	4.0	2.1	3.7	5.8	4.5	3.3	2.3
Italy	0.4	2.2	2.7	3.2	4.5	2.5	2.0
Canada	3.4	4.3	5.2	3.9	4.0	2.3	2.3
Growth of Government Consumption							
United States	1.1	4.4	7.3	3.8	1.8	1.9	0.8
Japan	2.9	2.8	2.0	6.6	(0.3)	2.5	3.0
West Germany	0.2	2.4	2.1	2.3	2.0	1.8	1.5
France	2.1	1.1	3.2	2.7	2.5	2.0	1.8
United Kingdom	1.9	0.8	(0.1)	0.9	0.5	1.0	1.0
Italy	2.8	2.0	3.5	3.0	2.8	2.5	1.8
Canada	1.4	1.5	2.7	1.0	2.0	1.8	1.0

(Continued)

Table 3. Reference Statistics
(Percentage Changes from Previous Period, SAAR*) (Continued)

	1983	1984	1985	1986	1987	1988	1989
Growth of Gross Fixed Investment							
United States	8.2	16.8	5.5	1.8	0.5	4.8	3.0
Japan	(0.3)	4.9	5.6	6.6	8.5	4.8	3.1
West Germany	3.1	0.8	0.1	3.1	1.0	1.5	1.0
France	(3.6)	(2.3)	1.1	3.1	3.0	2.5	2.3
United Kingdom	5.2	8.2	3.1	0.3	4.8	5.8	3.5
Italy	(1.6)	4.4	3.3	1.2	2.8	2.5	1.3
Canada	(0.7)	1.6	8.1	5.1	8.0	3.0	2.3
Growth of Real Exports							
United States	(3.8)	6.8	(1.7)	3.3	12.0	14.3	9.3
Japan	4.2	17.5	5.3	(4.8)	2.0	3.0	3.5
West Germany	(0.5)	9.0	7.2	(0.1)	0.0	1.0	1.0
France	3.7	7.1	2.1	(0.7)	(0.8)	2.5	2.5
United Kingdom	2.0	7.0	5.7	3.1	5.5	2.0	1.5
Italy	2.3	7.6	4.0	3.1	(1.0)	3.5	3.0
Canada	6.4	18.8	6.0	4.7	3.8	3.5	3.3
Growth of Real Imports							
United States	9.6	23.9	3.9	10.5	5.0	1.3	2.3
Japan	(5.1)	11.1	(0.1)	3.6	6.3	7.5	4.8
West Germany	0.6	5.3	4.7	3.5	3.3	3.5	3.5
France	(2.7)	2.8	4.7	6.9	4.8	3.0	3.0
United Kingdom	5.8	9.8	2.8	6.2	5.8	4.5	4.0
Italy	(1.6)	11.3	5.3	5.1	6.3	4.8	4.3
Canada	9.0	16.6	8.3	7.2	4.5	3.5	3.0

*Seasonally adjusted annual rate

Source: Dataquest
April 1988

Glossary

balance of payments. A double-entry accounting of the value of all exchanges and transfers of goods, services, capital loans, investments, and gold and international reserves between the public and private sectors of a given country and the rest of the world over a given time, usually one year. Balance of payments is divided into three accounts—current, capital, and the reserve and gold account.

balance of trade. The difference between the value of a country's exports and imports of *tangible goods* over a given period, usually one year.

balance on current account. See **current account.**

capacity utilization. The ratio of actual production output to potential production output, with existing plant, workers, and equipment.

capital account. Balance of payments category for the inward and outward flow of investment capital.

capital goods. All goods used for the *production* of other goods and services. See also **consumer goods.**

consumer. An individual who buys goods and services for personal use, rather than for manufacturing, processing, or resale.

consumer goods. Products used directly to satisfy human needs or wants, such as food and clothing. The distinction between consumer and capital goods lies in how products are *used* rather than in the products themselves.

consumer price indices (CPI). Monthly measures by the U.S. Bureau of Labor Statistics of the average retail prices of products commonly bought by households, compared with the average prices of a selected base year.

consumption. Expenditures for durable goods, nondurable goods, and services.

current account. Balance of payments category for **goods and services.** The difference between total exports and imports of goods and services is the **balance on current account.**

disposable income. An individual's income remaining after any payments to government (taxes, fines), and thus available for either spending or saving.

durable goods. Items that yield their services over an extended period of time, generally three years or more. Durables are often divided into the categories of *producer durables* (e.g., metals, machinery, equipment), and *consumer durables* (e.g., automobiles, appliances).

external debt. The total sum of a country's public and private debt owed to foreigners.

federal debt, federal deficit. See **public debt, public deficit.**

fixed investment. Assets for production of goods or services that cannot be quickly converted into money without disrupting operations, such as plant and equipment.

goods. Tangible items of trade, such as automobiles or shoes. Merchandise.

gross domestic product (GDP). The total market value of all goods and services produced each year within the domestic borders of a nation.

gross national product (GNP). GNP equals GDP plus the net of income accrued by domestic residents from investments abroad minus income earned in the domestic market by foreigners abroad.

gross national product deflator. A revision in the calculation of GNP derived by adjusting each component of GNP for price changes, then summing each into a weighted total. The result thus measures both changes in prices and shifts in consumption patterns.

industrial production index. A monthly measure of the quantity of U.S. output in mining, manufacturing, and utilities industries compared with a base year and seasonally adjusted.

inflation. A sustained increase in the average level of all prices.

internal debt. The total sum of a country's public and private debt owed to citizens of the same country.

investment. Expenditures for capital goods.

invisibles. Items of foreign trade that are intangible, such as banking, insurance, tourism, and transportation. Unlike visibles, such items are not recognized by customs and until recently were not reported in trade statistics.

nominal GDP/GNP. GDP/GNP valued in prices prevailing at the time of measurement. Year-to-year changes then reflect differences in both quantities and market prices.

nondurable goods. Items that yield their services over a short period of time, generally less than three years. Examples are food, clothing, paper, chemicals, petroleum, rubber.

private. Relating to individuals and businesses, rather than government.

producer price indices (PPI). Monthly measures by the U.S. Bureau of Labor Statistics of the prices of 2,800 representative commodities compared with those prices of a given base year.

public. Relating to local, state, or national governments.

public debt. The sum of debts outstanding of local, state, and national governments in a given country. Debt of the national government alone is the *national public debt* or *national debt*. In effect, the public debt is a measure of the extent to which government expenditures are financed by borrowing rather than taxation.

public deficit. Circumstance where government outlays for goods and services exceed receipts for a fiscal year.

real GDP/GNP. GDP/GNP valued in *constant* prices prevailing in a reference base year—1982 in this publication. Year-to-year changes thus reflect changes only in *quantities* produced.

recession. A broad downward movement of the economy over an extended time. Generally defined for the U.S. as two successive quarterly decreases in U.S. GNP.

seasonal variation. A regularly recurring pattern of change in economic activity owing to factors such as periodic climate changes, holidays, and vacations. Seasonal variations are commonly adjusted for in the analysis of data to clarify overall trends.

services. Intangible items of trade, such as education, transportation, banking, legal and medical care.

terms of trade. The ratio of the average price of a country's exports to the average price of its imports.

visibles or visible goods. Tangible items of foreign trade.

Dataquest

a company of The Dun & Bradstreet Corporation

1290 Ridder Park Drive
San Jose, California 95131-2398
(408) 437-8000
Telex: 171973
Fax: (408) 437-0292

Dataquest Boston
1740 Massachusetts Avenue
Boxborough, MA 01719
(617) 264-4373
Telex: 171973
Fax: (617) 263-0696

Dataquest International Offices:

Dataquest GmbH
Rosenkavalierplatz 17
D-8000 Munich 81
West Germany
Phone: (089)91 10 64
Telex: 5218070
Fax: (089)91 21 89

Dataquest Japan Limited
Taiyo Ginza Building/2nd Floor
7-14-16 Ginza, Chuo-ku
Tokyo 104 Japan
Phone: (03)546-3191
Telex: 32768
Fax: (03)546-3198

Dataquest UK Limited
13th Floor, Centrepoint
103 New Oxford Street
London WC1A 1DD
England
Phone: (01)379-6257
Telex: 266195
Fax: (01)240-3653

Dataquest SARL
Tour Gallieni 2
36, avenue Gallieni
93175 Bagnolet Cedex
France
Phone: (1)48 97 31 00
Telex: 233 263
Fax: (1)48 97 34 00

Dataquest Taiwan
Rm. 801, 8th Fl., Ever Spring Bldg.
147, Sec. 2, Chien Kuo N. Road
Taipei, Taiwan, R. O. C. 104
P. O. Box 52-25, Tienmou 111
Phone: (02)501-7960/501-5592
Telex: 27459
Fax: (02)505-4265

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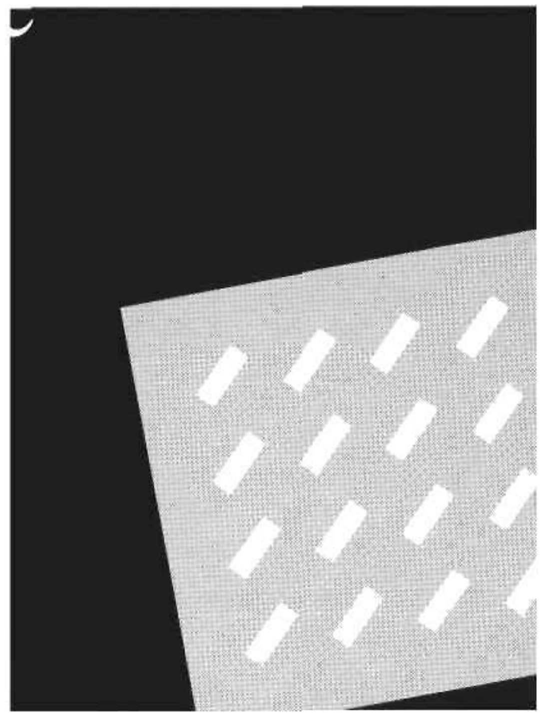

Economic Outlook Update

1988–1990

Dataquest

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The Dun & Bradstreet Corporation

Published by Dataquest Incorporated

Preface

This report is an update to the *Economic Outlook 1988-1989* that was published by Dataquest in early 1988. As such, many references and definitions in this report assume the reader will use it as a continuation of the data and projections in the previous report.

Highlights contained in this report are:

- Real U.S. GNP growth will continue at an average 3.4 percent annualized rate through the first quarter of 1989 then will slow through the last three quarters of that year. Overall 1989 real GNP will be 2.8 percent greater than the record for 1988. A recession is forecast in the first two quarters of 1990, followed by a sharp rebound led by consumer spending and private investment in the second half of the year.

- The rate of U.S. domestic spending on capital equipment and production capacity improvement that saw double-digit growth in the first half of 1988 will gradually slow until reaching negative growth in the fourth quarter of 1989. Investment spending will continue to decrease in early 1990, particularly in the second quarter. Improvement will follow in the second half.

- The U.S. trade deficit will show steady improvement toward a negative $50 billion annualized level by mid-1990, when higher interest rates and a stronger dollar will begin to attenuate the rate of progress.

- The U.S. federal budget deficit will be largely unaffected by the national elections and existing Gramm-Rudman legislation. New federal programs in 1990 will be funded by additional consumption taxes, changes in personal income tax ceilings, reductions in some personal tax credits and federally mandated shifts in some worker-related program funding to corporations.

Introduction

The last years of the 1980s are an exciting time. Political and economic events are unfolding in the United States and throughout the world in a vast interactive network. The influence of these economic developments is significant in our daily lives, in the prospects for business endeavors, and from the perspective of strategic national interests. The international influence of nations is based on their relative economic strengths, and long-term economic changes are resulting in unmistakable geographical shifts of power.

During autumn of 1988, we will see developments on many issues important to the nations listed below, that may cause reverberations in the economic outlooks of other nations:

United States

In the United States, Americans are wrestling with massive deficits in the federal budget and in international trade. Both problems will be treated with platitudes in the upcoming national elections due to the political realities of playing for votes and avoiding special-interest sensitivities. However, after the election, both issues will affect greatly the programs of the new president and his administration's performance rating.

Canada

Political debate is reaching a climax in Canada and the United States on the pending free trade agreement between the two countries. The Liberal opposition to Prime Minister Mulroney has threatened to delay action until Mr. Mulroney calls parliamentary elections, which in effect is a national referendum on free trade.

Japan

What country is the world's biggest donor of foreign aid, the second-largest contributor to the United Nations, and has the world's third-largest defense budget? Answer: Japan, with a $10 billion budget for foreign aid in 1988, pushing past the United States' $9.2 billion program. The Japanese are just beginning to formulate the manner and direction in which they will exercise their new economic power and wealth.

U.S.S.R.

The fascinating cultural and political experiments by Mikhail Gorbachev in attempt to rejuvenate the Soviet economy, coupled with the warming of U.S.-Soviet relations, have already resulted in benefits to U.S. electronics companies through a relaxation of U.S. technology export regulations.

Iran and Iraq

Iran and Iraq appear to be approaching a cease-fire that, if realized, will directly affect crude oil production and prices as the two countries boost output to help recover from the destruction and $300 billion expense of their eight-year war.

EEC

The 12-country European Economic Community (EEC) is proceeding steadily toward its target of standardizing internal financial regulations and eliminating *internal* trade restrictions by 1992. There are growing indications that the Europeans will implement strong protectionist measures to favor European "national champion" computer and telecommunications companies in the form of import quotas, bidding restrictions on government contracts, and minimum local content requirements on hardware.

In effect, they may replace national trade barriers with one large trade barrier around the entire community.

Taiwan and the Peoples' Republic of China

Taiwan and the Peoples' Republic of China are quickly warming to the possibilities of increased cooperation in bilateral trade, investment, and travel. China has raw materials, cheap labor, and is starved for foreign capital, while Taiwan needs to reduce manufacturing costs and continue to expand into new markets.

How will these events affect the electronics industry? What new opportunities will emerge? What are the best strategies to anticipate these changes? For U.S. multinational companies, the answers are based in part on expectations for the outlook for the U.S. economy through 1990.

United States International Trade

U.S. exports continue to surge ahead in the third quarter of 1988, at a pace 30 percent greater than the same period to date in 1987. U.S. industry's export record in 1987 was itself the largest one-year increase this decade: an 11 percent increase over 1986. The bulk of U.S. export volume is in chemicals, auto parts and subassemblies, industrial machinery (including computers and associated hardware) and raw materials. Many of these exporting industries were forced to restructure and upgrade production processes earlier in the decade in order to stay competitive when the dollar's value was peaking. The dollar's three-year (1985-1988) slide has since been accompanied by an acceleration of international sales.

Exporting companies began to feel the effects of the cheaper dollar in mid-1985, as the dollar began to decline and significant international orders followed shortly thereafter. This key relationship between dollar exchange rates and export sales is illustrated in Figures 1 and 2. Dollar exchange rates reached bottom in early 1988 and have shown a recent tendency to creep upward. Dataquest expects the index of dollar exchange rates against trade-weighted currencies will remain close to current levels through 1989, before mid-1990 increases bring the dollar back up to 1986 levels.

Where are U.S. exports going? Figure 3 ranks geographical markets in descending order by aggregate merchandise export value from January through May this year, compared with the same period last year. Western Europe alone accounts for more than $7 billion of the $30 billion export increase so far in 1988. When U.S. exports to Canada and Japan are included, these three market areas constitute 62 percent of the export trade, and 52 percent of the 1988 year-to-date increase. Percentage increases in export values through May of 1988 compared with the same period in 1987 are graphed in Figure 4.

It is worth noting in the midst of this success that most of the 1988 improvement in U.S. international trade has come in established markets, such as Western Europe, that are growing at slower rates than Pacific Rim economies. U.S. companies still focus their export strategies largely toward Europe, and think of Asian countries primarily in terms of defensive marketing strategies. U.S. exporters must quickly recognize that the Pacific Rim is a top priority market equal in value to the U.S. export trade with Western Europe, and will be twice the value of U.S.-European trade before the turn of the century.

U.S. import activity for 1988 to date is compared with the same period in 1987 in Figure 5, reflecting some percentage shifts toward new sources of imports from Asia and South America.

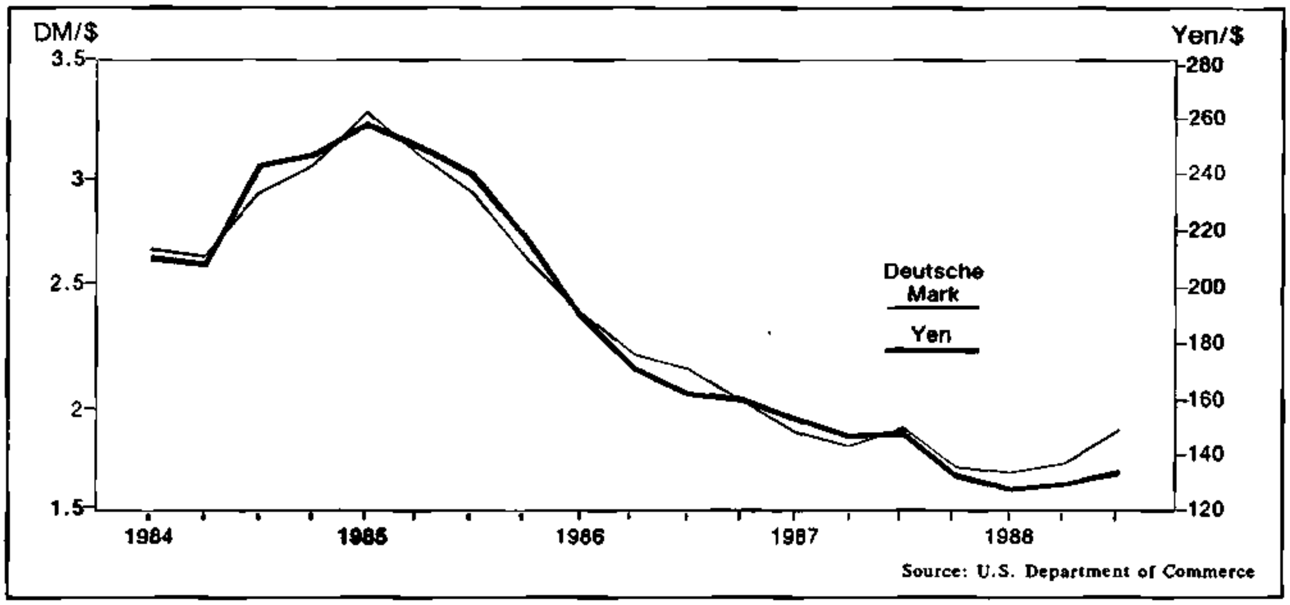

Figure 1. Dollar Exchange Rates (Quarterly Averages) 1984-1988

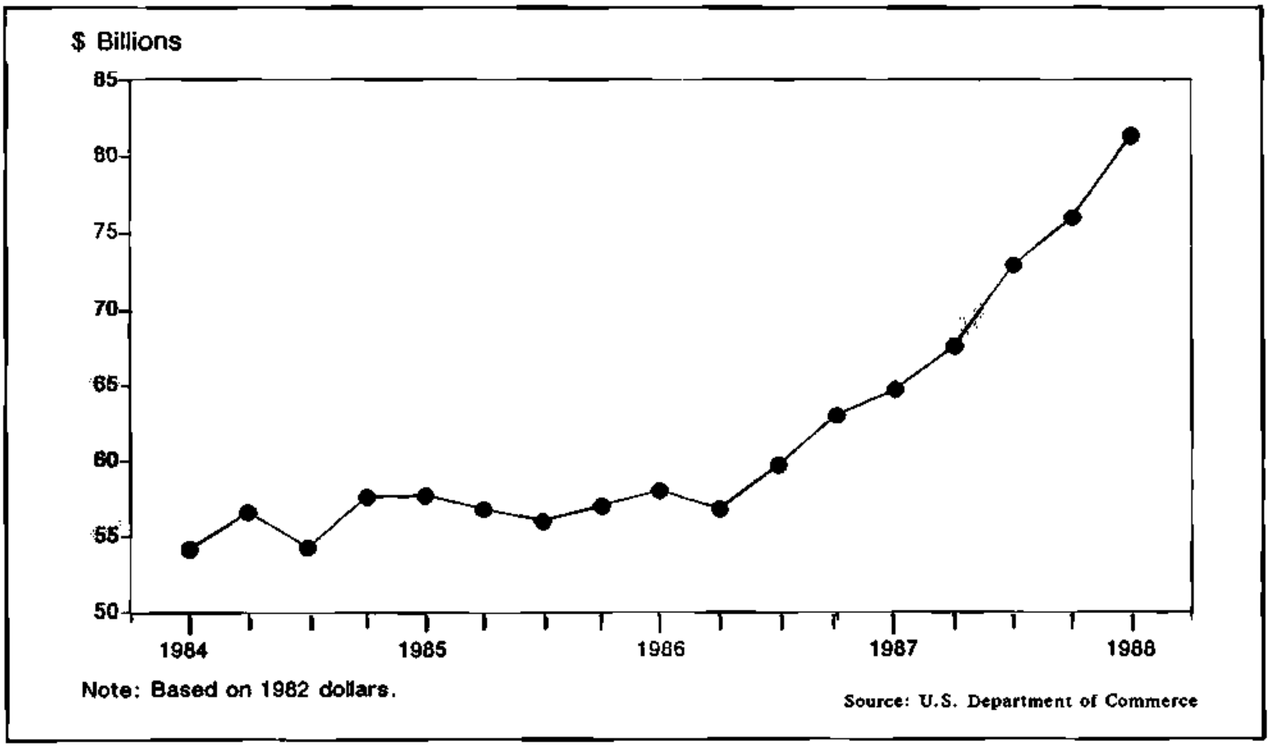

Figure 2. U.S. Merchandise Exports (Quarterly) 1984-1988

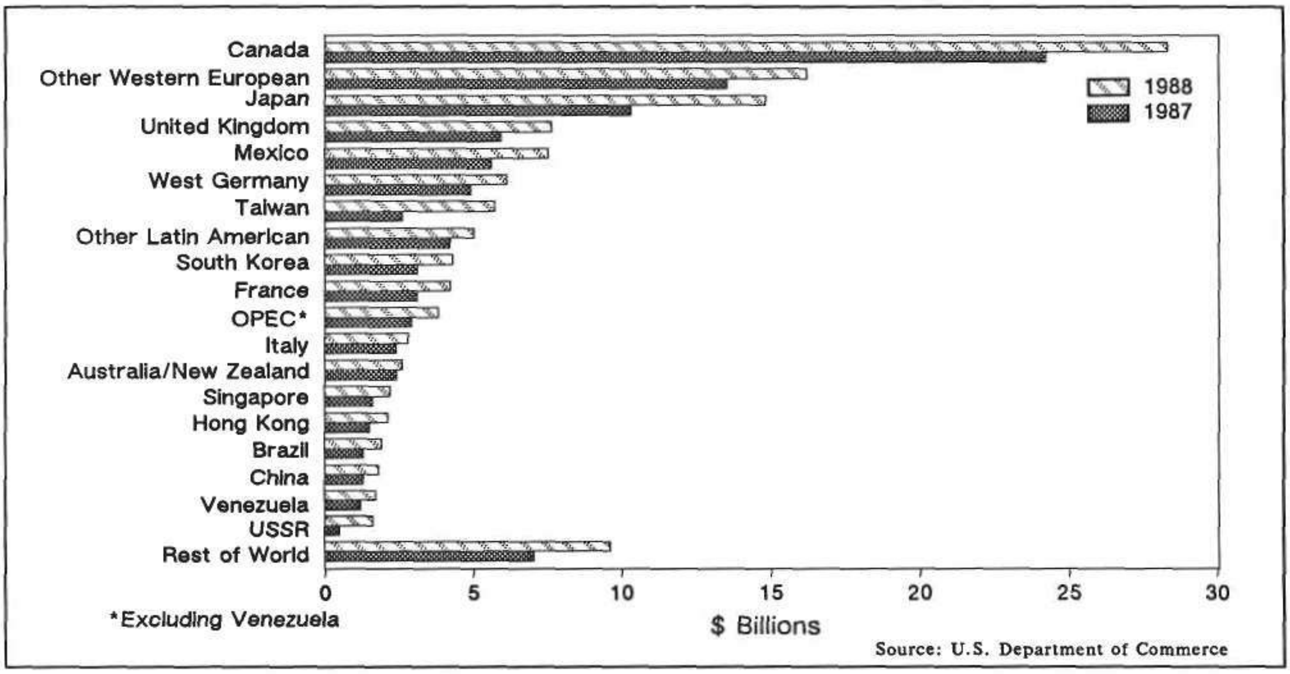

Figure 3. Comparison of U.S. Export Markets, January-May 1988 versus January-May 1987 (Bilions of Dollars)

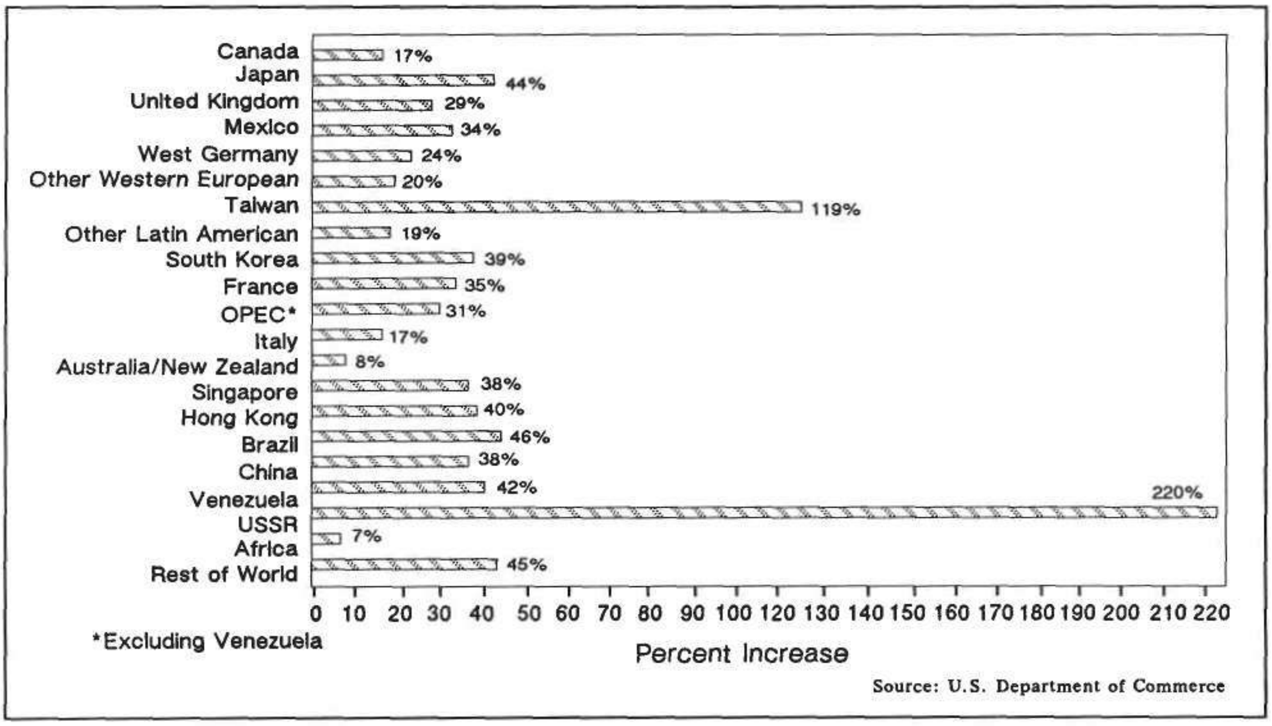

Figure 4. U.S. Merchandise Exports—Percentage Increases January-May 1988 versus January-May 1987

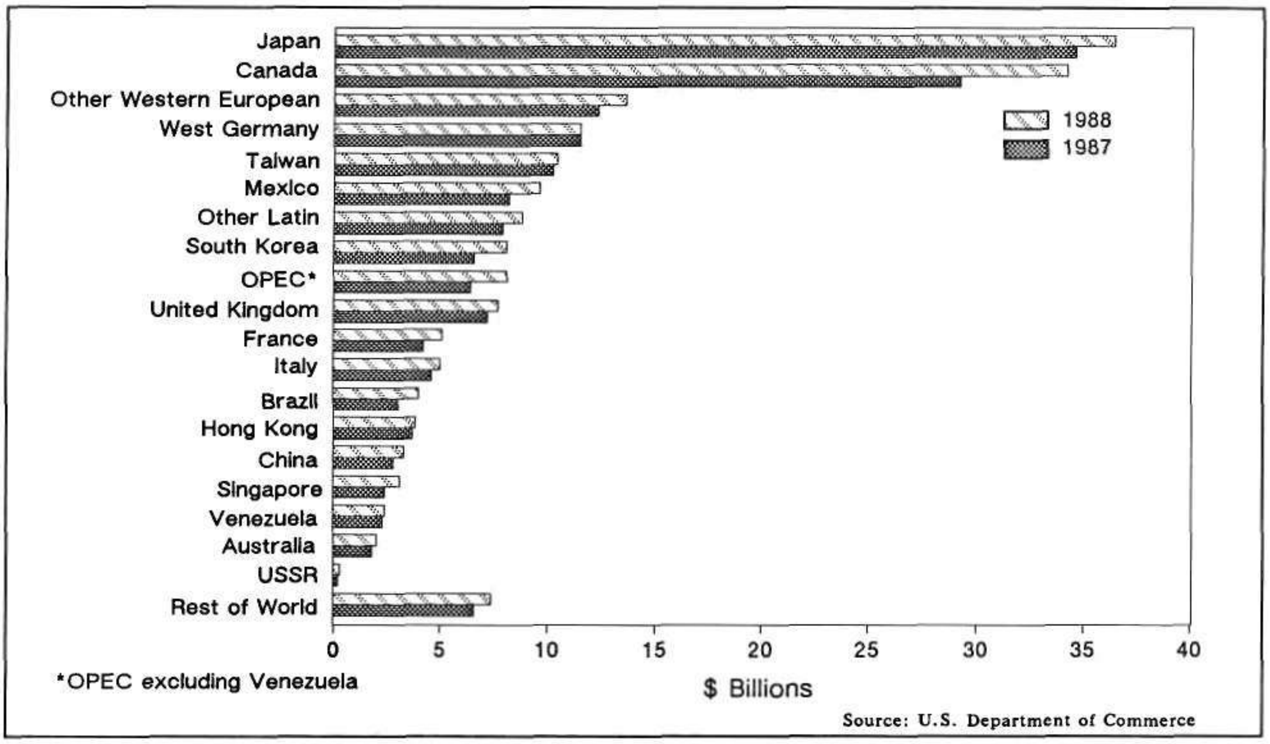

Figure 5. Comparison of U.S. Import Activity, January-May 1988 versus January-May 1987 (Bilions of Dollars)

What about the specific markets for electronics goods? Figure 6 ranks the top twelve national markets for three basic categories of American electronic products: computers, semiconductors, and telecommunications equipment. Canada, the United Kingdom, and Japan remain the top three markets in a pattern and product mix very similar to that of 1987. Figures 7 and 8 compare 1988 and 1987 electronics import and export activity through April of each year. In general, computer equipment shows the largest absolute increase: $1.9 billion in exports so far this year compared with the same period in 1987, a 36 percent increase. Telecommunications equipment accounted for the largest rise with an increase in export value of 40 percent.

Imports of foreign goods into the U.S. have slackened slightly, as importers have struggled to remain price-competitive in the face of weak dollar exchange rates. A significant part of this process has been a growing shift toward less-expensive imports from newly industrializing countries, particularly the Republic of Korea, Brazil, Singapore, and China. The American consumer's passion for imports has not diminished; it has been transferred to other, cheaper, sources of supply.

Figure 9 demonstrates the continuing close linkage between U.S. consumption, measured by final sales to domestic purchasers, and the value of imported goods into the United States. Final sales is an accurate measure of domestic demand in that it includes import sales and excludes unsold inventory and exports. Dataquest forecasts diminishing annual rates of increase in final sales, measured quarterly, through the remainder of 1988 and into early 1990. These and other projections are contained in Table 1. Along with a forecast of continued export strength, a corresponding decrease in the U.S. international trade deficit is projected, lowering it to an annualized $50 billion level by the middle of 1990. Figure 10 shows the history and Dataquest forecast of total merchandise trade on a quarterly basis through 1990.

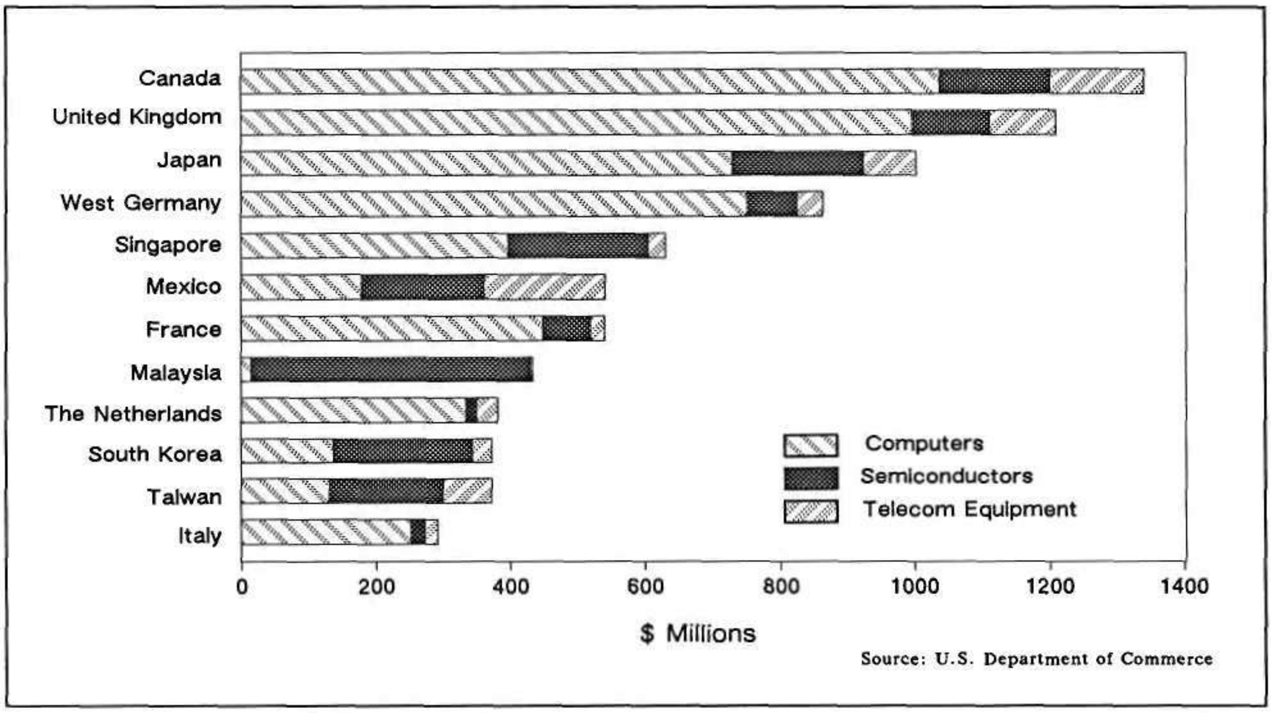

Figure 6. U.S. Electronics Exports—January-April 1988, Top Twelve Markets

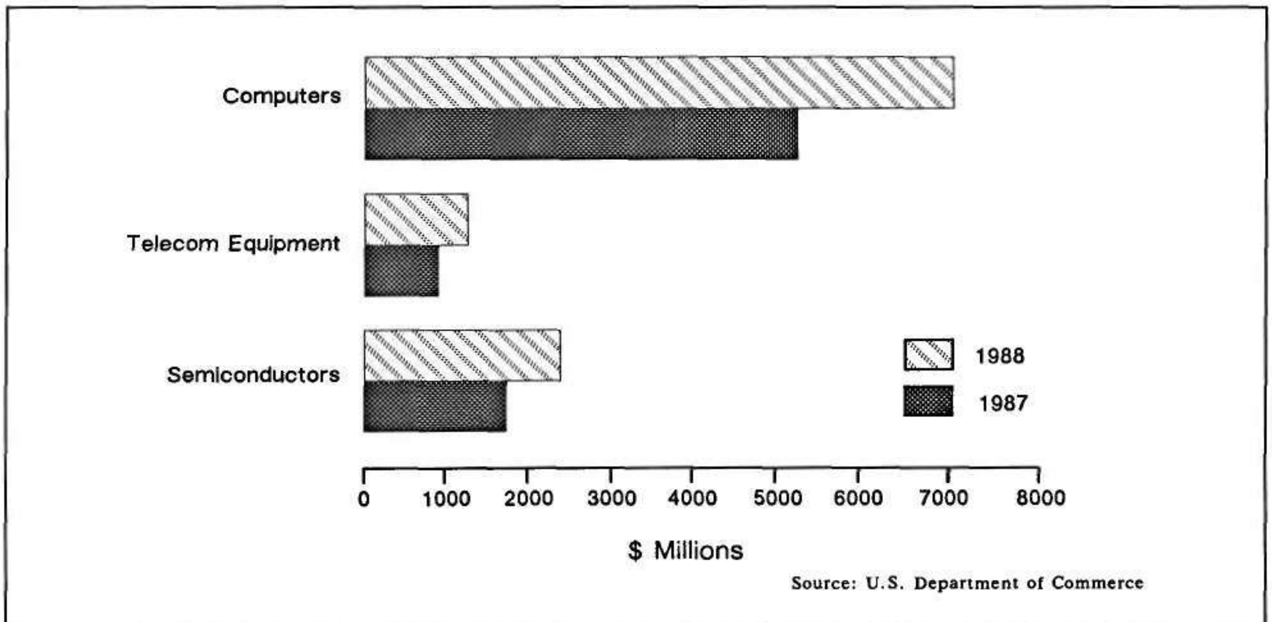

Figure 7. U.S. Electronics Exports January-April 1988 versus January-April 1987

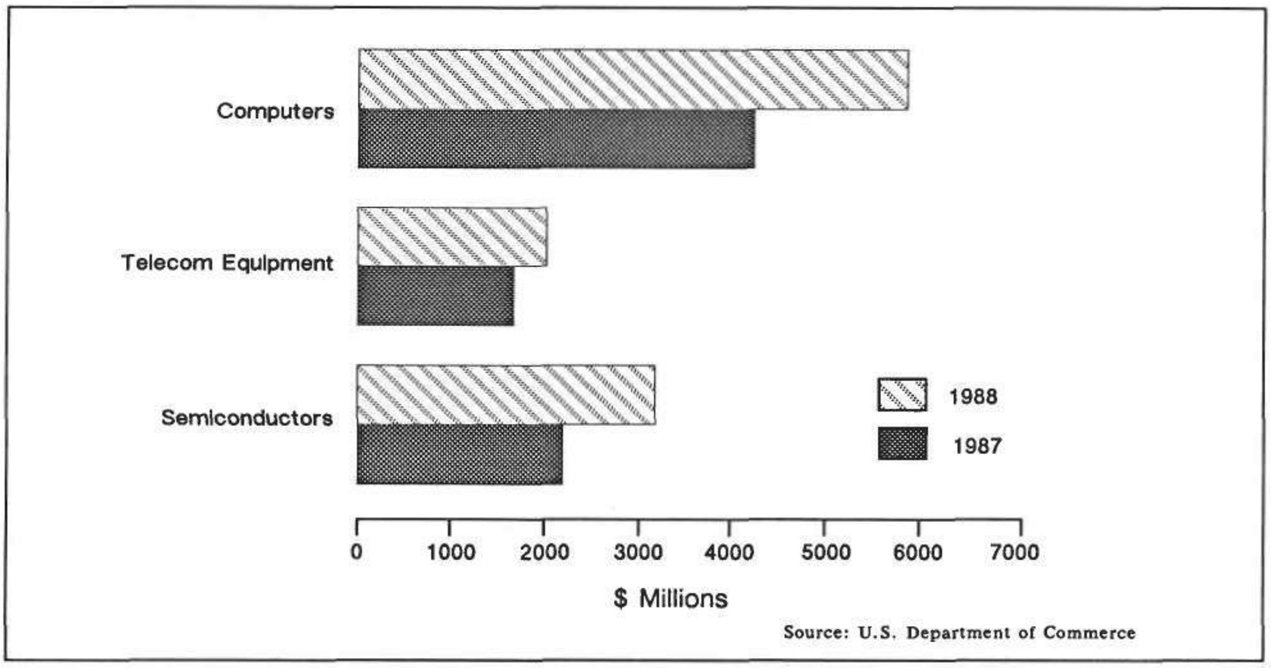

Figure 8. U.S. Electronics Imports January-April 1988 versus January-April 1987

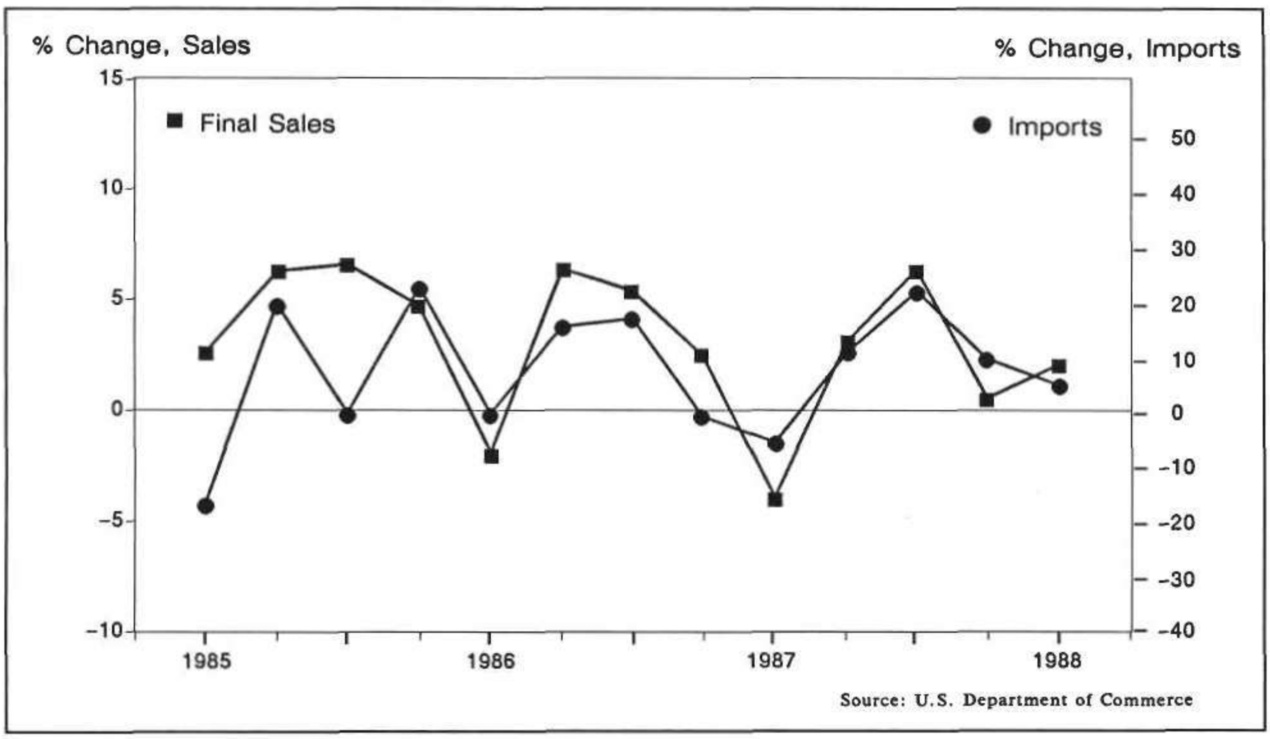

Figure 9. Final Sales to Domestic Purchasers versus Imports (Quarter-to-Quarter Changes) 1985-1988

Table 1. Dataquest Economic Forecast, 1988-1990

	1988 Q1	1988 Q2	1988 Q3	1988 Q4	Average 1988	1989 Q1	1989 Q2	1989 Q3	1989 Q4	Average 1989	1990 Q1	1990 Q2	1990 Q3	1990 Q4	Average 1990
Real GNP, SAAR	$3,956	$3,988	$4,015	$4,049	$4,002	$4,084	$4,110	$4,127	$4,134	$4,114	$4,109	$4,092	$4,132	$4,185	$4,129
% Change, Year Ago	4.8%	4.3%	3.9%	3.2%		2.4%	3.0%	2.8%	2.1%		0.6%	(0.4%)	0.1%	1.2%	
% Change, Annual Rate	3.4%	3.3%	2.6%	3.4%		3.4%	2.7%	1.7%	0.7%		(2.4%)	(1.6%)	3.9%	5.1%	
Consumer Spending	2,560	2,576	2,591	2,612	2,585	2,630	2,643	2,651	2,656	2,645	2,641	2,638	2,668	2,703	2,663
% Change, Year Ago	2.8%	2.4%	1.8%	3.2%		2.1%	2.7%	2.3%	1.7%		0.5%	(0.1%)	0.6%	1.7%	
% Change, Annual Rate	4.5%	2.5%	2.3%	3.3%		2.7%	2.1%	1.2%	0.7%		(2.1%)	(0.3%)	4.4%	5.0%	
Fixed Investment	473	489	501	512	494	520	526	529	527	525	518	503	505	514	510
% Change, Year Ago	13.2%	12.5%	8.2%	10.2%		9.8%	7.6%	5.7%	2.8%		(0.3%)	(4.5%)	(4.6%)	(2.3%)	
% Change, Annual Rate	7.6%	16.0%	9.7%	9.7%		5.8%	5.3%	2.1%	(2.0%)		(6.2%)	(11.3%)	1.5%	7.7%	
Equipment Investment	349	362	372	384	367	392	399	402	400	398	392	377	379	388	384
% Change, Year Ago	17.6%	15.3%	11.2%	15.3%		12.1%	10.3%	8.1%	4.3%		0.1%	(5.5%)	(5.7%)	(3.0%)	
% Change, Annual Rate	21.6%	14.8%	12.2%	12.8%		8.4%	7.5%	3.2%	(2.0%)		(7.3%)	(14.5%)	2.1%	10.1%	
Residential Investment	190	191	190	189	190	190	190	191	191	190	189	190	195	204	194
Government Purchases	776	777	792	796	785	799	802	810	812	806	806	808	815	820	812
% Change, Year Ago	0.5%	0.6%	1.2%	0.4%		2.9%	3.1%	2.3%	2.0%		0.9%	0.8%	0.5%	1.0%	
% Change, Annual Rate	(7.9%)	0.4%	8.0%	1.8%		1.5%	1.4%	4.4%	0.8%		(3.1%)	1.1%	3.3%	2.8%	
Net Exports	(109)	(90)	(96)	(93)	(97)	(88)	(83)	(77)	(67)	(79)	(55)	(48)	(48)	(51)	(50)
Inventory Change	66	45	37	33	45	33	32	23	15	26	10	1	(3)	(5)	1
Final Sales to Domestic Purchasers	3,975	4,019	4,049	4,077	4,030	4,093	4,101	4,117	4,132	4,111	4,136	4,157	4,196	4,235	4,181
% Change, Year Ago	3.0%	3.3%	2.5%	3.1%		3.0%	2.0%	1.7%	1.3%		1.1%	1.4%	1.9%	2.5%	
% Change, Annual Rate	1.9%	4.5%	3.0%	2.9%		1.6%	0.8%	1.5%	1.5%		0.4%	2.1%	3.8%	3.7%	
Dollar Exchange Rate Index	147	149	150	149	149	146	143	140	140	142	144	148	152	156	150
% Change, Year Ago	(0.3%)	1.8%	0.5%	0.4%		(0.7%)	(4.0%)	(6.7%)	(6.0%)		(1.4%)	3.5%	8.6%	11.4%	
% Change, Annual Rate	0.1%	5.4%	2.7%	(2.7%)		(8.1%)	(8.2%)	(8.4%)	0.0		11.4	11.1%	10.8%	10.5%	
Unemployment Rate	5.7%	5.4%	5.3%	5.2%	5.4%	5.4%	5.5%	5.7%	6.0%	5.7%	6.6%	7.4%	7.4%	7.3%	
Interest Rates															
3-Month T-Bills	5.7%	6.2%	6.9%	7.0%	6.5%	7.2%	7.9%	8.4%	8.9%	8.1%	8.6%	8.1%	7.7%	7.3%	7.9%
30-Year T-Bonds	8.6%	9.1%	9.2%	9.6%	9.1%	10.2%	10.6%	10.9%	10.1%	10.4%	9.3%	9.0%	8.8%	9.0%	9.0%
Savings Rate	4.7%	4.4%	4.3%	4.3%	4.4%	4.4%	4.6%	4.7%	4.3%	4.6%	4.4%	4.5%	4.4%	4.2%	4.4

Note: Values shown are billions of 1982 dollars and are seasonally adjusted annual rates.

Source: U.S. Department of Commerce
Dun & Bradstreet
Dataquest
September 1988

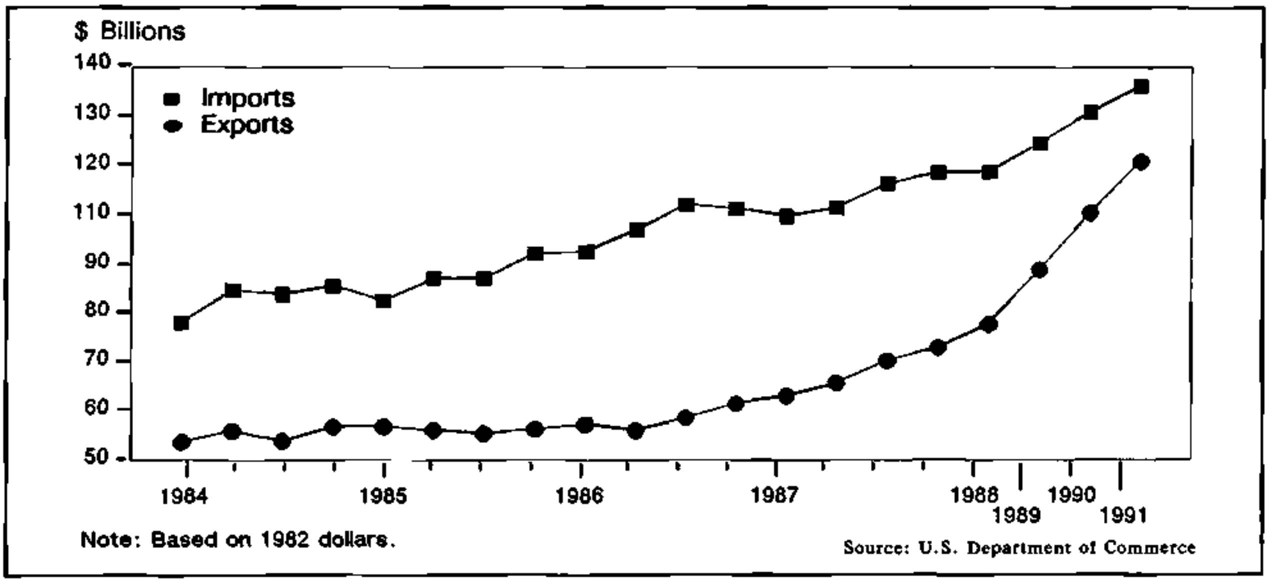

Figure 10. U.S. Merchandise Trade, Quarterly 1984-1990

The status of U.S. trade from February through May 1988 is shown in Figure 11. The predominant roles of Japan and Canada in the current U.S. trade position can be seen clearly, as can the broad distribution of the U.S. deficit across many markets. The fruitful relationship between the United States and Canada offers the United States more near-term possibilities for improved trade activity than does the U.S.-Japan trade relationship. This potential improvement centers on the pending free-trade agreement now being debated in both national legislatures. Seventy-five percent of the $140 billion value of goods passing between the two countries is currently duty free, while the remainder is subject to Canadian duties averaging 9.9 percent and U.S. duties of 3.3 percent. The agreement will remove all tariffs and many nontariff barriers to bilateral trade over 10 years, establishing rules for trade in services, investments, hydroelectric and petroleum energy, and government procurement activity. Studies by the two governments have concluded that this stimulus to direct trade ultimately could add as much as 10.0 percent to the Canadian GNP and 1.0 percent to that of the United States. Congress likely will approve the measure by September, but Liberal and New Democratic opposition leaders in the Canadian Parliament may force national elections this fall as a trade referendum. Canadian objections to final approval relate to the regulation of subsidies, procedures for settlement of disputes, and deep Canadian concern about dilution of their cultural and economic sovereignty by their southern partner.

More than 24 percent of U.S. exports go to Canada, while 17 percent of imports into the U.S. come from Canada, but in 1987 the net difference was a U.S. trade deficit of $12 billion. By comparison, 11 percent of U.S. exports are shipped to Japan, and 21 percent of U.S. imports are Japanese goods. U.S. exports to Japan are accelerating much faster than imports, 44 percent from January through May 1988 compared with the same period in 1987. However, the United States has a huge gap to bridge against the higher aggregate value of imported Japanese goods into the U.S., which rose only 5 percent.

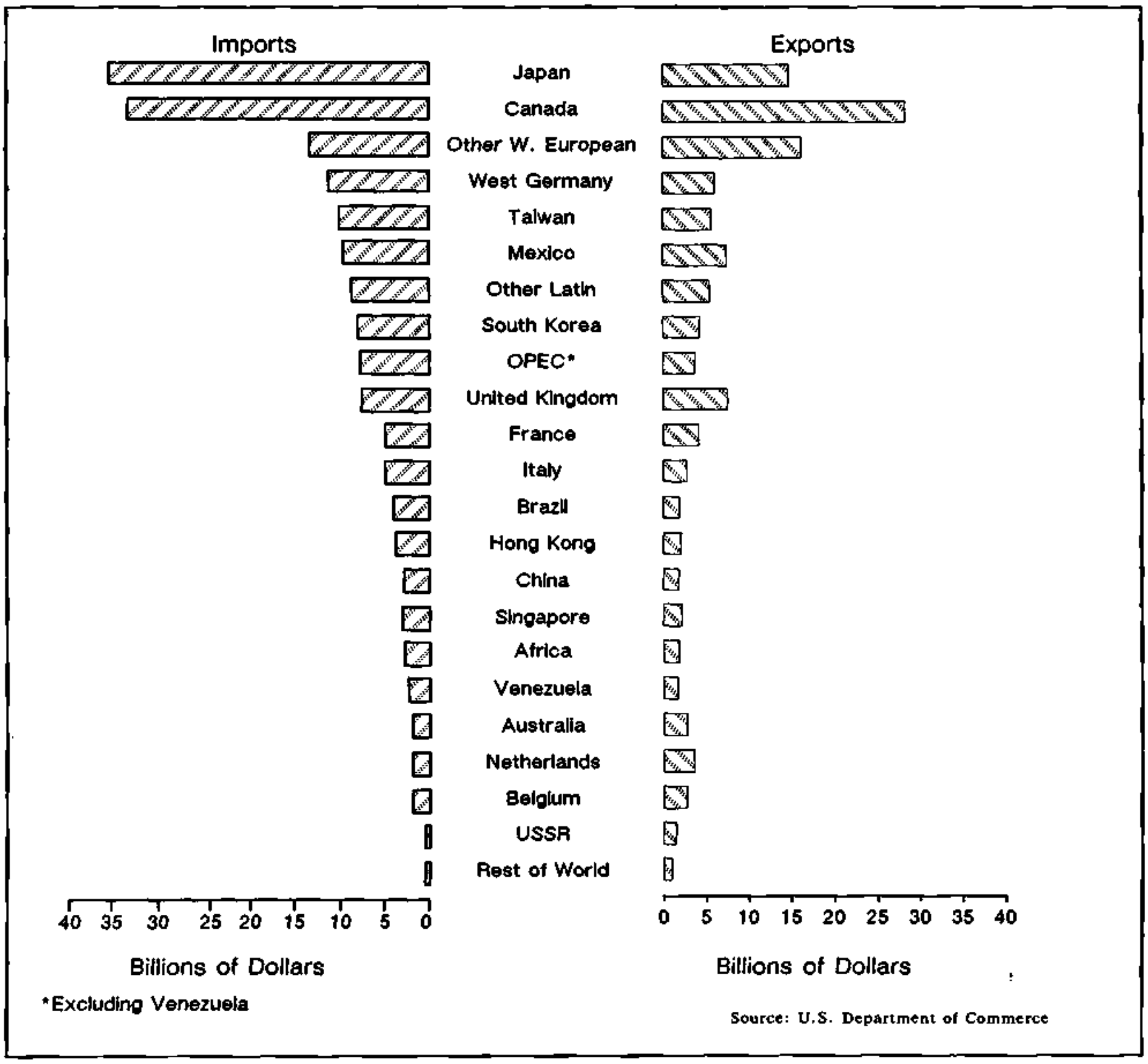

Figure 11. U.S. Merchandise Trade—January-May 1988 (Dollars in Billions)

U.S. Domestic Economic Outlook—downturn In The First Half Of 1990

The Dataquest outlook is for continued strong economic growth through the first three quarters of 1989. Robust exportation and domestic capital spending, coupled with healthy employment growth and a moderating level of consumer spending on imports, all translate into an optimistic economic forecast, particularly for sales of electronic goods and equipment.

There are, of course, many potentially destabilizing factors. When demand for skilled workers exceeds supply and limitations on production capacity are reached, manufacturers must train new workers and invest in additional plant and equipment. To the extent that these additional costs are not reflected directly in additional production, they are inflationary. A continuing deficit at the federal level itself creates inflationary pressures and affects consumer and business confidence. Any increases in the discount rate by the Federal Reserve Board in attempts to keep economic growth and inflation rates within reasonable limits are followed closely by increases in general interest rates. As interest rates in the United States increase, thedollar becomes more attractive and its exchange value against other currencies rises. Ultimately, a stronger dollar makes imported goods less expensive and U.S. goods more costly in foreign markets, tending to reverse U.S. trade gains.

Aside from catastrophic external events, the onset and magnitude of a general economic downturn are caused by the *coincident* rise of many of these separate factors to significant levels. Dataquest believes that the likelihood of a downturn is increasingly probable by late 1989, as outlined in the introduction to this report and in Table 1. Dataquest anticipates that the most likely scenario involves 1989 increases in interest rates by the Federal Reserve Board, coupled with plans for higher taxes and continued government spending. Declines in consumer sentiment and spending will result in a more pessimistic mood in the business community and subsequent capital spending cuts from the fourth quarter of 1989 through the second quarter of 1990.

The negative GNP growth is forecast to last only two quarters, with a maximum quarterly decrease of 2.4 percent. However, the equipment investment component of the economy is hypersensitive to interest rates and demand and will have a longer cycle of decline, consisting of three consecutive negative growth quarters. The Dataquest forecast shows equipment investment declining to negative 14.5 percent annualized growth in the second quarter of 1990 before beginning recovery in the third quarter. Purchases of computers, peripherals, and telecommunications equipment represent about 45.0 percent of U.S. equipment investment spending, and while they are more resistant to recession than many capital items, they will still be affected adversely by an economic slowdown.

As discussed in the *Economic Outlook 1988-1989*, Dataquest sees little prospect for significant improvement in the U.S. federal budget deficit through 1990, regardless of who become the new occupants of the White House and congress. In an election year, no one in Washington expects to gain any votes with tough talk about the deficit. After the election, there will be strong bipartisan interest to increase spending in a number of domestic areas that have seen lean times over the last eight years, such as health care, drug enforcement, environmental issues, and construction. The most likely budget scenario through 1989-1990 is one in which new program increases are balanced by raising personal income tax ceilings, elimination of some existing personal tax credits, increasing consumption taxes on tobacco, alcohol and gasoline, and modifying the corporate tax structure. Some programs that might otherwise have been federally funded, such as child care and worker retraining, will be shifted to corporate shoulders.

Dataquest projects federal deficits of $166 billion in 1988, $160 billion in 1989, and $145 billion in 1990, measured in current dollar terms. Figure 12 shows the 1976 to 1987 federal budget history, and projects the budget picture through 1990.

While Dataquest sees no perceptible slowdown in federal spending for computers, peripherals, and telecommunications equipment in civilian programs, the outlook is not good for the military budget. There is growing congressional sentiment for cuts of as much as 20 percent in the Pentagon's current annual spending level of $300 billion. Dataquest projects that the military's budget will be held to no real growth over the next two to three years. Our recommendation to related industries is to diversify into more commercial applications where possible, and into international markets where opportunities present themselves.

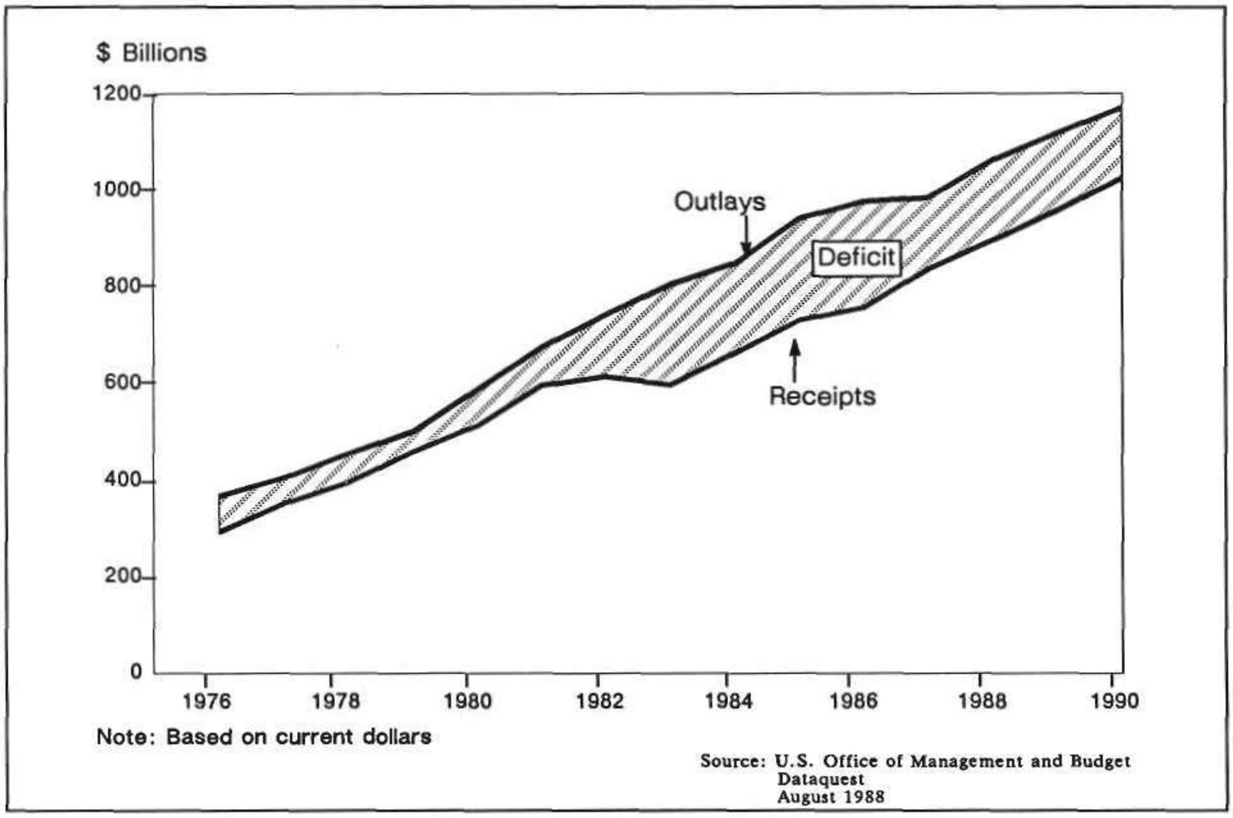

Figure 12. Federal Budget Receipts and Outlays—1976-1990

Dataquest

a company of
The Dun & Bradstreet Corporation

Dataquest Incorporated

1290 Ridder Park Drive
San Jose, California 95131-2398
(408) 437-8000
Telex: 171973
Fax: (408) 437-0292

Dataquest Boston
1740 Massachusetts Avenue
Boxborough, MA 01719-2209
(508) 264-4373
Telex: 171973
Fax: (508) 635-0183

Dataquest International Offices:

Dataquest GmbH
Rosenkavalierplatz 17
D-8000 Munich 81
West Germany
Phone: (089)91 10 64
Telex: 5218070
Fax: (089)91 21 89

Dataquest Japan Limited
Taiyo Ginza Building/2nd Floor
7-14-16 Ginza, Chuo-ku
Tokyo 104 Japan
Phone: (03)546-3191
Telex: 32768
Fax: (03)546-3198

Dataquest UK Limited
13th Floor, Centrepoint
103 New Oxford Street
London WC1A 1DD
England
Phone: (01)379-6257
Telex: 266195
Fax: (01)240-3653

Dataquest SARL
Tour Gallieni 2
36, avenue Gallieni
93175 Bagnolet Cedex
France
Phone: (1)48 97 31 00
Telex: 233 263
Fax: (1)48 97 34 00

Dataquest Taiwan
Rm. 801, 8th Fl., Ever Spring Bldg.
147, Sec. 2, Chien Kuo N. Road
Taipei, Taiwan, R. O. C. 104
P. O. Box 52-25, Tienmou 111
Phone: (02)501-7960/501-5592
Telex: 27459
Fax: (02)505-4265

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ril 1990

Semiconductor Revenue and Shipment Forecast

April 1990

Dataquest

a company of
The Dun & Bradstreet Corporation

Published by Dataquest Incorporated

Semiconductor Revenue and Shipment Forecast

Introduction

Semiconductor revenue and shipment data comprise a set of detailed tables that estimate the size of the semiconductor total available market (TAM) worldwide and for four major geographical regions for the years 1979 through 1994 and 1999. Semiconductor revenue and shipment tables contain both historical data and forecasts. Historical data begin with 1979 and end with 1989, while forecast data provide annual market size estimates for 1990 through 1994, with additional estimates for 1999. Below is a list of tables detailing the type of data, region, time period, and units of measure.

Each table gives estimates of semiconductor revenue or shipments listed by the major semiconductor device product categories. In these tables, semiconductor components are divided into three major product groups: integrated circuits, discrete devices, and optoelectronic devices. These groups are divided into a number of subgroups, some of which are segmented further.

LIST OF TABLES

Table	Region Covered	Years	Units
0	Japan and Western Europe Exchange Rates	1970-1989	Various
1a	Worldwide Market	1979-1983	Dollars
1b	Worldwide Market	1979-1983	Percent
1c	Worldwide Market	1984-1989	Dollars
1d	Worldwide Market	1984-1989	Percent
1e	Worldwide Market	1990-1994; 1999	Dollars
1f	Worldwide Market	1990-1994	Percent
1g	Worldwide Market	1979-1999	Percent, CAGR
2a	North American Market	1979-1983	Dollars
2b	North American Market	1979-1983	Percent
2c	North American Market	1984-1989	Dollars
2d	North American Market	1984-1989	Percent
2e	North American Market	1990-1994; 1999	Dollars
2f	North American Market	1990-1994	Percent
2g	North American Market	1979-1999	Percent, CAGR
3a	Japanese Market	1979-1983	Dollars
3b	Japanese Market	1979-1983	Percent
3c	Japanese Market	1984-1989	Dollars
3d	Japanese Market	1984-1989	Percent
3e	Japanese Market	1990-1994; 1999	Dollars
3f	Japanese Market	1990-1994	Percent
3g	Japanese Market	1979-1999	Percent, CAGR

(Continued)

LIST OF TABLES (Continued)

Definitions and Conventions

Dataquest uses a common manufacturer base for all data tables. This base includes all suppliers to the merchant semiconductor market. It includes aggregate revenue estimates for North American companies that manufacture devices solely for the benefit of the parent company, such as Burroughs, Delco, and IBM. Also included are companies that actively market semiconductor devices to the merchant market as well as to other divisions of their own companies. For such companies, both external and internal shipments are included. Devices that are used internally are valued at current market prices.

Shipment—Dataquest defines shipment as the purchase of a semiconductor device or devices. This definition must be differentiated from actual use of the device in a final product. A regional market size includes all devices sold to or shipped to that region, i.e., the total available market (TAM) in that region.

Hybrids—In earlier consumption data, hybrid devices were included as a separate segment of integrated circuits. Hybrid devices manufactured by semiconductor companies are now included in the most appropriate product segment, usually the analog segment.

The manufacturer base, product group definitions, and guidelines for including value of output that we have used in our tables may differ from those used in other studies of this type. Our base is nearly the same as that used by the World Semiconductor Trade Statistics (WSTS) program, with the following exceptions:

- Dataquest includes all of AT&T's semiconductor revenue, both merchant and captive.
- Dataquest includes—and has included all along—nonrecurring engineering (NRE) charges associated with application-specific integrated circuit (ASIC) revenue. (This applies to both the bipolar digital and MOS digital logic categories.)
- Dataquest includes the revenue generated by sales of standalone circuit design software, sold by certain U.S. manufacturers of ASIC logic devices.
- Dataquest includes Signetics revenue with that of its parent company, Netherlands-based N.V. Philips.
- Dataquest includes revenue for Taiwanese semiconductor manufacturers.
- Dataquest includes revenue for three Japanese companies not estimated by WSTS: NMB Semiconductor, Seiko-Epson, and Yamaha.
- As noted herein, Dataquest includes hybrid revenue in the analog category.

Further information on the above points is available through Dataquest's Client Inquiry Center at (408) 437-8099.

Regions—North America is defined as including both the United States and Canada. Latin America, including Mexico, is considered part of the Asia/Pacific-ROW category. Asia/Pacific includes South Korea, Taiwan, Hong Kong, Singapore, and China. Western Europe includes Austria, Belgium, the Federal Republic of Germany, France, Italy, Luxembourg, the Netherlands, the Scandinavian countries (Denmark, Finland, Norway, Sweden), Spain, the United Kingdom, and the rest of Europe. Japan, the fourth region, is the only single-country region.

Data Sources

The historical information presented in the revenue and shipment data has been consolidated from a variety of sources, each of which focuses on a specific part of the market. These sources include the following:

- World Semiconductor Trade Statistics (WSTS) data, and Dataquest's estimates of regional company sales are used to determine shipments to North America.
- Japanese trade statistics compiled and published by the Ministry of Finance (MOF) and the Ministry of International Trade and Industry (MITI), WSTS data, and Dataquest's estimates of regional company sales are used to determine shipments to Japan.
- For Western European markets, marketing statistics from WSTS data and Dataquest's estimates of regional company sales are used to determine market size.
- In Asia/Pacific-ROW, the major published sources used to estimate market size are WSTS data and Dataquest's estimates of company shipments into the region.

Dataquest believes that the estimates presented here are the most accurate and meaningful generally available today. The sources of the data and the guidelines for the forecasts presented in the tables are as follows:

- Unit shipments or revenue (or both) published by major industry participants, both in the United States and abroad
- Estimates presented by knowledgeable and reliable industry spokespersons

- Government data or trade association data such as those from the Electronics Industry Association (EIA), MITI, WSTS, and the U.S. Department of Commerce
- Published product literature and price lists
- Interviews with knowledgeable manufacturers, distributors, and users
- Relevant projected world economic data

Accuracy

The tables presented here represent Dataquest estimates that we believe are reasonably accurate. Where we have no reasonable estimate, none is given. A zero in a table represents an estimate.

Valuation of Shipments

Regional market size is expressed in U.S. dollars (with the Japanese market also expressed in yen). To make the tables in this study useful in comparing different regions, it is necessary to express all values in a common currency, and we chose the U.S. dollar for convenience. However, the choice of the U.S. dollar (or any single currency, for that matter) as the currency basis for the tables brings with it some problems that require the readers' careful consideration in interpreting the data.

Inflation

All countries that participate significantly in international semiconductor markets suffered from an overall price inflation in the 1970s, continuing into the 1980s. As a consequence, the dollar in a given year is not truly comparable with the dollar in any preceding year. Consumer and wholesale price indices and GNP deflators all measure price changes in various composite "market baskets" of goods. However, there is no price index that measures price changes of material, equipment, and labor inputs to the semiconductor industry. Indeed, the "mix" is changing so rapidly that what is used this year was sometimes unavailable last year, at any price. Nor is there a composite price index that measures price changes in aggregate semiconductor product. In an industry noted for its deflationary trends, this latter effect would tend to make the component purchaser's dollar worth more as time passed, in terms of purchasing ability.

We have made no adjustments in the historical data to account for these inflationary and deflationary effects. The data are expressed in current dollars (dollars that include the inflation rate and exchange rates of the given year) for all historical data; comparisons between different years must be interpreted accordingly.

Average Selling Prices

When considering the worldwide average selling prices (ASPs) for semiconductor components, one must look at the price per function of a circuit, the complexity of the circuit, and the product mix according to this increasing complexity. It is true that one characteristic of the semiconductor industry is that the price per function for integrated circuits has been dropping an average of 30 percent per year for the last 15 years. At the same time, circuits have become denser, resulting in an overall increase in the price of a device with a decreasing cost per function. Thus, Tables 7a through 7g show the worldwide ASPs increasing after many years of decreasing, due to the move toward higher-complexity devices. There are also regional differences in ASPs due to regional competition differences and the varying regional product consumption mix. The worldwide ASP is truly an aggregate measure and may differ significantly from ASPs in any specific market at any point in time.

Exchange Rates

Construction of the West European tables involves combining data from many countries, each of which has different and changing exchange rates. Dataquest uses Annual Foreign Exchange Rates for each year as published by The International Monetary Fund. As far as possible, we prepare our estimates in terms of local currencies before conversion to U.S. dollars. The exchange rates for major currencies can be found in Table 0 at the end of this introduction.

Japanese market size is originally expressed in yen. The Japanese data published in this study are expressed in both dollars (Tables 3a, 3b, and 3c) and in yen (Tables 4a, 4b, and 4c). The yen/dollar exchange rate used for each year can be found in Table 0. Because of the fluctuations in the exchange rate for the yen, the dollar values given tend to distort the growth rate of the Japanese market, but they do provide a useful basis for regional market size comparisons. However, the data in yen give a better picture of the real growth in the Japanese market.

Forecast

As mentioned previously, historical data are expressed in current dollars or dollars that include the given year's inflation rate and exchange rates. However, the revenue forecasts use constant dollars and exchange rates, with no allowance for inflation or variations in the rates of exchange between countries. All estimates for 1990 and beyond are made as if 1990 monetary conditions will continue through 1999 and, therefore, show the absolute year-to-year growth during this period.

Table 0

Foreign Exchange Rates
(In U.S. Dollars)

Year	Yrly/Qtrly	Japan (Yen per US$)	France (US$ per Franc)	West Germany (US$ per Deutsche Mark)	United Kingdom (US$ per Pound Sterling)
1970	YR	358	0.18	0.27	2.38
1971	YR	343	0.18	0.29	2.44
1972	YR	302	0.20	0.31	2.50
1973	YR	269	0.22	0.37	2.44
1974	YR	292	0.21	0.39	2.33
1975	YR	297	0.23	0.41	2.22
1976	YR	296	0.21	0.40	1.82
1977	YR	269	0.20	0.43	1.75
1978	YR	210	0.22	0.50	1.92
1979	YR	219	0.24	0.55	2.13
1980	YR	227	0.24	0.55	2.33
1981	YR	221	0.18	0.44	2.04
1982	YR	248	0.15	0.41	1.75
1983	YR	235	0.13	0.39	1.52
1984	YR	237	0.11	0.35	1.33
1985	YR	238	0.11	0.34	1.30
1986	YR	167	0.14	0.46	1.47
1987	YR	144	0.17	0.56	1.64
1988	YR	130	0.17	0.57	1.79
1989	YR	138	0.16	0.53	1.50

Source: The International Monetary Fund
Financial Times
Dataquest
February 1990

Table 1a

Worldwide Semiconductor Market
(Millions of Dollars)

	1979	1980	1981	1982	1983
Total Including Captives	11,114	14,118	14,828	15,261	21,552
North American Captives	N/A	N/A	N/A	N/A	2,015
Total Semiconductor	11,114	14,118	14,828	15,261	19,537
Total IC	7,028	9,546	10,046	10,894	14,700
Bipolar Digital	1,674	2,374	2,337	2,412	3,015
Memory	324	572	558	511	603
Logic	1,350	1,802	1,779	1,901	2,412
MOS Digital	3,346	4,715	4,822	5,642	7,951
Memory	1,676	2,230	2,075	2,701	3,719
Micro	541	862	1,085	1,318	1,979
Logic	1,129	1,623	1,662	1,623	2,253
Analog	2,008	2,457	2,887	2,840	3,734
Total Discrete	3,522	3,883	3,985	3,547	3,865
Total Optoelectronic	564	689	797	820	972

N/A = Not Available

Source: Dataquest
April 1990

Table 1b

Worldwide Semiconductor Market
(Percent Change)

	1979	1980	1981	1982	1983
Total Including Captives	24.1%	27.0%	5.0%	2.9%	41.2%
North American Captives	N/A	N/A	N/A	N/A	N/A
Total Semiconductor	24.1%	27.0%	5.0%	2.9%	28.0%
Total IC	34.4%	35.8%	5.2%	8.4%	34.9%
Bipolar Digital	32.8%	41.8%	(1.6%)	3.2%	25.0%
Memory	N/A	76.5%	(2.4%)	(8.4%)	18.0%
Logic	N/A	33.5%	(1.3%)	6.9%	26.9%
MOS Digital	43.5%	40.9%	2.3%	17.0%	40.9%
Memory	N/A	33.1%	(7.0%)	30.2%	37.7%
Micro	N/A	59.3%	25.9%	21.5%	50.2%
Logic	N/A	43.8%	2.4%	(2.3%)	38.8%
Analog	22.7%	22.4%	17.5%	(1.6%)	31.5%
Total Discrete	6.7%	10.2%	2.6%	(11.0%)	9.0%
Total Optoelectronic	33.6%	22.2%	15.7%	2.9%	18.5%

N/A = Not Available

Source: Dataquest
April 1990

Table 1c

Worldwide Semiconductor Market
(Millions of Dollars)

	1984	1985	1986	1987	1988	1989
Total Including Captives	31,325	27,116	33,729	41,478	54,521	60,480
North American Captives	2,500	2,773	2,895	3,227	3,662	4,065
Total Semiconductor	28,825	24,343	30,834	38,251	50,859	56,415
Total IC	22,618	18,552	23,618	29,887	41,068	46,514
Bipolar Digital	4,783	3,684	4,325	4,760	5,200	4,644
Memory	774	589	606	621	689	591
Logic	4,009	3,095	3,719	4,139	4,511	4,053
MOS Digital	12,947	10,103	12,815	17,473	26,988	32,783
Memory	6,225	3,817	4,511	6,056	11,692	16,133
Micro	3,229	2,745	3,489	5,108	7,144	8,081
Logic	3,493	3,541	4,815	6,309	8,152	8,569
Analog	4,888	4,765	6,478	7,654	8,880	9,087
Total Discrete	4,986	4,578	5,730	6,655	7,612	7,561
Total Optoelectronic	1,221	1,213	1,486	1,709	2,179	2,340

Source: Dataquest
April 1990

Table 1d

Worldwide Semiconductor Market
(Percent Change)

	1984	1985	1986	1987	1988	1989
Total Including Captives	45.3%	(13.4%)	24.4%	23.0%	31.4%	10.9%
North American Captives	24.1%	10.9%	4.4%	11.5%	13.5%	11.0%
Total Semiconductor	47.5%	(15.5%)	26.7%	24.1%	33.0%	10.9%
Total IC	53.9%	(18.0%)	27.3%	26.5%	37.4%	13.3%
Bipolar Digital	58.6%	(23.0%)	17.4%	10.1%	9.2%	(10.7%)
Memory	28.4%	(23.9%)	2.9%	2.5%	11.0%	(14.2%)
Logic	66.2%	(22.8%)	20.2%	11.3%	9.0%	(10.2%)
MOS Digital	62.8%	(22.0%)	26.8%	36.3%	54.5%	21.5%
Memory	67.4%	(38.7%)	18.2%	34.2%	93.1%	38.0%
Micro	63.2%	(15.0%)	27.1%	46.4%	39.9%	13.1%
Logic	55.0%	1.4%	36.0%	31.0%	29.2%	5.1%
Analog	30.9%	(2.5%)	35.9%	18.2%	16.0%	2.3%
Total Discrete	29.0%	(8.2%)	25.2%	16.1%	14.4%	(0.7%)
Total Optoelectronic	25.6%	(0.7%)	22.5%	15.0%	27.5%	7.4%

Source: Dataquest
April 1990

Table 1e

Worldwide Semiconductor Market
(Millions of Dollars)

	1990	1991	1992	1993	1994	1999
Total Including Captives	60,162	70,347	85,809	108,819	119,694	227,622
North American Captives	4,165	4,767	5,723	7,518	8,107	20,740
Total Semiconductor	55,997	65,580	80,086	101,301	111,587	206,882
Total IC	45,788	54,126	66,786	86,413	95,600	184,259
Bipolar Digital	4,085	4,379	4,620	4,899	4,640	4,194
Memory	489	435	382	348	307	263
Logic	3,596	3,944	4,238	4,551	4,333	3,931
MOS Digital	32,234	38,535	48,745	65,295	72,479	148,162
Memory	14,265	17,310	22,710	31,311	35,663	72,940
Micro	8,668	10,021	11,982	15,915	17,525	35,385
Logic	9,301	11,204	14,053	18,069	19,291	39,837
Analog	9,469	11,212	13,421	16,219	18,481	31,903
Total Discrete	7,775	8,628	10,008	11,093	11,683	15,744
Total Optoelectronic	2,434	2,826	3,292	3,795	4,304	6,879

Source: Dataquest
April 1990

Table 1f

Worldwide Semiconductor Market
(Percent Change)

	1990	1991	1992	1993	1994
Total Including Captives	(0.5%)	16.9%	22.0%	26.8%	10.0%
North American Captives	2.5%	14.5%	20.1%	31.4%	7.8%
Total Semiconductor	(0.7%)	17.1%	22.1%	26.5%	10.2%
Total IC	(1.6%)	18.2%	23.4%	29.4%	10.6%
Bipolar Digital	(12.0%)	7.2%	5.5%	6.0%	(5.3%)
Memory	(17.3%)	(11.0%)	(12.2%)	(8.9%)	(11.8%)
Logic	(11.3%)	9.7%	7.5%	7.4%	(4.8%)
MOS Digital	(1.7%)	19.5%	26.5%	34.0%	11.0%
Memory	(11.6%)	21.3%	31.2%	37.9%	13.9%
Micro	7.3%	15.6%	19.6%	32.8%	10.1%
Logic	8.5%	20.5%	25.4%	28.6%	6.8%
Analog	4.2%	18.4%	19.7%	20.8%	13.9%
Total Discrete	2.8%	11.0%	16.0%	10.8%	5.3%
Total Optoelectronic	4.0%	16.1%	16.5%	15.3%	13.4%

Source: Dataquest
April 1990

Table 1g

Worldwide Semiconductor Market
(Compound Annual Growth Rates)

	CAGR (79-84)	CAGR (84-89)	CAGR (89-94)	CAGR (94-99)	CAGR (79-89)	CAGR (89-99)
Total Including Captives	23.0%	14.1%	14.6%	13.7%	18.5%	14.2%
North American Captives	N/A	10.2%	14.8%	20.7%	N/A	17.7%
Total Semiconductor	21.0%	14.4%	14.6%	13.1%	17.6%	13.9%
Total IC	26.3%	15.5%	15.5%	14.0%	20.8%	14.8%
Bipolar Digital	23.4%	(0.6%)	0	(2.0%)	10.7%	(1.0%)
Memory	19.0%	(5.3%)	(12.3%)	(3.0%)	6.2%	(7.8%)
Logic	24.3%	0.2%	1.3%	(1.9%)	11.6%	(0.3%)
MOS Digital	31.1%	20.4%	17.2%	15.4%	25.6%	16.3%
Memory	30.0%	21.0%	17.2%	15.4%	25.4%	16.3%
Micro	42.9%	20.1%	16.7%	15.1%	31.0%	15.9%
Logic	25.3%	19.7%	17.6%	15.6%	22.5%	16.6%
Analog	19.5%	13.2%	15.3%	11.5%	16.3%	13.4%
Total Discrete	7.2%	8.7%	9.1%	6.1%	7.9%	7.6%
Total Optoelectronic	16.7%	13.9%	13.0%	9.8%	15.3%	11.4%

N/A = Not Available

Source: Dataquest
April 1990

Table 2a

North American Semiconductor Market
(Millions of Dollars)

	1979	1980	1981	1982	1983
Total Including Captives	4,538	6,053	6,529	6,970	10,625
North American Captives	N/A	N/A	N/A	N/A	1,623
Total Semiconductor	4,538	6,053	6,529	6,970	9,002
Total IC	3,179	4,562	4,867	5,466	7,301
Bipolar Digital	901	1,411	1,339	1,367	1,664
Memory	185	396	375	320	373
Logic	716	1,015	964	1,047	1,291
MOS Digital	1,703	2,442	2,595	3,183	4,326
Memory	1,028	1,230	1,107	1,592	2,051
Micro	186	377	489	641	1,034
Logic	489	835	999	950	1,241
Analog	575	709	933	916	1,311
Total Discrete	1,161	1,269	1,378	1,201	1,353
Total Optoelectronic	198	222	284	303	348

N/A = Not Available

Source: Dataquest
April 1990

Table 2b

North American Semiconductor Market
(Percent Change)

	1979	1980	1981	1982	1983
Total Including Captives	29.4%	33.4%	7.9%	6.8%	52.4%
North American Captives	N/A	N/A	N/A	N/A	N/A
Total Semiconductor	29.4%	33.4%	7.9%	6.8%	29.2%
Total IC	36.1%	43.5%	6.7%	12.3%	33.6%
Bipolar Digital	35.3%	56.6%	(5.1%)	2.1%	21.7%
Memory	N/A	114.1%	(5.3%)	(14.7%)	16.6%
Logic	N/A	41.8%	(5.0%)	8.6%	23.3%
MOS Digital	55.0%	43.4%	6.3%	22.7%	35.9%
Memory	N/A	19.6%	(10.0%)	43.8%	28.8%
Micro	N/A	102.7%	29.7%	31.1%	61.3%
Logic	N/A	70.8%	19.6%	(4.9%)	30.6%
Analog	0.9%	23.3%	31.6%	(1.8%)	43.1%
Total Discrete	15.5%	9.3%	8.6%	(12.8%)	12.7%
Total Optoelectronic	19.3%	12.1%	27.9%	6.7%	14.9%

N/A = Not Available

Source: Dataquest
April 1990

Table 2c

North American Semiconductor Market
(Millions of Dollars)

	1984	1985	1986	1987	1988	1989
Total Including Captives	15,033	11,663	13,171	15,454	18,789	20,978
North American Captives	2,027	2,243	2,327	2,596	2,945	3,271
Total Semiconductor	13,006	9,420	10,844	12,858	15,844	17,707
Total IC	11,089	7,757	8,986	10,886	13,815	15,694
Bipolar Digital	2,818	1,926	2,030	2,099	2,012	1,709
Memory	441	288	267	271	235	239
Logic	2,377	1,638	1,763	1,828	1,777	1,470
MOS Digital	6,503	4,322	4,912	6,738	9,606	11,602
Memory	3,426	1,753	1,775	2,497	4,298	6,056
Micro	1,634	1,258	1,362	2,012	2,707	2,739
Logic	1,443	1,311	1,775	2,229	2,601	2,807
Analog	1,768	1,509	2,044	2,049	2,197	2,383
Total Discrete	1,503	1,295	1,542	1,642	1,676	1,660
Total Optoelectronic	414	368	316	330	353	353

Source: Dataquest
April 1990

Table 2d

North American Semiconductor Market
(Percent Change)

	1984	1985	1986	1987	1988	1989
Total Including Captives	41.5%	(22.4%)	12.9%	17.3%	21.6%	11.7%
North American Captives	24.9%	10.7%	3.7%	11.6%	13.4%	11.1%
Total Semiconductor	44.5%	(27.6%)	15.1%	18.6%	23.2%	11.8%
Total IC	51.9%	(30.0%)	15.8%	21.1%	26.9%	13.6%
Bipolar Digital	69.4%	(31.7%)	5.4%	3.4%	(4.1%)	(15.1%)
Memory	18.2%	(34.7%)	(7.3%)	1.5%	(13.3%)	1.7%
Logic	84.1%	(31.1%)	7.6%	3.7%	(2.8%)	(17.3%)
MOS Digital	50.3%	(33.5%)	13.7%	37.2%	42.6%	20.8%
Memory	67.0%	(48.8%)	1.3%	40.7%	72.1%.	40.9%
Micro	58.0%	(23.0%)	8.3%	47.7%	34.5%	1.2%
Logic	16.3%	(9.1%)	35.4%	25.6%	16.7%	7.9%
Analog	34.9%	(14.6%)	35.5%	0.2%	7.2%	8.5%
Total Discrete	11.1%	(13.8%)	19.1%	6.5%	2.1%	(1.0%)
Total Optoelectronic	19.0%	(11.1%)	(14.1%)	4.4%	7.0%	0

Source: Dataquest
April 1990

Table 2e

North American Semiconductor Market
(Millions of Dollars)

	1990	1991	1992	1993	1994	1999
Total Including Captives	20,515	23,785	28,648	36,586	40,040	72,683
North American Captives	3,350	3,834	4,603	6,047	6,521	15,140
Total Semiconductor	17,165	19,951	24,045	30,539	33,519	57,543
Total IC	15,090	17,736	21,567	27,861	30,705	54,140
Bipolar Digital	1,571	1,655	1,734	1,816	1,633	921
Memory	207	187	165	153	136	80
Logic	1,364	1,468	1,569	1,663	1,497	841
MOS Digital	11,030	13,166	16,594	22,277	24,753	46,232
Memory	5,171	6,376	8,375	11,661	13,230	25,310
Micro	2,905	3,335	3,969	5,303	5,870	10,959
Logic	2,954	3,455	4,250	5,313	5,653	9,963
Analog	2,489	2,915	3,239	3,768	4,319	6,987
Total Discrete	1,722	1,833	2,073	2,239	2,337	2,786
Total Optoelectronic	353	382	405	439	477	617

Source: Dataquest
April 1990

Table 2f

North American Semiconductor Market
(Percent Change)

	1990	1991	1992	1993	1994
Total Including Captives	(2.2%)	15.9%	20.4%	27.7%	9.4%
North American Captives	2.4%	14.4%	20.1%	31.4%	7.8%
Total Semiconductor	(3.1%)	16.2%	20.5%	27.0%	9.8%
Total IC	(3.8%)	17.5%	21.6%	29.2%	10.2%
Bipolar Digital	(8.1%)	5.3%	4.8%	4.7%	(10.1%)
Memory	(13.4%)	(9.7%)	(11.8%)	(7.3%)	(11.1%)
Logic	(7.2%)	7.6%	6.9%	6.0%	(10.0%)
MOS Digital	(4.9%)	19.4%	26.0%	34.2%	11.1%
Memory	(14.6%)	23.3%	31.4%	39.2%	13.5%
Micro	6.1%	14.8%	19.0%	33.6%	10.7%
Logic	5.2%	17.0%	23.0%	25.0%	6.4%
Analog	4.4%	17.1%	11.1%	16.3%	14.6%
Total Discrete	3.7%	6.4%	13.1%	8.0%	4.4%
Total Optoelectronic	0	8.2%	6.0%	8.4%	8.7%

Source: Dataquest
April 1990

Table 2g

North American Semiconductor Market
(Compound Annual Growth Rates)

	CAGR (79-84)	CAGR (84-89)	CAGR (89-94)	CAGR (94-99)	CAGR (79-89)	CAGR (89-99)
Total Including Captives	27.1%	6.9%	13.8%	12.7%	16.5%	13.2%
North American Captives	N/A	10.0%	14.8%	18.3%	N/A	16.6%
Total Semiconductor	23.4%	6.4%	13.6%	11.4%	14.6%	12.5%
Total IC	28.4%	7.2%	14.4%	12.0%	17.3%	13.2%
Bipolar Digital	25.6%	(9.5%)	(0.9%)	(10.8%)	6.6%	(6.0%)
Memory	19.0%	(11.5%)	(10.7%)	(10.1%)	2.6%	(10.4%)
Logic	27.1%	(9.2%)	0.4%	(10.9%)	7.5%	(5.4%)
MOS Digital	30.7%	12.3%	16.4%	13.3%	21.2%	14.8%
Memory	27.2%	12.1%	16.9%	13.9%	19.4%	15.4%
Micro	54.4%	10.9%	16.5%	13.3%	30.9%	14.9%
Logic	24.2%	14.2%	15.0%	12.0%	19.1%	13.5%
Analog	25.2%	6.2%	12.6%	10.1%	15.3%	11.4%
Total Discrete	5.3%	2.0%	7.1%	3.6%	3.6%	5.3%
Total Optoelectronic	15.9%	(3.1%)	6.2%	5.3%	6.0%	5.7%

N/A = Not Available

Source: Dataquest
April 1990

Table 3a

Japanese Semiconductor Market
(Millions of Dollars)

	1979	1980	1981	1982	1983
Total Including Captives	2,768	3,383	4,295	4,082	5,834
North American Captives	N/A	N/A	N/A	N/A	112
Total Semiconductor	2,768	3,383	4,295	4,082	5,722
Total IC	1,738	2,201	2,793	2,855	4,167
Bipolar Digital	304	345	438	498	706
Memory	52	57	77	87	109
Logic	252	288	361	411	597
MOS Digital	762	991	1,174	1,263	1,948
Memory	256	423	491	534	893
Micro	213	269	404	446	594
Logic	293	299	279	283	461
Analog	672	865	1,181	1,094	1,513
Total Discrete	889	986	1,237	970	1,217
Total Optoelectronic	141	196	265	257	338

N/A = Not Available

Source: Dataquest
April 1990

Table 3b

Japanese Semiconductor Market
(Percent Change)

	1979	1980	1981	1982	1983
Total Including Captives	13.1%	22.2%	27.0%	(5.0%)	42.9%
North American Captives	N/A	N/A	N/A	N/A	N/A
Total Semiconductor	13.1%	22.2%	27.0%	(5.0%)	40.2%
Total IC	24.2%	26.6%	26.9%	2.2%	46.0%
Bipolar Digital	17.4%	13.5%	27.0%	13.7%	41.8%
Memory	N/A	9.6%	35.1%	13.0%	25.3%
Logic	N/A	14.3%	25.3%	13.9%	45.3%
MOS Digital	29.6%	30.1%	18.5%	7.6%	54.2%
Memory	N/A	65.2%	16.1%	8.8%	67.2%
Micro	N/A	26.3%	50.2%	10.4%	33.2%
Logic	N/A	2.0%	(6.7%)	1.4%	62.9%
Analog	21.7%	28.7%	36.5%	(7.4%)	38.3%
Total Discrete	(6.0%)	10.9%	25.5%	(21.6%)	25.5%
Total Optoelectronic	36.9%	39.0%	35.2%	(3.0%)	31.5%

N/A = Not Available

Source: Dataquest
April 1990

Table 3c

Japanese Semiconductor Market
(Millions of Dollars)

	1984	1985	1986	1987	1988	1989
Total Including Captives	8,909	8,300	12,018	15,107	20,977	23,134
North American Captives	135	151	163	180	205	226
Total Semiconductor	8,774	8,149	11,855	14,927	20,772	22,908
Total IC	6,517	5,985	8,802	11,263	16,127	18,129
Bipolar Digital	955	824	1,295	1,523	1,906	1,839
Memory	163	136	169	227	348	204
Logic	792	688	1,126	1,296	1,558	1,635
MOS Digital	3,621	3,232	4,762	6,424	10,501	12,671
Memory	1,579	1,185	1,738	2,268	4,424	6,171
Micro	979	884	1,368	1,902	2,573	2,933
Logic	1,063	1,163	1,656	2,254	3,504	3,567
Analog	1,941	1,929	2,745	3,316	3,720	3,619
Total Discrete	1,756	1,621	2,242	2,693	3,282	3,289
Total Optoelectronic	501	543	811	971	1,363	1,490

Source: Dataquest
April 1990

Table 3d

Japanese Semiconductor Market
(Percent Change)

	1984	1985	1986	1987	1988	1989
Total Including Captives	52.7%	(6.8%)	44.8%	25.7%	38.9%	10.3%
North American Captives	20.5%	11.9%	7.9%	10.4%	13.9%	10.2%
Total Semiconductor	53.3%	(7.1%)	45.5%	25.9%	39.2%	10.3%
Total IC	56.4%	(8.2%)	47.1%	28.0%	43.2%	12.4%
Bipolar Digital	35.3%	(13.7%)	57.2%	17.6%	25.1%	(3.5%)
Memory	49.5%	(16.6%)	24.3%	34.3%	53.3%	(41.4%)
Logic	32.7%	(13.1%)	63.7%	15.1%	20.2%	4.9%
MOS Digital	85.9%	(10.7%)	47.3%	34.9%	63.5%	20.7%
Memory	76.8%	(25.0%)	46.7%	30.5%	95.1%	39.5%
Micro	64.8%	(9.7%)	54.8%	39.0%	35.3%	14.0%
Logic	130.6%	9.4%	42.4%	36.1%	55.5%	1.8%
Analog	28.3%	(0.6%)	42.3%	20.8%	12.2%	(2.7%)
Total Discrete	44.3%	(7.7%)	38.3%	20.1%	21.9%	0.2%
Total Optoelectronic	48.2%	8.4%	49.4%	19.7%	40.4%	9.3%

Source: Dataquest
April 1990

Table 3e

Japanese Semiconductor Market
(Millions of Dollars)

	1990	1991	1992	1993	1994	1999
Total Including Captives	22,682	26,318	31,897	39,736	43,693	79,711
North American Captives	233	267	320	420	453	1,782
Total Semiconductor	22,449	26,051	31,577	39,316	43,240	77,929
Total IC	17,587	20,459	25,027	31,971	35,301	66,510
Bipolar Digital	1,482	1,546	1,599	1,647	1,571	1,497
Memory	154	138	121	109	95	85
Logic	1,328	1,408	1,478	1,538	1,476	1,412
MOS Digital	12,470	14,630	18,124	23,863	26,462	52,544
Memory	5,674	6,704	8,496	11,386	13,146	26,147
Micro	2,995	3,362	3,927	5,148	5,658	10,424
Logic	3,801	4,564	5,701	7,329	7,658	15,973
Analog	3,635	4,283	5,304	6,461	7,268	12,469
Total Discrete	3,322	3,792	4,405	4,845	5,089	6,830
Total Optoelectronic	1,540	1,800	2,145	2,500	2,850	4,589

Source: Dataquest
April 1990

Table 3f

Japanese Semiconductor Market
(Percent Change)

	1990	1991	1992	1993	1994
Total Including Captives	(2.0%)	16.0%	21.2%	24.6%	10.0%
North American Captives	3.1%	14.6%	19.9%	31.3%	7.9%
Total Semiconductor	(2.0%)	16.0%	21.2%	24.5%	10.0%
Total IC	(3.0%)	16.3%	22.3%	27.7%	10.4%
Bipolar Digital	(19.4%)	4.3%	3.4%	3.0%	(4.6%)
Memory	(24.5%)	(10.4%)	(12.3%)	(9.9%)	(12.8%)
Logic	(18.8%)	6.0%	5.0%	4.1%	(4.0%)
MOS Digital	(1.6%)	17.3%	23.9%	31.7%	10.9%
Memory	(8.1%)	18.2%	26.7%	34.0%	15.5%
Micro	2.1%	12.3%	16.8%	31.1%	9.9%
Logic	6.6%	20.1%	24.9%	28.6%	4.5%
Analog	0.4%	17.8%	23.8%	21.8%	12.5%
Total Discrete	1.0%	14.1%	16.2%	10.0%	5.0%
Total Optoelectronic	3.4%	16.9%	19.2%	16.6%	14.0%

Source: Dataquest
April 1990

Table 3g

Japanese Semiconductor Market
(Compound Annual Growth Rates in U.S. Dollars)

	CAGR (79-84)	CAGR (84-89)	CAGR (89-94)	CAGR (94-99)	CAGR (79-89)	CAGR (89-99)
Total Including Captives	26.3%	21.0%	13.6%	12.8%	23.7%	13.2%
North American Captives	N/A	10.9%	14.9%	31.5%	N/A	22.9%
Total Semiconductor	26.0%	21.2%	13.5%	12.5%	23.5%	13.0%
Total IC	30.3%	22.7%	14.3%	13.5%	26.4%	13.9%
Bipolar Digital	25.7%	14.0%	(3.1%)	(1.0%)	19.7%	(2.0%)
Memory	25.7%	4.6%	(14.2%)	(2.2%)	14.6%	(8.4%)
Logic	25.7%	15.6%	(2.0%)	(0.9%)	20.6%	(1.5%)
MOS Digital	36.6%	28.5%	15.9%	14.7%	32.5%	15.3%
Memory	43.9%	31.3%	16.3%	14.7%	37.5%	15.5%
Micro	35.7%	24.5%	14.0%	13.0%	30.0%	13.5%
Logic	29.4%	27.4%	16.5%	15.8%	28.4%	16.2%
Analog	23.6%	13.3%	15.0%	11.4%	18.3%	13.2%
Total Discrete	14.6%	13.4%	9.1%	6.1%	14.0%	7.6%
Total Optoelectronic	28.9%	24.4%	13.8%	10.0%	26.6%	11.9%

N/A = Not Available

Source: Dataquest
April 1990

Table 4a

Japanese Semiconductor Market
(Billions of Yen)

	1979	1980	1981	1982	1983
Total Including Captives	606.3	768.0	949.3	1,012.3	1,371.0
North American Captives	N/A	N/A	N/A	N/A	26.3
Total Semiconductor	606.3	768.0	949.3	1,012.3	1,344.7
Total IC	380.7	499.7	617.3	708.0	979.3
Bipolar Digital	66.6	78.3	96.8	123.5	165.9
Memory	11.4	12.9	17.0	21.6	25.6
Logic	55.2	65.4	79.8	101.9	140.3
MOS Digital	166.9	225.0	259.5	313.2	457.8
Memory	56.1	96.0	108.5	132.4	209.9
Micro	46.6	61.1	89.3	110.6	139.6
Logic	64.2	67.9	61.7	70.2	108.3
Analog	147.2	196.4	261.0	271.3	355.6
Total Discrete	194.7	223.8	273.4	240.6	286.0
Total Optoelectronic	30.9	44.5	58.6	63.7	79.4
Exchange Rate Yen/$	219	227	221	248	235

N/A = Not Available

Source: Dataquest
April 1990

Table 4b

Japanese Semiconductor Market
(Percent Change in Yen)

	1979	1980	1981	1982	1983
Total Including Captives	17.9%	26.7%	23.6%	6.6%	35.4%
North American Captives	N/A	N/A	N/A	N/A	N/A
Total Semiconductor	17.9%	26.7%	23.6%	6.6%	32.8%
Total IC	29.6%	31.3%	23.5%	14.7%	38.3%
Bipolar Digital	22.4%	17.6%	23.6%	27.6%	34.3%
Memory	N/A	13.2%	31.8%	27.1%	18.5%
Logic	N/A	18.5%	22.0%	27.7%	37.7%
MOS Digital	35.2%	34.8%	15.3%	20.7%	46.2%
Memory	N/A	71.1%	13.0%	22.0%	58.5%
Micro	N/A	31.1%	46.2%	23.9%	26.2%
Logic	N/A	5.8%	(9.1%)	13.8%	54.3%
Analog	27.0%	33.4%	32.9%	3.9%	31.1%
Total Discrete	(2.0%)	14.9%	22.2%	(12.0%)	18.9%
Total Optoelectronic	42.9%	44.0%	31.7%	8.7%	24.6%

N/A = Not Available

Source: Dataquest
April 1990

Table 4c

Japanese Semiconductor Market
(Billions of Yen)

	1984	1985	1986	1987	1988	1989
Total Including Captives	2,111.3	1,975.3	2,006.9	2,175.4	2,727.0	3,198.7
North American Captives	32.0	35.9	27.2	25.9	26.7	31.2
Total Semiconductor	2,079.3	1,939.4	1,979.7	2,149.5	2,700.3	3,167.5
Total IC	1,544.4	1,424.4	1,469.9	1,621.9	2,096.4	2,506.7
Bipolar Digital	226.3	196.1	216.2	219.3	247.7	254.3
Memory	38.6	32.4	28.2	32.7	45.2	28.2
Logic	187.7	163.7	188.0	186.6	202.5	226.1
MOS Digital	858.1	769.2	795.3	925.1	1,365.1	1,752.0
Memory	374.2	282.0	290.2	326.6	575.1	853.3
Micro	232.0	210.4	228.5	273.9	334.5	405.5
Logic	251.9	276.8	276.6	324.6	455.5	493.2
Analog	460.0	459.1	458.4	477.5	483.6	500.4
Total Discrete	416.2	385.8	374.4	387.8	426.7	454.8
Total Optoelectronic	118.7	129.2	135.4	139.8	177.2	206.0
Exchange Rate Yen/$	237	238	167	144	130	138

Source: Dataquest
April 1990

Table 4d

Japanese Semiconductor Market
(Percent Change in Yen)

	1984	1985	1986	1987	1988	1989
Total Including Captives	54.0%	(6.4%)	1.6%	8.4%	25.4%	17.3%
North American Captives	21.7%	12.2%	(24.2%)	(4.8%)	3.1%	16.9%
Total Semiconductor	54.6%	(6.7%)	2.1%	8.6%	25.6%	17.3%
Total IC	57.7%	(7.8%)	3.2%	10.3%	29.3%	19.6%
Bipolar Digital	36.4%	(13.3%)	10.2%	1.4%	13.0%	2.7%
Memory	50.8%	(16.1%)	(13.0%)	16.0%	38.2%	(37.6%)
Logic	33.8%	(12.8%)	14.8%	(0.7%)	8.5%	11.7%
MOS Digital	87.4%	(10.4%)	3.4%	16.3%	47.6%	28.3%
Memory	78.3%	(24.6%)	2.9%	12.5%	76.1%	48.4%
Micro	66.2%	(9.3%)	8.6%	19.9%	22.1%	21.2%
Logic	132.6%	9.9%	(0.1%)	17.4%	40.3%	8.3%
Analog	29.4%	(0.2%)	(0.2%)	4.2%	1.3%	3.5%
Total Discrete	45.5%	(7.3%)	(3.0%)	3.6%	10.0%	6.6%
Total Optoelectronic	49.5%	8.8%	4.8%	3.2%	26.8%	16.3%

Source: Dataquest
April 1990

Table 4e

Japanese Semiconductor Market
(Billions of Yen)

	1990	1991	1992	1993	1994	1999
Total Including Captives	3,379.6	3,921.4	4,752.5	5,920.7	6,510.3	11,877.1
North American Captives	34.7	39.8	47.7	62.6	67.5	265.5
Total Semiconductor	3,344.9	3,881.6	4,704.8	5,858.1	6,442.8	11,611.6
Total IC	2,620.4	3,048.4	3,728.9	4,763.7	5,259.8	9,910.1
Bipolar Digital	220.8	230.4	238.2	245.4	234.1	223.1
Memory	22.9	20.6	18.0	16.2	14.2	12.7
Logic	197.9	209.8	220.2	229.2	219.9	210.4
MOS Digital	1,858.0	2,179.8	2,700.4	3,555.6	3,942.8	7,829.1
Memory	845.4	998.9	1,265.9	1,696.5	1,958.8	3,895.9
Micro	446.3	500.9	585.1	767.1	843.0	1,553.2
Logic	566.3	680.0	849.4	1,092.0	1,141.0	2,380.0
Analog	541.6	638.2	790.3	962.7	1,082.9	1,857.9
Total Discrete	495.0	565.0	656.3	721.9	758.3	1,017.7
Total Optoelectronic	229.5	268.2	319.6	372.5	424.7	683.8
Exchange Rate Yen/$	149	149	149	149	149	149

Source: Dataquest
April 1990

Table 4f

Japanese Semiconductor Market
(Percent Change in Yen)

	1990	1991	1992	1993	1994
Total Including Captives	5.7%	16.0%	21.2%	24.6%	10.0%
North American Captives	11.2%	14.7%	19.8%	31.2%	7.8%
Total Semiconductor	5.6%	16.0%	21.2%	24.5%	10.0%
Total IC	4.5%	16.3%	22.3%	27.8%	10.4%
Bipolar Digital	(13.2%)	4.3%	3.4%	3.0%	(4.6%)
Memory	(18.8%)	(10.0%)	(12.6%)	(10.0%)	(12.3%)
Logic	(12.5%)	6.0%	5.0%	4.1%	(4.1%)
MOS Digital	6.1%	17.3%	23.9%	31.7%	10.9%
Memory	(0.9%)	18.2%	26.7%	34.0%	15.5%
Micro	10.1%	12.2%	16.8%	31.1%	9.9%
Logic	14.8%	20.1%	24.9%	28.6%	4.5%
Analog	8.2%	17.8%	23.8%	21.8%	12.5%
Total Discrete	8.8%	14.1%	16.2%	10.0%	5.0%
Total Optoelectronic	11.4%	16.9%	19.2%	16.6%	14.0%

Source: Dataquest
April 1990

Table 4g

Japanese Semiconductor Market
(Compound Annual Growth Rates in Yen)

	CAGR (79-84)	CAGR (84-89)	CAGR (89-94)	CAGR (94-99)	CAGR (79-89)	CAGR (89-99)
Total Including Captives	28.3%	8.7%	15.3%	12.8%	18.1%	14.0%
North American Captives	N/A	(0.5%)	16.7%	31.5%	N/A	23.9%
Total Semiconductor	28.0%	8.8%	15.3%	12.5%	18.0%	13.9%
Total IC	32.3%	10.2%	16.0%	13.5%	20.7%	14.7%
Bipolar Digital	27.7%	2.4%	(1.6%)	(1.0%)	14.3%	(1.3%)
Memory	27.6%	(6.1%)	(12.8%)	(2.2%)	9.5%	(7.7%)
Logic	27.7%	3.8%	(0.6%)	(0.9%)	15.1%	(0.7%)
MOS Digital	38.7%	15.3%	17.6%	14.7%	26.5%	16.1%
Memory	46.2%	17.9%	18.1%	14.7%	31.3%	16.4%
Micro	37.9%	11.8%	15.8%	13.0%	24.2%	14.4%
Logic	31.4%	14.4%	18.3%	15.8%	22.6%	17.0%
Analog	25.6%	1.7%	16.7%	11.4%	13.0%	14.0%
Total Discrete	16.4%	1.8%	10.8%	6.1%	8.9%	8.4%
Total Optoelectronic	30.9%	11.7%	15.6%	10.0%	20.9%	12.7%
Exchange Rate Yen/$						

N/A = Not Available

Source: Dataquest
April 1990

Table 5a

Western European Semiconductor Market
(Millions of Dollars)

	1979	1980	1981	1982	1983
Total Including Captives	3,018	3,686	3,041	3,167	3,650
North American Captives	N/A	N/A	N/A	N/A	280
Total Semiconductor	3,018	3,686	3,041	3,167	3,370
Total IC	1,747	2,333	1,892	1,988	2,323
Bipolar Digital	390	510	454	434	483
Memory	85	116	103	100	107
Logic	305	394	351	334	376
MOS Digital	781	1,139	882	948	1,227
Memory	367	543	426	469	581
Micro	125	189	149	168	239
Logic	289	407	307	311	407
Analog	576	684	556	606	613
Total Discrete	1,138	1,192	995	1,011	866
Total Optoelectronic	133	161	154	168	181

N/A = Not Available

Source: Dataquest
April 1990

Table 5b

Western European Semiconductor Market
(Percent Change)

	1979	1980	1981	1982	1983
Total Including Captives	29.0%	22.1%	(17.5%)	4.1%	15.3%
North American Captives	N/A	N/A	N/A	N/A	N/A
Total Semiconductor	29.0%	22.1%	(17.5%)	4.1%	6.4%
Total IC	41.1%	33.5%	(18.9%)	5.1%	16.9%
Bipolar Digital	34.0%	30.8%	(11.0%)	(4.4%)	11.3%
Memory	N/A	36.5%	(11.2%)	(2.9%)	7.0%
Logic	N/A	29.2%	(10.9%)	(4.8%)	12.6%
MOS Digital	46.0%	45.8%	(22.6%)	7.5%	29.4%
Memory	N/A	48.0%	(21.5%)	10.1%	23.9%
Micro	N/A	51.2%	(21.2%)	12.8%	42.3%
Logic	N/A	40.8%	(24.6%)	1.3%	30.9%
Analog	39.8%	18.8%	(18.7%)	9.0%	1.2%
Total Discrete	13.3%	4.7%	(16.5%)	1.6%	(14.3%)
Total Optoelectronic	37.1%	21.1%	(4.3%)	9.1%	7.7%

N/A = Not Available

Source: Dataquest
April 1990

Table 5c

Western European Semiconductor Market
(Millions of Dollars)

	1984	1985	1986	1987	1988	1989
Total Including Captives	5,202	5,174	5,992	6,949	9,003	10,105
North American Captives	338	379	405	451	512	568
Total Semiconductor	4,864	4,795	5,587	6,498	8,491	9,537
Total IC	3,731	3,615	4,116	4,840	6,669	7,632
Bipolar Digital	741	719	719	727	772	701
Memory	144	150	147	88	74	116
Logic	597	569	572	639	698	585
MOS Digital	2,123	1,933	2,270	2,761	4,364	5,283
Memory	986	745	813	854	1,797	2,380
Micro	471	486	574	805	1,212	1,459
Logic	666	702	883	1,102	1,355	1,444
Analog	867	963	1,127	1,352	1,533	1,648
Total Discrete	942	969	1,207	1,377	1,516	1,574
Total Optoelectronic	191	211	264	281	306	331

Source: Dataquest
April 1990

Table 5d

Western European Semiconductor Market
(Percent Change)

	1984	1985	1986	1987	1988	1989
Total Including Captives	42.5%	(0.5%)	15.8%	16.0%	29.6%	12.2%
North American Captives	20.7%	12.1%	6.9%	11.4%	13.5%	10.9%
Total Semiconductor	44.3%	(1.4%)	16.5%	16.3%	30.7%	12.3%
Total IC	60.6%	(3.1%)	13.9%	17.6%	37.8%	14.4%
Bipolar Digital	53.4%	(3.0%)	0	1.1%	6.2%	(9.2%)
Memory	34.6%	4.2%	(2.0%)	(40.1%)	(15.9%)	56.8%
Logic	58.8%	(4.7%)	0.5%	11.7%	9.2%	(16.2%)
MOS Digital	73.0%	(8.9%)	17.4%	21.6%	58.1%	21.1%
Memory	69.7%	(24.4%)	9.1%	5.0%	110.4%	32.4%
Micro	97.1%	3.2%	18.1%	40.2%	50.6%	20.4%
Logic	63.6%	5.4%	25.8%	24.8%	23.0%	6.6%
Analog	41.4%	11.1%	17.0%	20.0%	13.4%	7.5%
Total Discrete	8.8%	2.9%	24.6%	14.1%	10.1%	3.8%
Total Optoelectronic	5.5%	10.5%	25.1%	6.4%	8.9%	8.2%

Source: Dataquest
April 1990

Table 5e

Western European Semiconductor Market
(Millions of Dollars)

	1990	1991	1992	1993	1994	1999
Total Including Captives	10,319	12,042	14,705	18,505	20,295	38,715
North American Captives	582	666	800	1,051	1,133	3,314
Total Semiconductor	9,737	11,376	13,905	17,454	19,162	35,401
Total IC	7,792	9,285	11,543	14,857	16,438	31,644
Bipolar Digital	660	751	817	902	953	1,287
Memory	104	90	79	71	63	85
Logic	556	661	738	831	890	1,202
MOS Digital	5,344	6,458	8,290	11,040	12,195	25,315
Memory	1,978	2,424	3,346	4,654	5,213	11,112
Micro	1,668	1,922	2,261	2,952	3,236	6,552
Logic	1,698	2,112	2,683	3,434	3,746	7,651
Analog	1,788	2,076	2,436	2,915	3,290	5,042
Total Discrete	1,594	1,697	1,934	2,125	2,213	2,975
Total Optoelectronic	351	394	428	472	511	782

Source: Dataquest
April 1990

Table 5f

Western European Semiconductor Market
(Percent Change)

	1990	1991	1992	1993	1994
Total Including Captives	2.1%	16.7%	22.1%	25.8%	9.7%
North American Captives	2.5%	14.4%	20.1%	31.4%	7.8%
Total Semiconductor	2.1%	16.8%	22.2%	25.5%	9.8%
Total IC	2.1%	19.2%	24.3%	28.7%	10.6%
Bipolar Digital	(5.8%)	13.8%	8.8%	10.4%	5.7%
Memory	(10.3%)	(13.5%)	(12.2%)	(10.1%)	(11.3%)
Logic	(5.0%)	18.9%	11.6%	12.6%	7.1%
MOS Digital	1.2%	20.8%	28.4%	33.2%	10.5%
Memory	(16.9%)	22.5%	38.0%	39.1%	12.0%
Micro	14.3%	15.2%	17.6%	30.6%	9.6%
Logic	17.6%	24.4%	27.0%	28.0%	9.1%
Analog	8.5%	16.1%	17.3%	19.7%	12.9%
Total Discrete	1.3%	6.5%	14.0%	9.9%	4.1%
Total Optoelectronic	6.0%	12.3%	8.6%	10.3%	8.3%

Source: Dataquest
April 1990

Table 5g

Western European Semiconductor Market
(Compound Annual Growth Rates)

	CAGR (79-84)	CAGR (84-89)	CAGR (89-94)	CAGR (94-99)	CAGR (79-89)	CAGR (89-99)
Total Including Captives	11.5%	14.2%	15.0%	13.8%	12.8%	14.4%
North American Captives	N/A	10.9%	14.8%	23.9%	N/A	19.3%
Total Semiconductor	10.0%	14.4%	15.0%	13.1%	12.2%	14.0%
Total IC	16.4%	15.4%	16.6%	14.0%	15.9%	15.3%
Bipolar Digital	13.7%	(1.1%)	6.3%	6.2%	6.0%	6.3%
Memory	11.1%	(4.2%)	(11.5%)	6.2%	3.2%	(3.1%)
Logic	14.4%	(0.4%)	8.8%	6.2%	6.7%	7.5%
MOS Digital	22.1%	20.0%	18.2%	15.7%	21.1%	17.0%
Memory	21.9%	19.3%	17.0%	16.3%	20.6%	16.7%
Micro	30.4%	25.4%	17.3%	15.2%	27.9%	16.2%
Logic	18.2%	16.7%	21.0%	15.4%	17.5%	18.1%
Analog	8.5%	13.7%	14.8%	8.9%	11.1%	11.8%
Total Discrete	(3.7%)	10.8%	7.1%	6.1%	3.3%	6.6%
Total Optoelectronic	7.5%	11.6%	9.1%	8.9%	9.5%	9.0%

N/A = Not Available

Source: Dataquest
April 1990

Table 6a

Asia/Pacific-ROW Semiconductor Market
(Millions of Dollars)

	1979	1980	1981	1982	1983
Total Including Captives	790	996	963	1,042	1,443
North American Captives	N/A	N/A	N/A	N/A	0
Total Semiconductor	790	996	963	1,042	1,443
Total IC	364	450	494	585	909
Bipolar Digital	79	108	106	113	162
Memory	2	3	3	4	14
Logic	77	105	103	109	148
MOS Digital	100	143	171	248	450
Memory	25	34	51	106	194
Micro	17	27	43	63	112
Logic	58	82	77	79	144
Analog	185	199	217	224	297
Total Discrete	334	436	375	365	429
Total Optoelectronic	92	110	94	92	105

N/A = Not Available

Source: Dataquest
April 1990

Table 6b

Asia/Pacific-ROW Semiconductor Market
(Percent Change)

	1979	1980	1981	1982	1983
Total Including Captives	19.7%	26.1%	(3.3%)	8.2%	38.5%
North American Captives	N/A	N/A	N/A	N/A	N/A
Total Semiconductor	19.7%	26.1%	(3.3%)	8.2%	38.5%
Total IC	41.1%	23.6%	9.8%	18.4%	55.4%
Bipolar Digital	75.6%	36.7%	(1.9%)	6.6%	43.4%
Memory	N/A	50.0%	0	33.3%	250.0%
Logic	N/A	36.4%	(1.9%)	5.8%	35.8%
MOS Digital	(9.1%)	43.0%	19.6%	45.0%	81.5%
Memory	N/A	36.0%	50.0%	107.8%	83.0%
Micro	N/A	58.8%	59.3%	46.5%	77.8%
Logic	N/A	41.4%	(6.1%)	2.6%	82.3%
Analog	79.6%	7.6%	9.0%	3.2%	32.6%
Total Discrete	(3.5%)	30.5%	(14.0%)	(2.7%)	17.5%
Total Optoelectronic	64.3%	19.6%	(14.5%)	(2.1%)	14.1%

N/A = Not Available

Source: Dataquest
April 1990

Table 6c

Asia/Pacific-ROW Semiconductor Market
(Millions of Dollars)

	1984	1985	1986	1987	1988	1989
Total Including Captives	2,181	1,979	2,548	3,968	5,752	6,263
North American Captives	0	0	0	0	0	0
Total Semiconductor	2,181	1,979	2,548	3,968	5,752	6,263
Total IC	1,281	1,195	1,714	2,898	4,457	5,059
Bipolar Digital	269	215	281	411	510	395
Memory	26	15	23	35	32	32
Logic	243	200	258	376	478	363
MOS Digital	700	616	871	1,550	2,517	3,227
Memory	234	134	185	437	1,173	1,526
Micro	145	117	185	389	652	950
Logic	321	365	501	724	692	751
Analog	312	364	562	937	1,430	1,437
Total Discrete	785	693	739	943	1,138	1,038
Total Optoelectronic	115	91	95	127	157	166

Source: Dataquest
April 1990

Table 6d

Asia/Pacific-ROW Semiconductor Market
(Percent Change)

	1984	1985	1986	1987	1988	1989
Total Including Captives	51.1%	(9.3%)	28.8%	55.7%	45.0%	8.9%
North American Captives	N/M	N/M	N/M	N/M	N/M	N/M
Total Semiconductor	51.1%	(9.3%)	28.8%	55.7%	45.0%	8.9%
Total IC	40.9%	(6.7%)	43.4%	69.1%	53.8%	13.5%
Bipolar Digital	66.0%	(20.1%)	30.7%	46.3%	24.1%	(22.5%)
Memory	85.7%	(42.3%)	53.3%	52.2%	(8.6%)	0
Logic	64.2%	(17.7%)	29.0%	45.7%	27.1%	(24.1%)
MOS Digital	55.6%	(12.0%)	41.4%	78.0%	62.4%	28.2%
Memory	20.6%	(42.7%)	38.1%	136.2%	168.4%	30.1%
Micro	29.5%	(19.3%)	58.1%	110.3%	67.6%	45.7%
Logic	122.9%	13.7%	37.3%	44.5%	(4.4%)	8.5%
Analog	5.1%	16.7%	54.4%	66.7%	52.6%	0.5%
Total Discrete	83.0%	(11.7%)	6.6%	27.6%	20.7%	(8.8%)
Total Optoelectronic	9.5%	(20.9%)	4.4%	33.7%	23.6%	5.7%

N/M = Not Meaningful

Source: Dataquest
April 1990

Table 6e

Asia/Pacific-ROW Semiconductor Market
(Millions of Dollars)

	1990	1991	1992	1993	1994	1999
Total Including Captives	6,646	8,202	10,559	13,992	15,666	36,513
North American Captives	0	0	0	0	0	504
Total Semiconductor	6,646	8,202	10,559	13,992	15,666	36,009
Total IC	5,319	6,646	8,649	11,724	13,156	31,965
Bipolar Digital	372	427	470	534	483	489
Memory	24	20	17	15	13	13
Logic	348	407	453	519	470	476
MOS Digital	3,390	4,281	5,737	8,115	9,069	24,071
Memory	1,442	1,806	2,493	3,610	4,074	10,371
Micro	1,100	1,402	1,825	2,512	2,761	7,450
Logic	848	1,073	1,419	1,993	2,234	6,250
Analog	1,557	1,938	2,442	3,075	3,604	7,405
Total Discrete	1,137	1,306	1,596	1,884	2,044	3,153
Total Optoelectronic	190	250	314	384	466	891

Source: Dataquest
April 1990

Table 6f

Asia/Pacific-ROW Semiconductor Market
(Percent Change)

	1990	1991	1992	1993	1994
Total Including Captives	6.1%	23.4%	28.7%	32.5%	12.0%
North American Captives	N/M	N/M	N/M	N/M	N/M
Total Semiconductor	6.1%	23.4%	28.7%	32.5%	12.0%
Total IC	5.1%	24.9%	30.1%	35.6%	12.2%
Bipolar Digital	(5.8%)	14.8%	10.1%	13.6%	(9.6%)
Memory	(25.0%)	(16.7%)	(15.0%)	(11.8%)	(13.3%)
Logic	(4.1%)	17.0%	11.3%	14.6%	(9.4%)
MOS Digital	5.1%	26.3%	34.0%	41.5%	11.8%
Memory	(5.5%)	25.2%	38.0%	44.8%	12.9%
Micro	15.8%	27.5%	30.2%	37.6%	9.9%
Logic	12.9%	26.5%	32.2%	40.5%	12.1%
Analog	8.4%	24.5%	26.0%	25.9%	17.2%
Total Discrete	9.5%	14.9%	22.2%	18.0%	8.5%
Total Optoelectronic	14.5%	31.6%	25.6%	22.3%	21.4%

N/M = Not Meaningful

Source: Dataquest
April 1990

Table 6g

Asia/Pacific-ROW Semiconductor Market
(Compound Annual Growth Rates)

	CAGR (79-84)	CAGR (84-89)	CAGR (89-94)	CAGR (94-99)	CAGR (79-89)	CAGR (89-99)
Total Including Captives	22.5%	23.5%	20.1%	18.4%	23.0%	19.3%
North American Captives	N/A	N/M	N/M	N/M	N/A	N/M
Total Semiconductor	22.5%	23.5%	20.1%	18.1%	23.0%	19.1%
Total IC	28.6%	31.6%	21.1%	19.4%	30.1%	20.2%
Bipolar Digital	27.8%	8.0%	4.1%	0.2%	17.5%	2.2%
Memory	67.0%	4.2%	(16.5%)	0	32.0%	(8.6%)
Logic	25.8%	8.4%	5.3%	0.3%	16.8%	2.7%
MOS Digital	47.6%	35.8%	23.0%	21.6%	41.5%	22.3%
Memory	56.4%	45.5%	21.7%	20.5%	50.9%	21.1%
Micro	53.5%	45.6%	23.8%	22.0%	49.5%	22.9%
Logic	40.8%	18.5%	24.4%	22.8%	29.2%	23.6%
Analog	11.0%	35.7%	20.2%	15.5%	22.8%	17.8%
Total Discrete	18.6%	5.7%	14.5%	9.1%	12.0%	11.8%
Total Optoelectronic	4.6%	7.6%	22.9%	13.8%	6.1%	18.3%

N/A = Not Available
N/M = Not Meaningful

Source: Dataquest
April 1990

Table 7a

Worldwide Average Selling Prices
(Dollars)

	1979	1980	1981	1982	1983
Total Semiconductor	0.29	0.33	0.31	0.33	0.32
Total IC	0.97	1.07	1.02	0.99	1.03
Bipolar Digital	0.57	0.70	0.70	0.62	0.65
MOS Digital	1.93	1.81	1.66	1.63	1.66
Memory	5.15	4.90	3.17	2.62	2.79
Micro	3.96	3.61	3.40	3.26	3.35
Logic	0.89	0.85	0.86	0.80	0.79
Analog	0.78	0.83	0.81	0.79	0.76
Total Discrete	0.12	0.12	0.11	0.11	0.09
Total Optoelectronic	0.51	0.44	0.39	0.29	0.28

Source: Dataquest
April 1990

Table 7b

Worldwide Average Selling Prices
(Percent Change)

	1979	1980	1981	1982	1983
Total Semiconductor	3.6%	11.7%	(6.4%)	7.5%	(3.0%)
Total IC	(4.0%)	9.8%	(3.9%)	(2.8%)	3.1%
Bipolar Digital	(9.5%)	22.8%	0	(11.4%)	4.8%
MOS Digital	1.2%	(6.3%)	(8.4%)	(1.8%)	2.2%
Memory	N/A	(4.9%)	(35.3%)	(17.4%)	6.5%
Micro	N/A	(8.8%)	(5.8%)	(4.1%)	2.8%
Logic	N/A	(4.5%)	1.2%	(7.0%)	(1.3%)
Analog	(7.1%)	6.4%	(2.4%)	(2.5%)	(3.8%)
Total Discrete	(7.7%)	0	(8.3%)	0	(18.2%)
Total Optoelectronic	8.0%	(12.8%)	(11.9%)	(25.6%)	(3.4%)

N/A = Not Available

Source: Dataquest
April 1990

Table 7c

Worldwide Average Selling Prices
(Dollars)

	1984	1985	1986	1987	1988	1989
Total Semiconductor	0.36	0.30	0.34	0.33	0.42	0.49
Total IC	1.10	1.05	1.09	1.18	1.32	1.46
Bipolar Digital	0.65	0.71	0.71	0.69	0.70	0.70
MOS Digital	1.95	1.64	1.63	1.94	2.38	2.65
Memory	3.90	2.59	2.41	3.09	4.87	6.07
Micro	3.53	3.14	3.13	3.56	4.15	3.77
Logic	0.85	0.93	0.99	1.12	1.13	1.13
Analog	0.75	0.76	0.84	0.82	0.72	0.71
Total Discrete	0.09	0.08	0.09	0.08	0.09	0.10
Total Optoelectronic	0.28	0.22	0.25	0.28	0.34	0.30

Source: Dataquest
April 1990

Table 7d

Worldwide Average Selling Prices
(Percent Change)

	1984	1985	1986	1987	1988	1989
Total Semiconductor	11.8%	(15.7%)	13.2%	(2.7%)	24.8%	17.5%
Total IC	7.5%	(4.4%)	3.5%	8.5%	11.6%	10.7%
Bipolar Digital	0	9.2%	0	(2.8%)	1.4%	0
MOS Digital	17.3%	(16.0%)	(0.5%)	18.6%	23.0%	11.2%
Memory	39.8%	(33.6%)	(6.9%)	28.2%	57.6%	24.6%
Micro	5.4%	(11.0%)	(0.3%)	13.7%	16.6%	(9.2%)
Logic	7.6%	9.4%	6.5%	13.1%	0.9%	0
Analog	(1.3%)	1.3%	10.5%	(2.4%)	(12.2%)	(1.4%)
Total Discrete	0	(11.1%)	15.0%	(13.0%)	12.5%	11.1%
Total Optoelectronic	0	(21.4%)	13.6%	12.0%	21.4%	(11.8%)

Source: Dataquest
April 1990

Table 7e

Worldwide Average Selling Prices
(Dollars)

	1990	1991	1992	1993	1994	1999
Total Semiconductor	0.47	0.53	0.56	0.63	0.59	0.81
Total IC	1.38	1.48	1.56	1.73	1.63	1.95
Bipolar Digital	0.69	0.70	0.71	0.72	0.70	0.70
MOS Digital	2.34	2.67	2.80	3.21	2.85	3.23
Memory	5.13	5.68	6.82	8.08	8.52	12.00
Micro	3.75	4.16	4.23	4.29	4.16	4.50
Logic	1.07	1.25	1.25	1.42	1.13	1.25
Analog	0.70	0.71	0.71	0.71	0.70	0.75
Total Discrete	0.10	0.11	0.11	0.11	0.10	0.11
Total Optoelectronic	0.30	0.33	0.34	0.35	0.35	0.38

Source: Dataquest
April 1990

Table 7f

Worldwide Average Selling Prices
(Percent Change)

	1990	1991	1992	1993	1994
Total Semiconductor	(4.0%)	13.0%	5.1%	12.3%	(5.1%)
Total IC	(5.7%)	7.7%	5.1%	10.8%	(5.5%)
Bipolar Digital	(1.4%)	1.4%	1.4%	1.4%	(2.8%)
MOS Digital	(11.6%)	14.2%	4.8%	14.6%	(11.3%)
Memory	(15.5%)	10.7%	20.1%	18.5%	5.4%
Micro	(0.5%)	10.9%	1.7%	1.5%	(3.1%)
Logic	(5.3%)	16.7%	0	13.3%	(20.2%)
Analog	(1.4%)	1.4%	0	0	(1.4%)
Total Discrete	0	10.0%	0	0	(9.1%)
Total Optoelectronic	0	10.0%	3.0%	2.9%	0

Source: Dataquest
April 1990

Table 7g

Worldwide Average Selling Prices
(Compound Annual Growth Rates)

	CAGR (79-84)	CAGR (84-89)	CAGR (89-94)	CAGR (94-99)	CAGR (79-89)	CAGR (89-99)
Total Semiconductor	4.1%	6.4%	4.0%	6.4%	5.2%	5.2%
Total IC	2.6%	5.8%	2.3%	3.6%	4.2%	2.9%
Bipolar Digital	2.7%	1.5%	0	0	2.1%	0
MOS Digital	0.2%	6.3%	1.5%	2.6%	3.2%	2.0%
Memory	(5.4%)	9.3%	7.0%	7.1%	1.7%	7.1%
Micro	(2.3%)	1.3%	2.0%	1.6%	(0.5%)	1.8%
Logic	(0.9%)	5.9%	0	2.0%	2.4%	1.0%
Analog	(0.8%)	(1.1%)	(0.3%)	1.4%	(0.9%)	0.5%
Total Discrete	(5.6%)	2.1%	0	1.9%	(1.8%)	1.0%
Total Optoelectronic	(11.2%)	1.4%	3.1%	1.7%	(5.1%)	2.4%

Source: Dataquest
April 1990

Table 8a

Worldwide Semiconductor Shipments
(Millions of Units)

	1979	1980	1981	1982	1983
Total Semiconductor	37,703	42,870	48,081	46,022	60,743
Total IC	7,242	8,955	9,809	10,949	14,327
Bipolar Digital	2,937	3,391	3,339	3,890	4,638
MOS Digital	1,731	2,603	2,906	3,464	4,776
Memory	325	455	655	1,031	1,333
Micro	137	239	319	404	591
Logic	1,269	1,909	1,933	2,029	2,852
Analog	2,574	2,960	3,564	3,595	4,913
Total Discrete	29,350	32,358	36,227	32,245	42,944
Total Optoelectronic	1,111	1,557	2,045	2,828	3,471

Source: Dataquest
April 1990

Table 8b

Worldwide Semiconductor Shipments
(Percent Change in Units)

	1979	1980	1981	1982	1983
Total Semiconductor	20%	14%	12%	(4%)	32%
Total IC	40%	24%	10%	12%	31%
Bipolar Digital	47%	15%	(2%)	17%	19%
MOS Digital	42%	50%	12%	19%	38%
Memory	N/A	40%	44%	57%	29%
Micro	N/A	75%	34%	27%	46%
Logic	N/A	51%	1%	5%	41%
Analog	32%	15%	20%	1%	37%
Total Discrete	16%	10%	12%	(11%)	33%
Total Optoelectronic	24%	40%	31%	38%	23%

N/A = Not Available

Source: Dataquest
April 1990

Table 8c

Worldwide Semiconductor Shipments
(Millions of Units)

	1984	1985	1986	1987	1988	1989
Total Semiconductor	80,377	80,380	89,881	114,551	122,085	115,227
Total IC	20,573	17,607	21,654	25,260	31,098	31,817
Bipolar Digital	7,340	5,172	6,092	6,899	7,429	6,634
MOS Digital	6,639	6,171	7,850	9,028	11,336	12,385
Memory	1,597	1,475	1,872	1,960	2,401	2,658
Micro	916	875	1,115	1,435	1,721	2,144
Logic	4,126	3,820	4,864	5,633	7,214	7,583
Analog	6,593	6,264	7,712	9,334	12,333	12,799
Total Discrete	55,411	57,200	62,283	83,188	84,578	75,610
Total Optoelectronic	4,393	5,573	5,944	6,104	6,409	7,800

Source: Dataquest
April 1990

Table 8d

Worldwide Semiconductor Shipments
(Percent Change in Units)

	1984	1985	1986	1987	1988	1989
Total Semiconductor	32%	0	12%	27%	7%	(6%)
Total IC	44%	(14%)	23%	17%	23%	2%
Bipolar Digital	58%	(30%)	18%	13%	8%	(11%)
MOS Digital	39%	(7%)	27%	15%	26%	9%
Memory	20%	(8%)	27%	5%	22%	11%
Micro	55%	(4%)	27%	29%	20%	25%
Logic	45%	(7%)	27%	16%	28%	5%
Analog	34%	(5%)	23%	21%	32%	4%
Total Discrete	29%	3%	9%	34%	2%	(11%)
Total Optoelectronic	27%	27%	7%	3%	5%	22%

Source: Dataquest
April 1990

Table 8e

Worldwide Semiconductor Shipments
(Millions of Units)

	1990	1991	1992	1993	1994	1999
Total Semiconductor	119,091	123,474	143,487	161,683	187,627	255,597
Total IC	33,228	36,474	42,823	49,995	58,500	94,367
Bipolar Digital	5,920	6,256	6,507	6,804	6,629	5,991
MOS Digital	13,781	14,427	17,413	20,347	25,470	45,838
Memory	2,781	3,048	3,330	3,875	4,186	6,078
Micro	2,312	2,409	2,831	3,706	4,212	7,863
Logic	8,688	8,971	11,252	12,765	17,072	31,896
Analog	13,527	15,792	18,903	22,844	26,401	42,537
Total Discrete	77,750	78,436	90,982	100,845	116,830	143,127
Total Optoelectronic	8,113	8,564	9,682	10,843	12,297	18,103

Source: Dataquest
April 1990

Table 8f

Worldwide Semiconductor Shipments
(Percent Change in Units)

	1990	1991	1992	1993	1994
Total Semiconductor	3%	4%	16%	13%	16%
Total IC	4%	10%	17%	17%	17%
Bipolar Digital	(11%)	6%	4%	5%	(3%)
MOS Digital	11%	5%	21%	17%	25%
Memory	5%	10%	9%	16%	8%
Micro	8%	4%	18%	31%	14%
Logic	15%	3%	25%	13%	34%
Analog	6%	17%	20%	21%	16%
Total Discrete	3%	1%	16%	11%	16%
Total Optoelectronic	4%	6%	13%	12%	13%

Source: Dataquest
April 1990

Table 8g

Worldwide Semiconductor Shipments
(Millions of Units)

	CAGR (79-84)	CAGR (84-89)	CAGR (89-94)	CAGR (94-99)	CAGR (79-89)	CAGR (89-99)
Total Semiconductor	16.3%	7.5%	10.2%	6.4%	11.8%	8.3%
Total IC	23.2%	9.1%	13.0%	10.0%	16.0%	11.5%
Bipolar Digital	20.1%	(2.0%)	0	(2.0%)	8.5%	(1.0%)
MOS Digital	30.9%	13.3%	15.5%	12.5%	21.7%	14.0%
Memory	37.5%	10.7%	9.5%	7.7%	23.4%	8.6%
Micro	46.3%	18.5%	14.5%	13.3%	31.7%	13.9%
Logic	26.6%	12.9%	17.6%	13.3%	19.6%	15.4%
Analog	20.7%	14.2%	15.6%	10.0%	17.4%	12.8%
Total Discrete	13.6%	6.4%	9.1%	4.1%	9.9%	6.6%
Total Optoelectronic	31.6%	12.2%	9.5%	8.0%	21.5%	8.8%

Source: Dataquest
April 1990

Dataquest

a company of The Dun & Bradstreet Corporation

Dataquest Research and Sales Offices:

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

Technology Products Group
Phone: (800) 624-3280

Dataquest Incorporated
Invitational Computer Conferences Division
3151 Airway Avenue, C-2
Costa Mesa, California 92626
Phone: (714) 957-0171
Telex: 5101002189 ICCDQ
Fax: (714) 957-0903

Dataquest Incorporated
Ledgeway Group
430 Bedford Street
Suite 340
Lexington, MA 02173
Phone: (617) 862-8500
Fax: (617) 862-8207

Dataquest Australia
Suite 1, Century Plaza
80 Berry Street
North Sydney, NSW 2060
Australia
Phone: (02) 959 4544
Telex: 25468
Fax: (02) 929 0635

Dataquest Boston
1740 Massachusetts Ave.
Boxborough, MA 01719-2209
Phone: (508) 264-4373
Telex: 171973
Fax: (508) 635-0183

Dataquest Europe GmbH
Rosenkavalierplatz 17
D-8000 Munich 81
West Germany
Phone: (089) 91 1064
Telex: 5218070
Fax: (089) 91 2189

Dataquest Europe Limited
Roussel House, Broadwater Park
Denham, Uxbridge, Middx UB9 5HP
England
Phone: 0895-835050
Telex: 266195
Fax: 0895 835260/1/2

Dataquest Europe SA
Tour Gallieni 2
36, avenue Gallieni
93175 Bagnolet Cedex
France
Phone: (1) 48 97 31 00
Telex: 233 263
Fax: (1) 48 97 34 00

Dataquest Hong Kong
Rm. 401, Connaught Comm. Bldg.
185 Wanchai Rd.
Wanchai, Hong Kong
Phone: 8387336
Telex: 80587
Fax: 5722375

Dataquest Israel
59 Mishmar Ha'yarden Street
Tel Aviv, Israel 69865
or
P.O. Box 18198
Tel Aviv, Israel
Phone: 52 913937
Telex: 341118
Fax: 52 32865

Dataquest Japan Limited
Shinkawa Sanko Building
1-3-17 Shinkawa, Chuo-ku
Tokyo 104 Japan
Phone: (03) 5566-0411
Fax: (03) 5566-0425

Dataquest Korea
Daeheung Bldg., Room 505
648-23 Yeoksam-dong
Kangnam-gu
Seoul, Korea 135
Phone: (02) 552-2332
Fax: (02) 552-2661

Dataquest Singapore
4012 Ang Mo Kio Industrial Park 1
Ave. 10, #03-10 to #03-12
Singapore 2056
Phone: 4597181
Telex: 38257
Fax: 4563129

Dataquest Taiwan
Room 801/8th Floor
Ever Spring Building
147, Sect. 2, Chien Kuo N. Rd.
Taipei, Taiwan R.O.C. 104
Phone: (02) 501-7960
Telex: 27459
Fax: (02) 505-4265

Dataquest West Germany
In der Schneithohl 17
6242 Kronberg 2
West Germany
Phone: 06173/61685
Telex: 418089
Fax: 06173/67901

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Semiconductor Revenue and Shipment Forecast

October 1990

Dataquest

a company of
The Dun & Bradstreet Corporation

Published by Dataquest Incorporated

Semiconductor Revenue and Shipment Forecast

Introduction

Semiconductor revenue and shipment data comprise a set of detailed tables that estimate the size of the semiconductor total available market (TAM) worldwide and for four major geographical regions for the years 1980 through 1995 and 2000. Semiconductor revenue and shipment tables contain both historical data and forecasts. Historical data begin with 1980 and end with 1989, while forecast data provide annual market size estimates for 1990 through 1995, with additional estimates for 2000. Below is a list of tables detailing the type of data, region, time period, and units of measure.

Each table gives estimates of semiconductor revenue or shipments listed by the major semiconductor device product categories. In these tables, semiconductor components are divided into three major product groups: integrated circuits, discrete devices, and optoelectronic devices. These groups are divided into a number of subgroups, some of which are segmented further.

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(Continued)

LIST OF TABLES (Continued)

Definitions and Conventions

Dataquest uses a common manufacturer base for all data tables. This base includes all suppliers to the merchant semiconductor market. It includes aggregate revenue estimates for North American companies that manufacture devices solely for the benefit of the parent company, such as Burroughs, Delco, and IBM. Also included are companies that actively market semiconductor devices to the merchant market as well as to other divisions of their own companies. For such companies, both external and internal shipments are included. Devices that are used internally are valued at current market prices.

Shipment—Dataquest defines shipment as the purchase of a semiconductor device or devices. This definition must be differentiated from actual use of the device in a final product. A regional market size includes all devices sold to or shipped to that region, i.e., the total available market (TAM) in that region.

Hybrids—In earlier consumption data, hybrid devices were included as a separate segment of integrated circuits. Hybrid devices manufactured by semiconductor companies are now included in the most appropriate product segment, usually the analog segment.

The manufacturer base, product group definitions, and guidelines for including value of output that we have used in our tables may differ from those used in other studies of this type. Our base is nearly the same as that used by the World Semiconductor Trade Statistics (WSTS) program, with the following exceptions:

- Dataquest includes all of AT&T's semiconductor revenue, both merchant and captive.
- Dataquest includes—and has included all along—nonrecurring engineering (NRE) charges associated with application-specific integrated circuit (ASIC) revenue. (This applies to both the bipolar digital and MOS digital logic categories.)
- Dataquest includes the revenue generated by sales of standalone circuit design software, sold by certain US manufacturers of ASIC logic devices.
- Dataquest includes Signetics revenue with that of its parent company, Netherlands-based N.V. Philips.
- Dataquest includes revenue for Taiwanese semiconductor manufacturers.
- Dataquest includes revenue for three Japanese companies not estimated by WSTS: NMB Semiconductor, Seiko-Epson, and Yamaha.
- As noted herein, Dataquest includes hybrid revenue in the analog category.

Further information on the above points is available through Dataquest's Client Inquiry Center at (408) 437-8099.

Regions—North America is defined as including both the United States and Canada. Latin America, including Mexico, is considered part of the Asia/Pacific-ROW category. Asia/Pacific includes South Korea, Taiwan, Hong Kong, Singapore, China, India, and the countries of Oceania. Western Europe includes Austria, Belgium, the Federal Republic of Germany, France, Italy, Luxembourg, the Netherlands, the Scandinavian countries (Denmark, Finland, Norway, Sweden), Spain, the United Kingdom and Ireland, and the rest of Europe. As a result of the union of West Germany and East Germany in 1990, henceforth the unified Germany will be included in Western Europe. Japan, the fourth region, is the only single-country region.

Data Sources

The historical information presented in the revenue and shipment data has been consolidated from a variety of sources, each of which focuses on a specific part of the market. These sources include the following:

- World Semiconductor Trade Statistics (WSTS) data and Dataquest's estimates of regional company sales are used to determine sales to North America.
- Japanese trade statistics compiled and published by the Ministry of Finance (MOF) and the Ministry of International Trade and Industry (MITI), WSTS data, and Dataquest's estimates of regional company sales are used to determine sales to Japan.
- For Western European markets, WSTS data and Dataquest's estimates of regional company sales are used to determine market size.
- In Asia/Pacific-ROW, the major sources used to estimate market size are WSTS data and Dataquest's estimates of company sales into the region.

Dataquest believes that the estimates presented here are the most accurate and meaningful generally available today. The sources of the data and the guidelines for the forecasts presented in the tables are as follows:

- Unit shipments or revenue (or both) published by major industry participants, both in the United States and abroad

- Estimates presented by knowledgeable and reliable industry spokespersons
- Government data or trade association data such as those from the Electronics Industry Association (EIA), MITI, WSTS, and the U.S. Department of Commerce
- Published product literature and price lists
- Interviews with knowledgeable manufacturers, distributors, and users
- Relevant projected world economic data

Accuracy

The tables presented here represent Dataquest estimates that we believe are reasonably accurate. Where we have no reasonable estimate, none is given. A zero in a table represents an estimate.

Valuation of Shipments

Regional market size is expressed in US dollars (with the Japanese market also expressed in yen). To make the tables in this study useful in comparing different regions, it is necessary to express all values in a common currency, and we chose the US dollar for convenience. However, the choice of the US dollar (or any single currency, for that matter) as the currency basis for the tables brings with it some problems that require the readers' careful consideration in interpreting the data.

Inflation

All countries that participate significantly in international semiconductor markets suffered from an overall price inflation in the 1970s, continuing into the 1980s and 1990s. As a consequence, the dollar in a given year is not truly comparable with the dollar in any preceding year. Consumer and wholesale price indexes and GNP deflators all measure price changes in various composite "market baskets" of goods. However, there is no price index that measures price changes of material, equipment, and labor inputs to the semiconductor industry. Indeed, the "mix" is changing so rapidly that what is used this year was sometimes unavailable last year, at any price. Nor is there a composite price index that measures price changes in aggregate semiconductor product. In an industry noted for its deflationary trends, this latter effect would tend to make the component purchaser's dollar worth more as time passed, in terms of purchasing ability.

We have made no adjustments in the historical data to account for these inflationary and deflationary effects. The data are expressed in current dollars (dollars that include the inflation rate and exchange rates of the given year) for all historical data; comparisons between different years must be interpreted accordingly.

Average Selling Prices

When considering the worldwide average selling prices (ASPs) for semiconductor components, one must look at the price per function of a circuit, the complexity of the circuit, and the product mix according to this increasing complexity. It is true that one characteristic of the semiconductor industry is that the price per function for integrated circuits has been dropping an average of 30 percent per year for the last 15 years. At the same time, circuits have become denser, resulting in an overall increase in the price of a device with a decreasing cost per function. Thus, Tables 7a through 7g show the worldwide ASPs increasing after many years of decreasing, due to the move toward higher-complexity devices. There are also regional differences in ASPs due to regional competition differences and the varying regional product consumption mix. The worldwide ASP is truly an aggregate measure and may differ significantly from ASPs in any specific market at any point in time.

Exchange Rates

Construction of the West European tables involves combining data from many countries, each of which has different and changing exchange rates. Dataquest uses Annual Foreign Exchange Rates for each year as published by The International Monetary Fund. As far as possible, we prepare our estimates in terms of local currencies before conversion to US dollars. The exchange rates for major currencies can be found in Table 0 at the end of this introduction.

Japanese market size is originally expressed in yen. The Japanese data published in this study are expressed in both dollars (Tables 3a through 3g) and in yen (Tables 4a through 4g). The yen/dollar exchange rate used for each year can be found in Table 0. Because of the fluctuations in the exchange rate for the yen, the dollar values given tend to distort the growth rate of the Japanese market, but they do provide a useful basis for regional market size comparisons. However, the data in yen give a better picture of the real growth in the Japanese market.

Forecast

As mentioned previously, historical data are expressed in current dollars or dollars that include the given year's inflation rate and exchange rates. However, the revenue forecasts use constant dollars and exchange rates, with no allowance for inflation or variations in the rates of exchange between countries. All estimates for 1990 and beyond are made as if 1990 monetary conditions will continue through 2000 and, therefore, show the absolute year-to-year growth during this period.

Table 0

Japan and Western Europe Exchange Rates
(In US Dollars)

Year	Yrly/Qtrly	Japan (Yen per US$)	France (US$ per Franc)	West Germany (US$ per Deutsche Mark)	United Kingdom (US$ per Pound Sterling)
1970	YR	358	0.18	0.27	2.38
1971	YR	343	0.18	0.29	2.44
1972	YR	302	0.20	0.31	2.50
1973	YR	269	0.22	0.37	2.44
1974	YR	292	0.21	0.39	2.33
1975	YR	297	0.23	0.41	2.22
1976	YR	296	0.21	0.40	1.82
1977	YR	269	0.20	0.43	1.75
1978	YR	210	0.22	0.50	1.92
1979	YR	219	0.24	0.55	2.13
1980	YR	227	0.24	0.55	2.33
1981	YR	221	0.18	0.44	2.04
1982	YR	248	0.15	0.41	1.75
1983	YR	235	0.13	0.39	1.52
1984	YR	237	0.11	0.35	1.33
1985	YR	238	0.11	0.34	1.30
1986	YR	167	0.14	0.46	1.47
1987	YR	144	0.17	0.56	1.64
1988	YR	130	0.17	0.57	1.79
1989	YR	138	0.16	0.53	1.50

Source: The International Monetary Fund, Financial Times, Dataquest (October 1990)

Table 1a

Worldwide Semiconductor Market
(Millions of Dollars)

	1980	1981	1982	1983	1984
Total Including Captives	14,118	14,828	15,261	21,552	31,325
North American Captives	NA	NA	NA	2,015	2,500
Total Semiconductor	14,118	14,828	15,261	19,537	28,825
Total IC	9,546	10,046	10,894	14,700	22,618
Bipolar Digital	2,374	2,337	2,412	3,015	4,783
Memory	572	558	511	603	774
Logic	1,802	1,779	1,901	2,412	4,009
MOS Digital	4,715	4,822	5,642	7,951	12,947
Memory	2,230	2,075	2,701	3,719	6,225
Micro	862	1,085	1,318	1,979	3,229
Logic	1,623	1,662	1,623	2,253	3,493
Analog	2,457	2,887	2,840	3,734	4,888
Total Discrete	3,883	3,985	3,547	3,865	4,986
Total Optoelectronic	689	797	820	972	1,221

NA = Not available
Source: Dataquest (October 1990)

Table 1b

Worldwide Semiconductor Market
(Percent Change)

	1980	1981	1982	1983	1984
Total Including Captives	NA	NA	NA	NA	45.3
North American Captives	NA	NA	NA	NA	24.1
Total Semiconductor	27.0	5.0	2.9	28.0	47.5
Total IC	35.8	5.2	8.4	34.9	53.9
Bipolar Digital	41.8	(1.6)	3.2	25.0	58.6
Memory	76.5	(2.4)	(8.4)	18.0	28.4
Logic	33.5	(1.3)	6.9	26.9	66.2
MOS Digital	40.9	2.3	17.0	40.9	62.8
Memory	33.1	(7.0)	30.2	37.7	67.4
Micro	59.3	25.9	21.5	50.2	63.2
Logic	43.8	2.4	(2.3)	38.8	55.0
Analog	22.4	17.5	(1.6)	31.5	30.9
Total Discrete	10.2	2.6	(11.0)	9.0	29.0
Total Optoelectronic	22.2	15.7	2.9	18.5	25.6

NA = Not available
Source: Dataquest (October 1990)

Table 1c

Worldwide Semiconductor Market
(Millions of Dollars)

	1985	1986	1987	1988	1989	1990
Total Including Captives	27,116	33,729	41,478	54,521	61,454	61,031
North American Captives	2,773	2,895	3,227	3,662	4,241	4,562
Total Semiconductor	24,343	30,834	38,251	50,859	57,213	56,469
Total IC	18,552	23,618	29,887	41,068	46,924	45,946
Bipolar Digital	3,684	4,325	4,760	5,200	4,510	4,253
Memory	589	606	621	689	540	452
Logic	3,095	3,719	4,139	4,511	3,970	3,801
MOS Digital	10,103	12,815	17,473	26,988	33,024	31,677
Memory	3,817	4,511	6,056	11,692	16,361	13,413
Micro	2,745	3,489	5,108	7,144	8,202	9,198
Logic	3,541	4,815	6,309	8,152	8,461	9,066
Analog	4,765	6,478	7,654	8,880	9,390	10,016
Total Discrete	4,578	5,730	6,655	7,612	7,662	7,806
Total Optoelectronic	1,213	1,486	1,709	2,179	2,627	2,717

Source: Dataquest (October 1990)

Table 1d

Worldwide Semiconductor Market
(Percent Change)

	1985	1986	1987	1988	1989	1990
Total Including Captives	(13.4)	24.4	23.0	31.4	12.7	(0.7)
North American Captives	10.9	4.4	11.5	13.5	15.8	7.6
Total Semiconductor	(15.5)	26.7	24.1	33.0	12.5	(1.3)
Total IC	(18.0)	27.3	26.5	37.4	14.3	(2.1)
Bipolar Digital	(23.0)	17.4	10.1	9.2	(13.3)	(5.7)
Memory	(23.9)	2.9	2.5	11.0	(21.6)	(16.3)
Logic	(22.8)	20.2	11.3	9.0	(12.0)	(4.3)
MOS Digital	(22.0)	26.8	36.3	54.5	22.4	(4.1)
Memory	(38.7)	18.2	34.2	93.1	39.9	(18.0)
Micro	(15.0)	27.1	46.4	39.9	14.8	12.1
Logic	1.4	36.0	31.0	29.2	3.8	7.2
Analog	(2.5)	35.9	18.2	16.0	5.7	6.7
Total Discrete	(8.2)	25.2	16.1	14.4	0.7	1.9
Total Optoelectronic	(0.7)	22.5	15.0	27.5	20.6	3.4

Source: Dataquest (October 1990)

Table 1e

Worldwide Semiconductor Market
(Millions of Dollars)

	1991	1992	1993	1994	1995	2000
Total Including Captives	70,318	83,528	102,250	110,855	117,467	225,569
North American Captives	5,377	6,269	7,573	8,299	8,582	16,480
Total Semiconductor	64,941	77,259	94,677	102,556	108,885	209,089
Total IC	53,311	64,367	80,470	87,382	93,125	186,097
Bipolar Digital	4,542	4,856	5,002	4,674	4,497	3,842
Memory	423	423	412	388	358	263
Logic	4,119	4,433	4,590	4,286	4,139	3,579
MOS Digital	37,296	46,333	60,218	65,782	71,256	151,630
Memory	16,004	20,620	27,625	29,580	32,149	71,677
Micro	10,869	13,047	16,726	18,644	20,162	41,250
Logic	10,423	12,666	15,867	17,558	18,945	38,703
Analog	11,473	13,178	15,250	16,926	17,372	30,625
Total Discrete	8,592	9,522	10,396	11,061	11,302	15,989
Total Optoelectronic	3,038	3,370	3,811	4,113	4,458	7,003

Source: Dataquest (October 1990)

Table 1f

Worldwide Semiconductor Market
(Percent Change)

	1991	1992	1993	1994	1995
Total Including Captives	15.2	18.8	22.4	8.4	6.0
North American Captives	17.9	16.6	20.8	9.6	3.4
Total Semiconductor	15.0	19.0	22.5	8.3	6.2
Total IC	16.0	20.7	25.0	8.6	6.6
Bipolar Digital	6.8	6.9	3.0	(6.6)	(3.8)
Memory	(6.4)	0	(2.6)	(5.8)	(7.7)
Logic	8.4	7.6	3.5	(6.6)	(3.4)
MOS Digital	17.7	24.2	30.0	9.2	8.3
Memory	19.3	28.8	34.0	7.1	8.7
Micro	18.2	20.0	28.2	11.5	8.1
Logic	15.0	21.5	25.3	10.7	7.9
Analog	14.5	14.9	15.7	11.0	2.6
Total Discrete	10.1	10.8	9.2	6.4	2.2
Total Optoelectronic	11.8	10.9	13.1	7.9	8.4

Source: Dataquest (October 1990)

Table 1g

Worldwide Semiconductor Market (Compound Annual Growth Rate)

	CAGR (%) 1980-1985	CAGR (%) 1985-1990	CAGR (%) 1990-1995	CAGR (%) 1995-2000	CAGR (%) 1980-1990	CAGR (%) 1990-2000
Total Including Captives	13.9	17.6	14.0	13.9	15.8	14.0
North American Captives	NA	10.5	13.5	13.9	NA	13.7
Total Semiconductor	11.5	18.3	14.0	13.9	14.9	14.0
Total IC	14.2	19.9	15.2	14.9	17.0	15.0
Bipolar Digital	9.2	2.9	1.1	(3.1)	6.0	(1.0)
Memory	0.6	(5.2)	(4.6)	(6.0)	(2.3)	(5.3)
Logic	11.4	4.2	1.7	(2.9)	7.7	(0.6)
MOS Digital	16.5	25.7	17.6	16.3	21.0	17.0
Memory	11.3	28.6	19.1	17.4	19.7	18.2
Micro	26.1	27.4	17.0	15.4	26.7	16.2
Logic	16.9	20.7	15.9	15.4	18.8	15.6
Analog	14.2	16.0	11.6	12.0	15.1	11.8
Total Discrete	3.3	11.3	7.7	7.2	7.2	7.4
Total Optoelectronic	12.0	17.5	10.4	9.5	14.7	9.9

NA = Not available
Source: Dataquest (October 1990)

Table 2a

North American Semiconductor Market
(Millions of Dollars)

	1980	1981	1982	1983	1984
Total Including Captives	6,053	6,529	6,970	10,625	15,033
North American Captives	NA	NA	NA	1,623	2,027
Total Semiconductor	6,053	6,529	6,970	9,002	13,006
Total IC	4,562	4,867	5,466	7,301	11,089
Bipolar Digital	1,411	1,339	1,367	1,664	2,818
Memory	396	375	320	373	441
Logic	1,015	964	1,047	1,291	2,377
MOS Digital	2,442	2,595	3,183	4,326	6,503
Memory	1,230	1,107	1,592	2,051	3,426
Micro	377	489	641	1,034	1,634
Logic	835	999	950	1,241	1,443
Analog	709	933	916	1,311	1,768
Total Discrete	1,269	1,378	1,201	1,353	1,503
Total Optoelectronic	222	284	303	348	414

NA = Not available
Source: Dataquest (October 1990)

Table 2b

North American Semiconductor Market
(Percent Change)

	1980	1981	1982	1983	1984
Total Including Captives	NA	NA	NA	NA	41.5
North American Captives	NA	NA	NA	NA	24.9
Total Semiconductor	33.4	7.9	6.8	29.2	44.5
Total IC	43.5	6.7	12.3	33.6	51.9
Bipolar Digital	56.6	(5.1)	2.1	21.7	69.4
Memory	114.1	(5.3)	(14.7)	16.6	18.2
Logic	41.8	(5.0)	8.6	23.3	84.1
MOS Digital	43.4	6.3	22.7	35.9	50.3
Memory	19.6	(10.0)	43.8	28.8	67.0
Micro	102.7	29.7	31.1	61.3	58.0
Logic	70.8	19.6	(4.9)	30.6	16.3
Analog	23.3	31.6	(1.8)	43.1	34.9
Total Discrete	9.3	8.6	(12.8)	12.7	11.1
Total Optoelectronic	12.1	27.9	6.7	14.9	19.0

NA = Not available
Source: Dataquest (October 1990)

Table 2c

North American Semiconductor Market
(Millions of Dollars)

	1985	1986	1987	1988	1989	1990
Total Including Captives	11,663	13,171	15,454	18,789	21,348	21,126
North American Captives	2,243	2,327	2,596	2,945	3,411	3,669
Total Semiconductor	9,420	10,844	12,858	15,844	17,937	17,457
Total IC	7,757	8,986	10,886	13,815	15,909	15,360
Bipolar Digital	1,926	2,030	2,099	2,012	1,701	1,670
Memory	288	267	271	235	203	170
Logic	1,638	1,763	1,828	1,777	1,498	1,500
MOS Digital	4,322	4,912	6,738	9,606	11,682	11,014
Memory	1,753	1,775	2,497	4,298	6,163	4,925
Micro	1,258	1,362	2,012	2,707	2,972	3,328
Logic	1,311	1,775	2,229	2,601	2,547	2,761
Analog	1,509	2,044	2,049	2,197	2,526	2,676
Total Discrete	1,295	1,542	1,642	1,676	1,683	1,715
Total Optoelectronic	368	316	330	353	345	382

Source: Dataquest (October 1990)

Table 2d

North American Semiconductor Market
(Percent Change)

	1985	1986	1987	1988	1989	1990
Total Including Captives	(22.4)	12.9	17.3	21.6	13.6	(1.0)
North American Captives	10.7	3.7	11.6	13.4	15.8	7.6
Total Semiconductor	(27.6)	15.1	18.6	23.2	13.2	(2.7)
Total IC	(30.0)	15.8	21.1	26.9	15.2	(3.5)
Bipolar Digital	(31.7)	5.4	3.4	(4.1)	(15.5)	(1.8)
Memory	(34.7)	(7.3)	1.5	(13.3)	(13.6)	(16.3)
Logic	(31.1)	7.6	3.7	(2.8)	(15.7)	0.1
MOS Digital	(33.5)	13.7	37.2	42.6	21.6	(5.7)
Memory	(48.8)	1.3	40.7	72.1	43.4	(20.1)
Micro	(23.0)	8.3	47.7	34.5	9.8	12.0
Logic	(9.1)	35.4	25.6	16.7	(2.1)	8.4
Analog	(14.6)	35.5	0.2	7.2	15.0	5.9
Total Discrete	(13.8)	19.1	6.5	2.1	0.4	1.9
Total Optoelectronic	(11.1)	(14.1)	4.4	7.0	(2.3)	10.7

Source: Dataquest (October 1990)

Table 2e

North American Semiconductor Market
(Millions of Dollars)

	1991	1992	1993	1994	1995	2000
Total Including Captives	24,681	28,831	34,818	38,146	39,437	73,922
North American Captives	4,324	5,042	6,091	6,675	6,902	13,255
Total Semiconductor	20,357	23,789	28,727	31,471	32,535	60,667
Total IC	18,074	21,262	26,017	28,621	29,696	56,139
Bipolar Digital	1,783	1,905	1,844	1,707	1,592	987
Memory	149	148	137	122	110	50
Logic	1,634	1,757	1,707	1,585	1,482	937
MOS Digital	13,144	15,934	20,227	22,484	23,536	46,044
Memory	5,837	7,112	9,103	10,236	10,649	21,217
Micro	4,076	4,848	6,156	6,814	7,290	14,036
Logic	3,231	3,974	4,968	5,434	5,597	10,791
Analog	3,147	3,423	3,946	4,430	4,568	9,108
Total Discrete	1,871	2,088	2,240	2,350	2,338	3,583
Total Optoelectronic	412	439	470	500	501	945

Source: Dataquest (October 1990)

Table 2f

North American Semiconductor Market
(Percent Change)

	1991	1992	1993	1994	1995
Total Including Captives	16.8	16.8	20.8	9.6	3.4
North American Captives	17.9	16.6	20.8	9.6	3.4
Total Semiconductor	16.6	16.9	20.8	9.6	3.4
Total IC	17.7	17.6	22.4	10.0	3.8
Bipolar Digital	6.8	6.8	(3.2)	(7.4)	(6.7)
Memory	(12.4)	(0.7)	(7.4)	(10.9)	(9.8)
Logic	8.9	7.5	(2.8)	(7.1)	(6.5)
MOS Digital	19.3	21.2	26.9	11.2	4.7
Memory	18.5	21.8	28.0	12.4	4.0
Micro	22.5	18.9	27.0	10.7	7.0
Logic	17.0	23.0	25.0	9.4	3.0
Analog	17.6	8.8	15.3	12.3	3.1
Total Discrete	9.1	11.6	7.3	4.9	(0.5)
Total Optoelectronic	7.9	6.6	7.1	6.4	0.2

Source: Dataquest (October 1990)

Table 2g

North American Semiconductor Market
(Compound Annual Growth Rate)

	CAGR (%) 1980-1985	CAGR (%) 1985-1990	CAGR (%) 1990-1995	CAGR (%) 1995-2000	CAGR (%) 1980-1990	CAGR (%) 1990-2000
Total Including Captives	14.0	12.6	13.3	13.4	13.3	13.3
North American Captives	NA	10.3	13.5	13.9	NA	13.7
Total Semiconductor	9.2	13.1	13.3	13.3	11.2	13.3
Total IC	11.2	14.6	14.1	13.6	12.9	13.8
Bipolar Digital	6.4	(2.8)	(1.0)	(9.1)	1.7	(5.1)
Memory	(6.2)	(10.0)	(8.3)	(14.6)	(8.1)	(11.5)
Logic	10.0	(1.7)	(0.2)	(8.8)	4.0	(4.6)
MOS Digital	12.1	20.6	16.4	14.4	16.3	15.4
Memory	7.3	22.9	16.7	14.8	14.9	15.7
Micro	27.3	21.5	17.0	14.0	24.3	15.5
Logic	9.4	16.1	15.2	14.0	12.7	14.6
Analog	16.3	12.1	11.3	14.8	14.2	13.0
Total Discrete	0.4	5.8	6.4	8.9	3.1	7.6
Total Optoelectronic	10.6	0.7	5.6	13.5	5.6	9.5

NA = Not available
Source: Dataquest (October 1990)

Table 3a

Japanese Semiconductor Market
(Millions of Dollars)

	1980	1981	1982	1983	1984
Total Including Captives	3,383	4,295	4,082	5,834	8,909
North American Captives	NA	NA	NA	112	135
Total Semiconductor	3,383	4,295	4,082	5,722	8,774
Total IC	2,201	2,793	2,855	4,167	6,517
Bipolar Digital	345	438	498	706	955
Memory	57	77	87	109	163
Logic	288	361	411	597	792
MOS Digital	991	1,174	1,263	1,948	3,621
Memory	423	491	534	893	1,579
Micro	269	404	446	594	979
Logic	299	279	283	461	1,063
Analog	865	1,181	1,094	1,513	1,941
Total Discrete	986	1,237	970	1,217	1,756
Total Optoelectronic	196	265	257	338	501

NA = Not available
Source: Dataquest (October 1990)

Table 3b

Japanese Semiconductor Market
(Percent Change)

	1980	1981	1982	1983	1984
Total Including Captives	NA	NA	NA	NA	52.7
North American Captives	NA	NA	NA	NA	20.5
Total Semiconductor	22.2	27.0	(5.0)	40.2	53.3
Total IC	26.6	26.9	2.2	46.0	56.4
Bipolar Digital	13.5	27.0	13.7	41.8	35.3
Memory	9.6	35.1	13.0	25.3	49.5
Logic	14.3	25.3	13.9	45.3	32.7
MOS Digital	30.1	18.5	7.6	54.2	85.9
Memory	65.2	16.1	8.8	67.2	76.8
Micro	26.3	50.2	10.4	33.2	64.8
Logic	2.0	(6.7)	1.4	62.9	130.6
Analog	28.7	36.5	(7.4)	38.3	28.3
Total Discrete	10.9	25.5	(21.6)	25.5	44.3
Total Optoelectronic	39.0	35.2	(3.0)	31.5	48.2

NA = Not available
Source: Dataquest (October 1990)

Table 3c

Japanese Semiconductor Market
(Millions of Dollars)

	1985	1986	1987	1988	1989	1990
Total Including Captives	8,300	12,018	15,107	20,977	23,234	21,632
North American Captives	151	163	180	205	237	255
Total Semiconductor	8,149	11,855	14,927	20,772	22,997	21,377
Total IC	5,985	8,802	11,263	16,127	17,946	16,569
Bipolar Digital	824	1,295	1,523	1,906	1,750	1,524
Memory	136	169	227	348	246	194
Logic	688	1,126	1,296	1,558	1,504	1,330
MOS Digital	3,232	4,762	6,424	10,501	12,497	11,353
Memory	1,185	1,738	2,268	4,424	5,992	4,685
Micro	884	1,368	1,902	2,573	2,828	2,864
Logic	1,163	1,656	2,254	3,504	3,677	3,804
Analog	1,929	2,745	3,316	3,720	3,699	3,692
Total Discrete	1,621	2,242	2,693	3,282	3,321	3,100
Total Optoelectronic	543	811	971	1,363	1,730	1,708

Source: Dataquest (October 1990)

Table 3d

Japanese Semiconductor Market
(Percent Change)

	1985	1986	1987	1988	1989	1990
Total Including Captives	(6.8)	44.8	25.7	38.9	10.8	(6.9)
North American Captives	11.9	7.9	10.4	13.9	15.6	7.6
Total Semiconductor	(7.1)	45.5	25.9	39.2	10.7	(7.0)
Total IC	(8.2)	47.1	28.0	43.2	11.3	(7.7)
Bipolar Digital	(13.7)	57.2	17.6	25.1	(8.2)	(12.9)
Memory	(16.6)	24.3	34.3	53.3	(29.3)	(21.1)
Logic	(13.1)	63.7	15.1	20.2	(3.5)	(11.6)
MOS Digital	(10.7)	47.3	34.9	63.5	19.0	(9.2)
Memory	(25.0)	46.7	30.5	95.1	35.4	(21.8)
Micro	(9.7)	54.8	39.0	35.3	9.9	1.3
Logic	9.4	42.4	36.1	55.5	4.9	3.5
Analog	(0.6)	42.3	20.8	12.2	(0.6)	(0.2)
Total Discrete	(7.7)	38.3	20.1	21.9	1.2	(6.7)
Total Optoelectronic	8.4	49.4	19.7	40.4	26.9	(1.3)

Source: Dataquest (October 1990)

Table 3e

Japanese Semiconductor Market
(Millions of Dollars)

	1991	1992	1993	1994	1995	2000
Total Including Captives	24,316	28,733	34,335	35,718	38,688	70,471
North American Captives	301	351	423	464	480	921
Total Semiconductor	24,015	28,382	33,912	35,254	38,208	69,550
Total IC	18,772	22,696	27,728	28,727	31,202	59,714
Bipolar Digital	1,610	1,679	1,751	1,686	1,702	1,672
Memory	192	192	192	190	185	170
Logic	1,418	1,487	1,559	1,496	1,517	1,502
MOS Digital	12,957	16,219	20,702	21,336	23,739	49,578
Memory	5,435	7,338	9,759	9,272	10,292	22,468
Micro	3,160	3,691	4,559	5,010	5,511	10,657
Logic	4,362	5,190	6,384	7,054	7,936	16,453
Analog	4,205	4,798	5,275	5,705	5,761	8,464
Total Discrete	3,329	3,580	3,800	4,000	4,200	5,620
Total Optoelectronic	1,914	2,106	2,384	2,527	2,806	4,216

Source: Dataquest (October 1990)

Table 3f

Japanese Semiconductor Market
(Percent Change)

	1991	1992	1993	1994	1995
Total Including Captives	12.4	18.2	19.5	4.0	8.3
North American Captives	18.0	16.6	20.5	9.7	3.4
Total Semiconductor	12.3	18.2	19.5	4.0	8.4
Total IC	13.3	20.9	22.2	3.6	8.6
Bipolar Digital	5.6	4.3	4.3	(3.7)	0.9
Memory	(1.0)	0	0	(1.0)	(2.6)
Logic	6.6	4.9	4.8	(4.0)	1.4
MOS Digital	14.1	25.2	27.6	3.1	11.3
Memory	16.0	35.0	33.0	(5.0)	11.0
Micro	10.3	16.8	23.5	9.9	10.0
Logic	14.7	19.0	23.0	10.5	12.5
Analog	13.9	14.1	9.9	8.2	1.0
Total Discrete	7.4	7.5	6.1	5.3	5.0
Total Optoelectronic	12.1	10.0	13.2	6.0	11.0

Source: Dataquest (October 1990)

Table 3g

Japanese Semiconductor Market
(Compound Annual Growth Rate in US Dollars)

	CAGR (%) 1980-1985	CAGR (%) 1985-1990	CAGR (%) 1990-1995	CAGR (%) 1995-2000	CAGR (%) 1980-1990	CAGR (%) 1990-2000
Total Including Captives	19.7	21.1	12.3	12.7	20.4	12.5
North American Captives	NA	11.0	13.5	13.9	NA	13.7
Total Semiconductor	19.2	21.3	12.3	12.7	20.2	12.5
Total IC	22.1	22.6	13.5	13.9	22.4	13.7
Bipolar Digital	19.0	13.1	2.2	(0.4)	16.0	0.9
Memory	19.0	7.4	(0.9)	(1.7)	13.0	(1.3)
Logic	19.0	14.1	2.7	(0.2)	16.5	1.2
MOS Digital	26.7	28.6	15.9	15.9	27.6	15.9
Memory	22.9	31.6	17.0	16.9	27.2	17.0
Micro	26.9	26.5	14.0	14.1	26.7	14.0
Logic	31.2	26.7	15.8	15.7	29.0	15.8
Analog	17.4	13.9	9.3	8.0	15.6	8.7
Total Discrete	10.5	13.8	6.3	6.0	12.1	6.1
Total Optoelectronic	22.6	25.8	10.4	8.5	24.2	9.5

NA = Not available
Source: Dataquest (October 1990)

Table 4a

Japanese Semiconductor Market
(Billions of Yen)

	1980	1981	1982	1983	1984
Total Including Captives	768.0	949.3	1,012.3	1,371.0	2,111.3
North American Captives	NA	NA	NA	26.3	32.0
Total Semiconductor	768.0	949.3	1,012.3	1,344.7	2,079.3
Total IC	499.7	617.3	708.0	979.3	1,544.4
Bipolar Digital	78.3	96.8	123.5	165.9	226.3
Memory	12.9	17.0	21.6	25.6	38.6
Logic	65.4	79.8	101.9	140.3	187.7
MOS Digital	225.0	259.5	313.2	457.8	858.1
Memory	96.0	108.5	132.4	209.9	374.2
Micro	61.1	89.3	110.6	139.6	232.0
Logic	67.9	61.7	70.2	108.3	251.9
Analog	196.4	261.0	271.3	355.6	460.0
Total Discrete	223.8	273.4	240.6	286.0	416.2
Total Optoelectronic	44.5	58.6	63.7	79.4	118.7
Exchange Rate (Yen/$)	227	221	248	235	237

NA = Not available
Source: Dataquest (October 1990)

Table 4b

Japanese Semiconductor Market
(Percent Change in Yen)

	1980	1981	1982	1983	1984
Total Including Captives	NA	NA	NA	NA	54.0
North American Captives	NA	NA	NA	NA	21.7
Total Semiconductor	26.7	23.6	6.6	32.8	54.6
Total IC	31.3	23.5	14.7	38.3	57.7
Bipolar Digital	17.6	23.6	27.6	34.3	36.4
Memory	13.2	31.8	27.1	18.5	50.8
Logic	18.5	22.0	27.7	37.7	33.8
MOS Digital	34.8	15.3	20.7	46.2	87.4
Memory	71.1	13.0	22.0	58.5	78.3
Micro	31.1	46.2	23.9	26.2	66.2
Logic	5.8	(9.1)	13.8	54.3	132.6
Analog	33.4	32.9	3.9	31.1	29.4
Total Discrete	14.9	22.2	(12.0)	18.9	45.5
Total Optoelectronic	44.0	31.7	8.7	24.6	49.5

NA = Not available
Source: Dataquest (October 1990)

Table 4c

Japanese Semiconductor Market
(Billions of Yen)

	1985	1986	1987	1988	1989	1990
Total Including Captives	1,975.3	2,006.9	2,175.4	2,727.0	3,212.6	3,309.7
North American Captives	35.9	27.2	25.9	26.7	32.8	39.0
Total Semiconductor	1,939.4	1,979.7	2,149.5	2,700.3	3,179.8	3,270.7
Total IC	1,424.4	1,469.9	1,621.9	2,096.4	2,481.4	2,535.1
Bipolar Digital	196.1	216.2	219.3	247.7	242.0	233.2
Memory	32.4	28.2	32.7	45.2	34.0	29.7
Logic	163.7	188.0	186.6	202.5	208.0	203.5
MOS Digital	769.2	795.3	925.1	1,365.1	1,727.9	1,737.0
Memory	282.0	290.2	326.6	575.1	828.5	716.8
Micro	210.4	228.5	273.9	334.5	391.0	438.2
Logic	276.8	276.6	324.6	455.5	508.4	582.0
Analog	459.1	458.4	477.5	483.6	511.5	564.9
Total Discrete	385.8	374.4	387.8	426.7	459.2	474.3
Total Optoelectronic	129.2	135.4	139.8	177.2	239.2	261.3
Exchange Rate (Yen/$)	238	167	144	130	138	153

Source: Dataquest (October 1990)

Table 4d

Japanese Semiconductor Market
(Percent Change in Yen)

	1985	1986	1987	1988	1989	1990
Total Including Captives	(6.4)	1.6	8.4	25.4	17.8	3.0
North American Captives	12.2	(24.2)	(4.8)	3.1	22.8	18.9
Total Semiconductor	(6.7)	2.1	8.6	25.6	17.8	2.9
Total IC	(7.8)	3.2	10.3	29.3	18.4	2.2
Bipolar Digital	(13.3)	10.2	1.4	13.0	(2.3)	(3.6)
Memory	(16.1)	(13.0)	16.0	38.2	(24.8)	(12.6)
Logic	(12.8)	14.8	(0.7)	8.5	2.7	(2.2)
MOS Digital	(10.4)	3.4	16.3	47.6	26.6	0.5
Memory	(24.6)	2.9	12.5	76.1	44.1	(13.5)
Micro	(9.3)	8.6	19.9	22.1	16.9	12.1
Logic	9.9	(0.1)	17.4	40.3	11.6	14.5
Analog	(0.2)	(0.2)	4.2	1.3	5.8	10.4
Total Discrete	(7.3)	(3.0)	3.6	10.0	7.6	3.3
Total Optoelectronic	8.8	4.8	3.2	26.8	35.0	9.2

Source: Dataquest (October 1990)

Table 4e

Japanese Semiconductor Market
(Billions of Yen)

	1991	1992	1993	1994	1995	2000
Total Including Captives	3,769.1	4,453.7	5,321.8	5,536.5	5,996.7	10,923.0
North American Captives	46.7	54.4	65.6	71.9	74.4	142.8
Total Semiconductor	3,722.4	4,399.3	5,256.2	5,464.6	5,922.3	10,780.2
Total IC	2,909.7	3,518.0	4,297.7	4,452.9	4,836.4	9,255.6
Bipolar Digital	249.6	260.3	271.4	261.4	263.8	259.2
Memory	29.8	29.8	29.8	29.5	28.7	26.4
Logic	219.8	230.5	241.6	231.9	235.1	232.8
MOS Digital	2,008.3	2,514.0	3,208.7	3,307.2	3,679.6	7,684.5
Memory	842.4	1,137.4	1,512.6	1,437.2	1,595.3	3,482.5
Micro	489.8	572.1	706.6	776.6	854.2	1,651.8
Logic	676.1	804.5	989.5	1,093.4	1,230.1	2,550.2
Analog	651.8	743.7	817.6	884.3	893.0	1,311.9
Total Discrete	516.0	554.9	589.0	620.0	651.0	871.1
Total Optoelectronic	296.7	326.4	369.5	391.7	434.9	653.5
Exchange Rate (Yen/$)	155	155	155	155	155	155

Source: Dataquest (October 1990)

Table 4f

Japanese Semiconductor Market
(Percent Change in Yen)

	1991	1992	1993	1994	1995
Total Including Captives	13.9	18.2	19.5	4.0	8.3
North American Captives	19.7	16.5	20.6	9.6	3.5
Total Semiconductor	13.8	18.2	19.5	4.0	8.4
Total IC	14.8	20.9	22.2	3.6	8.6
Bipolar Digital	7.0	4.3	4.3	(3.7)	0.9
Memory	0.3	0	0	(1.0)	(2.7)
Logic	8.0	4.9	4.8	(4.0)	1.4
MOS Digital	15.6	25.2	27.6	3.1	11.3
Memory	17.5	35.0	33.0	(5.0)	11.0
Micro	11.8	16.8	23.5	9.9	10.0
Logic	16.2	19.0	23.0	10.5	12.5
Analog	15.4	14.1	9.9	8.2	1.0
Total Discrete	8.8	7.5	6.1	5.3	5.0
Total Optoelectronic	13.5	10.0	13.2	6.0	11.0

Source: Dataquest (October 1990)

Table 4g

Japanese Semiconductor Market
(Compound Annual Growth Rate in Yen)

	CAGR (%) 1980-1985	CAGR (%) 1985-1990	CAGR (%) 1990-1995	CAGR (%) 1995-2000	CAGR (%) 1980-1990	CAGR (%) 1990-2000
Total Including Captives	20.8	10.9	12.6	12.7	15.7	12.7
North American Captives	NA	1.7	13.8	13.9	NA	13.9
Total Semiconductor	20.4	11.0	12.6	12.7	15.6	12.7
Total IC	23.3	12.2	13.8	13.9	17.6	13.8
Bipolar Digital	20.2	3.5	2.5	(0.4)	11.5	1.1
Memory	20.2	(1.7)	(0.7)	(1.7)	8.7	(1.2)
Logic	20.1	4.4	2.9	(0.2)	12.0	1.4
MOS Digital	27.9	17.7	16.2	15.9	22.7	16.0
Memory	24.0	20.5	17.4	16.9	22.3	17.1
Micro	28.1	15.8	14.3	14.1	21.8	14.2
Logic	32.5	16.0	16.1	15.7	24.0	15.9
Analog	18.5	4.2	9.6	8.0	11.1	8.8
Total Discrete	11.5	4.2	6.5	6.0	7.8	6.3
Total Optoelectronic	23.8	15.1	10.7	8.5	19.4	9.6

NA = Not available
Source: Dataquest (October 1990)

Table 5a

West European Semiconductor Market
(Millions of Dollars)

	1980	1981	1982	1983	1984
Total Including Captives	3,686	3,041	3,167	3,650	5,202
North American Captives	NA	NA	NA	280	338
Total Semiconductor	3,686	3,041	3,167	3,370	4,864
Total IC	2,333	1,892	1,988	2,323	3,731
Bipolar Digital	510	454	434	483	741
Memory	116	103	100	107	144
Logic	394	351	334	376	597
MOS Digital	1,139	882	948	1,227	2,123
Memory	543	426	469	581	986
Micro	189	149	168	239	471
Logic	407	307	311	407	666
Analog	684	556	606	613	867
Total Discrete	1,192	995	1,011	866	942
Total Optoelectronic	161	154	168	181	191

NA = Not available
Source: Dataquest (October 1990)

Table 5b

West European Semiconductor Market
(Percent Change)

	1980	1981	1982	1983	1984
Total Including Captives	NA	NA	NA	NA	42.5
North American Captives	NA	NA	NA	NA	20.7
Total Semiconductor	22.1	(17.5)	4.1	6.4	44.3
Total IC	33.5	(18.9)	5.1	16.9	60.6
Bipolar Digital	30.8	(11.0)	(4.4)	11.3	53.4
Memory	36.5	(11.2)	(2.9)	7.0	34.6
Logic	29.2	(10.9)	(4.8)	12.6	58.8
MOS Digital	45.8	(22.6)	7.5	29.4	73.0
Memory	48.0	(21.5)	10.1	23.9	69.7
Micro	51.2	(21.2)	12.8	42.3	97.1
Logic	40.8	(24.6)	1.3	30.9	63.6
Analog	18.8	(18.7)	9.0	1.2	41.4
Total Discrete	4.7	(16.5)	1.6	(14.3)	8.8
Total Optoelectronic	21.1	(4.3)	9.1	7.7	5.5

NA = Not available
Source: Dataquest (October 1990)

Table 5c

West European Semiconductor Market
(Millions of Dollars)

	1985	1986	1987	1988	1989	1990
Total Including Captives	5,174	5,992	6,949	9,003	10,348	11,204
North American Captives	379	405	451	512	593	638
Total Semiconductor	4,795	5,587	6,498	8,491	9,755	10,566
Total IC	3,615	4,116	4,840	6,669	7,794	8,285
Bipolar Digital	719	719	727	772	640	636
Memory	150	147	88	74	72	70
Logic	569	572	639	698	568	566
MOS Digital	1,933	2,270	2,761	4,364	5,458	5,646
Memory	745	813	854	1,797	2,548	2,232
Micro	486	574	805	1,212	1,469	1,762
Logic	702	883	1,102	1,355	1,441	1,652
Analog	963	1,127	1,352	1,533	1,696	2,003
Total Discrete	969	1,207	1,377	1,516	1,594	1,872
Total Optoelectronic	211	264	281	306	367	409

Source: Dataquest (October 1990)

Table 5d

West European Semiconductor Market
(Percent Change)

	1985	1986	1987	1988	1989	1990
Total Including Captives	(0.5)	15.8	16.0	29.6	14.9	8.3
North American Captives	12.1	6.9	11.4	13.5	15.8	7.6
Total Semiconductor	(1.4)	16.5	16.3	30.7	14.9	8.3
Total IC	(3.1)	13.9	17.6	37.8	16.9	6.3
Bipolar Digital	(3.0)	0	1.1	6.2	(17.1)	(0.6)
Memory	4.2	(2.0)	(40.1)	(15.9)	(2.7)	(2.8)
Logic	(4.7)	0.5	11.7	9.2	(18.6)	(0.4)
MOS Digital	(8.9)	17.4	21.6	58.1	25.1	3.4
Memory	(24.4)	9.1	5.0	110.4	41.8	(12.4)
Micro	3.2	18.1	40.2	50.6	21.2	19.9
Logic	5.4	25.8	24.8	23.0	6.3	14.6
Analog	11.1	17.0	20.0	13.4	10.6	18.1
Total Discrete	2.9	24.6	14.1	10.1	5.1	17.4
Total Optoelectronic	10.5	25.1	6.4	8.9	19.9	11.4

Source: Dataquest (October 1990)

Table 5e

West European Semiconductor Market
(Millions of Dollars)

	1991	1992	1993	1994	1995	2000
Total Including Captives	12,870	15,220	19,042	21,170	22,401	43,887
North American Captives	752	876	1,059	1,160	1,200	2,304
Total Semiconductor	12,118	14,344	17,983	20,010	21,201	41,583
Total IC	9,621	11,561	14,908	16,733	17,846	37,012
Bipolar Digital	662	729	785	719	642	627
Memory	70	72	74	69	57	42
Logic	592	657	711	650	585	585
MOS Digital	6,718	8,251	11,060	12,626	13,690	30,854
Memory	2,772	3,461	4,838	5,639	6,244	16,195
Micro	2,071	2,524	3,382	3,798	4,065	8,319
Logic	1,875	2,266	2,840	3,189	3,381	6,340
Analog	2,241	2,581	3,063	3,388	3,514	5,531
Total Discrete	2,043	2,283	2,528	2,672	2,725	3,646
Total Optoelectronic	454	500	547	605	630	925

Source: Dataquest (October 1990)

Table 5f

West European Semiconductor Market
(Percent Change)

	1991	1992	1993	1994	1995
Total Including Captives	14.9	18.3	25.1	11.2	5.8
North American Captives	17.9	16.5	20.9	9.5	3.4
Total Semiconductor	14.7	18.4	25.4	11.3	6.0
Total IC	16.1	20.2	29.0	12.2	6.7
Bipolar Digital	4.1	10.1	7.7	(8.4)	(10.7)
Memory	0	2.9	2.8	(6.8)	(17.4)
Logic	4.6	11.0	8.2	(8.6)	(10.0)
MOS Digital	19.0	22.8	34.0	14.2	8.4
Memory	24.2	24.9	39.8	16.6	10.7
Micro	17.5	21.9	34.0	12.3	7.0
Logic	13.5	20.9	25.3	12.3	6.0
Analog	11.9	15.2	18.7	10.6	3.7
Total Discrete	9.1	11.7	10.7	5.7	2.0
Total Optoelectronic	11.0	10.1	9.4	10.6	4.1

Source: Dataquest (October 1990)

Table 5g

West European Semiconductor Market
(Compound Annual Growth Rate)

	CAGR (%) 1980-1985	CAGR (%) 1985-1990	CAGR (%) 1990-1995	CAGR (%) 1995-2000	CAGR (%) 1980-1990	CAGR (%) 1990-2000
Total Including Captives	7.0	16.7	14.9	14.4	11.8	14.6
North American Captives	NA	11.0	13.5	13.9	NA	13.7
Total Semiconductor	5.4	17.1	14.9	14.4	11.1	14.7
Total IC	9.2	18.0	16.6	15.7	13.5	16.1
Bipolar Digital	7.1	(2.4)	0.2	(0.5)	2.2	(0.1)
Memory	5.3	(14.1)	(4.0)	(5.9)	(4.9)	(5.0)
Logic	7.6	(0.1)	0.7	0	3.7	0.3
MOS Digital	11.2	23.9	19.4	17.6	17.4	18.5
Memory	6.5	24.5	22.8	21.0	15.2	21.9
Micro	20.8	29.4	18.2	15.4	25.0	16.8
Logic	11.5	18.7	15.4	13.4	15.0	14.4
Analog	7.1	15.8	11.9	9.5	11.3	10.7
Total Discrete	(4.1)	14.1	7.8	6.0	4.6	6.9
Total Optoelectronic	5.6	14.2	9.0	8.0	9.8	8.5

NA = Not available
Source: Dataquest (October 1990)

Table 6a

Asia/Pacific-ROW Semiconductor Market
(Millions of Dollars)

	1980	1981	1982	1983	1984
Total Including Captives	996	963	1,042	1,443	2,181
North American Captives	NA	NA	NA	0	0
Total Semiconductor	996	963	1,042	1,443	2,181
Total IC	450	494	585	909	1,281
Bipolar Digital	108	106	113	162	269
Memory	3	3	4	14	26
Logic	105	103	109	148	243
MOS Digital	143	171	248	450	700
Memory	34	51	106	194	234
Micro	27	43	63	112	145
Logic	82	77	79	144	321
Analog	199	217	224	297	312
Total Discrete	436	375	365	429	785
Total Optoelectronic	110	94	92	105	115

NA = Not available
Source: Dataquest (October 1990)

Table 6b

Asia/Pacific-ROW Semiconductor Market
(Percent Change)

	1980	1981	1982	1983	1984
Total Including Captives	NA	NA	NA	NA	51.1
North American Captives	NA	NA	NA	NA	NM
Total Semiconductor	26.1	(3.3)	8.2	38.5	51.1
Total IC	23.6	9.8	18.4	55.4	40.9
Bipolar Digital	36.7	(1.9)	6.6	43.4	66.0
Memory	50.0	0	33.3	250.0	85.7
Logic	36.4	(1.9)	5.8	35.8	64.2
MOS Digital	43.0	19.6	45.0	81.5	55.6
Memory	36.0	50.0	107.8	83.0	20.6
Micro	58.8	59.3	46.5	77.8	29.5
Logic	41.4	(6.1)	2.6	82.3	122.9
Analog	7.6	9.0	3.2	32.6	5.1
Total Discrete	30.5	(14.0)	(2.7)	17.5	83.0
Total Optoelectronic	19.6	(14.5)	(2.1)	14.1	9.5

NA = Not available
NM = Not meaningful
Source: Dataquest (October 1990)

Table 6c

Asia/Pacific-ROW Semiconductor Market
(Millions of Dollars)

	1985	1986	1987	1988	1989	1990
Total Including Captives	1,979	2,548	3,968	5,752	6,524	7,069
North American Captives	0	0	0	0	0	0
Total Semiconductor	1,979	2,548	3,968	5,752	6,524	7,069
Total IC	1,195	1,714	2,898	4,457	5,275	5,732
Bipolar Digital	215	281	411	510	419	423
Memory	15	23	35	32	19	18
Logic	200	258	376	478	400	405
MOS Digital	616	871	1,550	2,517	3,387	3,664
Memory	134	185	437	1,173	1,658	1,571
Micro	117	185	389	652	933	1,244
Logic	365	501	724	692	796	849
Analog	364	562	937	1,430	1,469	1,645
Total Discrete	693	739	943	1,138	1,064	1,119
Total Optoelectronic	91	95	127	157	185	218

Source: Dataquest (October 1990)

Table 6d

Asia/Pacific-ROW Semiconductor Market
(Percent Change)

	1985	1986	1987	1988	1989	1990
Total Including Captives	(9.3)	28.8	55.7	45.0	13.4	8.4
North American Captives	NM	NM	NM	NM	NM	NM
Total Semiconductor	(9.3)	28.8	55.7	45.0	13.4	8.4
Total IC	(6.7)	43.4	69.1	53.8	18.4	8.7
Bipolar Digital	(20.1)	30.7	46.3	24.1	(17.8)	1.0
Memory	(42.3)	53.3	52.2	(8.6)	(40.6)	(5.3)
Logic	(17.7)	29.0	45.7	27.1	(16.3)	1.3
MOS Digital	(12.0)	41.4	78.0	62.4	34.6	8.2
Memory	(42.7)	38.1	136.2	168.4	41.3	(5.2)
Micro	(19.3)	58.1	110.3	67.6	43.1	33.3
Logic	13.7	37.3	44.5	(4.4)	15.0	6.7
Analog	16.7	54.4	66.7	52.6	2.7	12.0
Total Discrete	(11.7)	6.6	27.6	20.7	(6.5)	5.2
Total Optoelectronic	(20.9)	4.4	33.7	23.6	17.8	17.8

NM = Not meaningful
Source: Dataquest (October 1990)

Table 6e

Asia/Pacific-ROW Semiconductor Market
(Millions of Dollars)

	1991	1992	1993	1994	1995	2000
Total Including Captives	8,451	10,744	14,055	15,821	16,941	37,289
North American Captives	0	0	0	0	0	0
Total Semiconductor	8,451	10,744	14,055	15,821	16,941	37,289
Total IC	6,844	8,848	11,817	13,301	14,381	33,232
Bipolar Digital	487	543	622	562	561	556
Memory	12	11	9	7	6	1
Logic	475	532	613	555	555	555
MOS Digital	4,477	5,929	8,229	9,336	10,291	25,154
Memory	1,960	2,709	3,925	4,433	4,964	11,797
Micro	1,562	1,984	2,629	3,022	3,296	8,238
Logic	955	1,236	1,675	1,881	2,031	5,119
Analog	1,880	2,376	2,966	3,403	3,529	7,522
Total Discrete	1,349	1,571	1,828	2,039	2,039	3,140
Total Optoelectronic	258	325	410	481	521	917

Source: Dataquest (October 1990)

Table 6f

Asia/Pacific-ROW Semiconductor Market
(Percent Change)

	1991	1992	1993	1994	1995
Total Including Captives	19.6	27.1	30.8	12.6	7.1
North American Captives	NM	NM	NM	NM	NM
Total Semiconductor	19.6	27.1	30.8	12.6	7.1
Total IC	19.4	29.3	33.6	12.6	8.1
Bipolar Digital	15.1	11.5	14.5	(9.6)	(0.2)
Memory	(33.3)	(8.3)	(18.2)	(22.2)	(14.3)
Logic	17.3	12.0	15.2	(9.5)	0
MOS Digital	22.2	32.4	38.8	13.5	10.2
Memory	24.8	38.2	44.9	12.9	12.0
Micro	25.6	27.0	32.5	14.9	9.1
Logic	12.5	29.4	35.5	12.3	8.0
Analog	14.3	26.4	24.8	14.7	3.7
Total Discrete	20.6	16.5	16.4	11.5	0
Total Optoelectronic	18.3	26.0	26.2	17.3	8.3

NM = Not meaningful
Source: Dataquest (October 1990)

Table 6g

Asia/Pacific-ROW Semiconductor Market
(Compound Annual Growth Rate)

	CAGR (%) 1980-1985	CAGR (%) 1985-1990	CAGR (%) 1990-1995	CAGR (%) 1995-2000	CAGR (%) 1980-1990	CAGR (%) 1990-2000
Total Including Captives	14.7	29.0	19.1	17.1	21.6	18.1
North American Captives	NA	NA	NA	NA	NA	NA
Total Semiconductor	14.7	29.0	19.1	17.1	21.6	18.1
Total IC	21.6	36.8	20.2	18.2	29.0	19.2
Bipolar Digital	14.8	14.5	5.8	(0.2)	14.6	2.8
Memory	38.0	3.7	(19.7)	(30.1)	19.6	(25.1)
Logic	13.8	15.2	6.5	0	14.5	3.2
MOS Digital	33.9	42.8	22.9	19.6	38.3	21.2
Memory	31.6	63.6	25.9	18.9	46.7	22.3
Micro	34.1	60.4	21.5	20.1	46.7	20.8
Logic	34.8	18.4	19.1	20.3	26.3	19.7
Analog	12.8	35.2	16.5	16.3	23.5	16.4
Total Discrete	9.7	10.1	12.8	9.0	9.9	10.9
Total Optoelectronic	(3.7)	19.1	19.0	12.0	7.1	15.4

NA = Not available
Source: Dataquest (October 1990)

Table 7a

Worldwide Average Selling Prices
(Dollars)

	1980	1981	1982	1983	1984
Total Semiconductor	0.33	0.31	0.33	0.32	0.36
Total IC	1.07	1.02	0.99	1.03	1.10
Bipolar Digital	0.70	0.70	0.62	0.65	0.65
Memory	NA	NA	NA	NA	NA
Logic	NA	NA	NA	NA	NA
MOS Digital	1.81	1.66	1.63	1.66	1.95
Memory	4.90	3.17	2.62	2.79	3.90
Micro	3.61	3.40	3.26	3.35	3.53
Logic	0.85	0.86	0.80	0.79	0.85
Analog	0.83	0.81	0.79	0.76	0.75
Total Discrete	0.12	0.11	0.11	0.09	0.09
Total Optoelectronic	0.44	0.39	0.29	0.28	0.28

NA = Not available
Source: Dataquest (October 1990)

Table 7b

Worldwide Average Selling Prices
(Percent Change in Dollars)

	1980	1981	1982	1983	1984
Total Semiconductor	11.7	(6.4)	7.5	(3.0)	11.8
Total IC	9.8	(3.9)	(2.8)	3.1	7.5
Bipolar Digital	22.8	0	(11.4)	4.8	0
Memory	NA	NA	NA	NA	NA
Logic	NA	NA	NA	NA	NA
MOS Digital	(6.3)	(8.4)	(1.8)	2.2	17.3
Memory	(4.9)	(35.3)	(17.4)	6.5	39.8
Micro	(8.8)	(5.8)	(4.1)	2.8	5.4
Logic	(4.5)	1.2	(7.0)	(1.3)	7.6
Analog	6.4	(2.4)	(2.5)	(3.8)	(1.3)
Total Discrete	0	(8.3)	0	(18.2)	0
Total Optoelectronic	(12.8)	(11.9)	(25.6)	(3.4)	0

NA = Not available
Source: Dataquest (October 1990)

Table 7c

Worldwide Average Selling Prices
(Dollars)

	1985	1986	1987	1988	1989	1990
Total Semiconductor	0.30	0.34	0.33	0.42	0.42	0.40
Total IC	1.05	1.09	1.18	1.32	1.45	1.35
Bipolar Digital	0.71	0.71	0.69	0.70	0.70	0.65
Memory	NA	NA	NA	NA	NA	NA
Logic	NA	NA	NA	NA	NA	NA
MOS Digital	1.64	1.63	1.94	2.38	2.65	2.35
Memory	2.59	2.41	3.09	4.87	5.88	4.86
Micro	3.14	3.13	3.56	4.15	3.77	4.08
Logic	0.93	0.99	1.12	1.13	1.13	1.07
Analog	0.76	0.84	0.82	0.72	0.70	0.71
Total Discrete	0.08	0.09	0.08	0.09	0.08	0.08
Total Optoelectronic	0.22	0.25	0.28	0.34	0.27	0.26

NA = Not available
Source: Dataquest (October 1990)

Table 7d

Worldwide Average Selling Prices
(Percent Change in Dollars)

	1985	1986	1987	1988	1989	1990
Total Semiconductor	(15.7)	13.2	(2.7)	24.8	(0.3)	(4.3)
Total IC	(4.4)	3.5	8.5	11.6	10.0	(7.3)
Bipolar Digital	9.2	0	(2.8)	1.4	0	(7.1)
Memory	NA	NA	NA	NA	NA	NA
Logic	NA	NA	NA	NA	NA	NA
MOS Digital	(16.0)	(0.5)	18.6	23.0	11.5	(11.5)
Memory	(33.6)	(6.9)	28.2	57.6	20.7	(17.3)
Micro	(11.0)	(0.3)	13.7	16.6	(9.2)	8.2
Logic	9.4	6.5	13.1	0.9	0	(5.3)
Analog	1.3	10.5	(2.4)	(12.2)	(2.8)	1.4
Total Discrete	(11.1)	15.0	(13.0)	12.5	(11.1)	0
Total Optoelectronic	(21.4)	13.6	12.0	21.4	(20.6)	(3.7)

NA = Not available
Source: Dataquest (October 1990)

Table 7e

Worldwide Average Selling Prices
(Dollars)

	1991	1992	1993	1994	1995	2000
Total Semiconductor	0.42	0.45	0.50	0.50	0.51	0.65
Total IC	1.47	1.55	1.73	1.70	1.69	2.01
Bipolar Digital	0.70	0.71	0.72	0.70	0.69	0.69
Memory	NA	NA	NA	NA	NA	NA
Logic	NA	NA	NA	NA	NA	NA
MOS Digital	2.71	2.85	3.23	3.07	3.02	3.51
Memory	5.70	6.81	7.80	8.30	7.30	11.00
Micro	4.16	4.23	4.29	4.16	4.10	4.15
Logic	1.25	1.25	1.42	1.31	1.33	1.45
Analog	0.72	0.72	0.73	0.73	0.69	0.70
Total Discrete	0.08	0.08	0.08	0.08	0.08	0.08
Total Optoelectronic	0.26	0.26	0.26	0.26	0.26	0.26

NA = Not available
Source: Dataquest (October 1990)

Table 7f

Worldwide Average Selling Prices
(Percent Change in Dollars)

	1991	1992	1993	1994	1995
Total Semiconductor	5.3	6.5	11.2	0.8	2.1
Total IC	9.5	5.6	11.3	(1.6)	(1.0)
Bipolar Digital	7.7	1.4	1.4	(2.8)	(1.4)
Memory	NA	NA	NA	NA	NA
Logic	NA	NA	NA	NA	NA
MOS Digital	15.4	5.2	13.3	(5.0)	(1.4)
Memory	17.3	19.5	14.5	6.4	(12.0)
Micro	2.0	1.7	1.5	(3.1)	(1.5)
Logic	16.7	0	13.3	(7.5)	1.5
Analog	1.4	0	1.4	0	(5.5)
Total Discrete	0	0	0	0	0
Total Optoelectronic	0	0	0	0	0

NA = Not available
Source: Dataquest (October 1990)

Table 7g

Worldwide Average Selling Prices
(Compound Annual Growth Rate)

	CAGR (%) 1980-1985	CAGR (%) 1985-1990	CAGR (%) 1990-1995	CAGR (%) 1995-2000	CAGR (%) 1980-1990	CAGR (%) 1990-2000
Total Semiconductor	(1.7)	5.6	5.1	5.1	2.5	5.1
Total IC	(0.2)	5.0	4.6	3.6	1.8	4.1
Bipolar Digital	0.3	(1.8)	1.2	0	0	0.6
Memory	NA	NA	NA	NA	NA	NA
Logic	NA	NA	NA	NA	NA	NA
MOS Digital	(2.0)	7.4	5.2	3.1	1.5	4.1
Memory	(12.0)	13.4	8.5	8.5	4.2	8.5
Micro	(2.8)	5.4	0.1	0.2	0.1	0.2
Logic	1.8	2.8	4.4	1.7	0.9	3.1
Analog	(1.7)	(1.4)	(0.6)	0.3	0.1	(0.1)
Total Discrete	(7.8)	0	0	0	0	0
Total Optoelectronic	(13.0)	3.4	0	0	0	0

NA = Not available
Source: Dataquest (October 1990)

Table 8a

Worldwide Semiconductor Shipments
(Millions of Units)

	1980	1981	1982	1983	1984
Total Semiconductor	42,870	48,081	46,022	60,743	80,377
Total IC	8,955	9,809	10,949	14,327	20,573
Bipolar Digital	3,391	3,339	3,890	4,638	7,340
Memory	NA	NA	NA	NA	NA
Logic	NA	NA	NA	NA	NA
MOS Digital	2,603	2,906	3,464	4,776	6,639
Memory	455	655	1,031	1,333	1,597
Micro	239	319	404	591	916
Logic	1,909	1,933	2,029	2,852	4,126
Analog	2,960	3,564	3,595	4,913	6,593
Total Discrete	32,358	36,227	32,245	42,944	55,411
Total Optoelectronic	1,557	2,045	2,828	3,471	4,393

NA = Not available
Source: Dataquest (October 1990)

Table 8b

Worldwide Semiconductor Shipments
(Percent Change in Units)

	1980	1981	1982	1983	1984
Total Semiconductor	13.7	12.2	(4.3)	32.0	32.3
Total IC	23.7	9.5	11.6	30.9	43.6
Bipolar Digital	15.5	(1.6)	16.5	19.2	58.2
Memory	NA	NA	NA	NA	NA
Logic	NA	NA	NA	NA	NA
MOS Digital	50.4	11.6	19.2	37.9	39.0
Memory	39.8	43.8	57.5	29.3	19.8
Micro	74.8	33.6	26.7	46.1	55.1
Logic	50.5	1.2	5.0	40.6	44.7
Analog	15.0	20.4	0.9	36.7	34.2
Total Discrete	10.2	12.0	(11.0)	33.2	29.0
Total Optoelectronic	40.1	31.3	38.3	22.8	26.5

NA = Not available
Source: Dataquest (October 1990)

Table 8c

Worldwide Semiconductor Shipments
(Millions of Units)

	1985	1986	1987	1988	1989	1990
Total Semiconductor	80,380	89,881	114,551	122,085	137,808	142,162
Total IC	17,607	21,654	25,260	31,098	32,303	34,137
Bipolar Digital	5,172	6,092	6,899	7,429	6,443	6,543
Memory	NA	NA	NA	NA	NA	NA
Logic	NA	NA	NA	NA	NA	NA
MOS Digital	6,171	7,850	9,028	11,336	12,446	13,487
Memory	1,475	1,872	1,960	2,401	2,782	2,760
Micro	875	1,115	1,435	1,721	2,176	2,254
Logic	3,820	4,864	5,633	7,214	7,488	8,473
Analog	6,264	7,712	9,334	12,333	13,414	14,107
Total Discrete	57,200	62,283	83,188	84,578	95,775	97,575
Total Optoelectronic	5,573	5,944	6,104	6,409	9,730	10,450

NA = Not available
Source: Dataquest (October 1990)

Table 8d

Worldwide Semiconductor Shipments
(Percent Change in Units)

	1985	1986	1987	1988	1989	1990
Total Semiconductor	0	11.8	27.4	6.6	12.9	3.2
Total IC	(14.4)	23.0	16.7	23.1	3.9	5.7
Bipolar Digital	(29.5)	17.8	13.2	7.7	(13.3)	1.6
Memory	NA	NA	NA	NA	NA	NA
Logic	NA	NA	NA	NA	NA	NA
MOS Digital	(7.1)	27.2	15.0	25.6	9.8	8.4
Memory	(7.6)	26.9	4.7	22.5	15.9	(0.8)
Micro	(4.5)	27.4	28.7	20.0	26.4	3.6
Logic	(7.4)	27.3	15.8	28.1	3.8	13.2
Analog	(5.0)	23.1	21.0	32.1	8.8	5.2
Total Discrete	3.2	8.9	33.6	1.7	13.2	1.9
Total Optoelectronic	26.9	6.7	2.7	5.0	51.8	7.4

NA = Not available
Source: Dataquest (October 1990)

Table 8e

Worldwide Semiconductor Shipments
(Millions of Units)

	1991	1992	1993	1994	1995	2000
Total Semiconductor	155,274	173,381	191,092	205,394	213,681	319,263
Total IC	36,189	41,394	46,484	51,312	55,260	92,466
Bipolar Digital	6,489	6,839	6,947	6,677	6,517	5,568
Memory	NA	NA	NA	NA	NA	NA
Logic	NA	NA	NA	NA	NA	NA
MOS Digital	13,766	16,252	18,647	21,448	23,566	43,148
Memory	2,808	3,028	3,542	3,564	4,404	6,516
Micro	2,613	3,083	3,895	4,481	4,918	9,940
Logic	8,345	10,141	11,210	13,403	14,244	26,692
Analog	15,935	18,303	20,890	23,186	25,177	43,750
Total Discrete	107,400	119,025	129,950	138,263	141,275	199,863
Total Optoelectronic	11,685	12,962	14,658	15,819	17,146	26,935

NA = Not available
Source: Dataquest (October 1990)

Table 8f

Worldwide Semiconductor Shipments
(Percent Change in Units)

	1991	1992	1993	1994	1995
Total Semiconductor	9.2	11.7	10.2	7.5	4.0
Total IC	6.0	14.4	12.3	10.4	7.7
Bipolar Digital	(0.8)	5.4	1.6	(3.9)	(2.4)
Memory	NA	NA	NA	NA	NA
Logic	NA	NA	NA	NA	NA
MOS Digital	2.1	18.1	14.7	15.0	9.9
Memory	1.7	7.8	17.0	0.6	23.6
Micro	15.9	18.0	26.4	15.0	9.7
Logic	(1.5)	21.5	10.5	19.6	6.3
Analog	13.0	14.9	14.1	11.0	8.6
Total Discrete	10.1	10.8	9.2	6.4	2.2
Total Optoelectronic	11.8	10.9	13.1	7.9	8.4

NA = Not available
Source: Dataquest (October 1990)

Table 8g

Worldwide Semiconductor Shipments
(Compound Annual Growth Rate of Units)

	CAGR (%) 1980-1985	CAGR (%) 1985-1990	CAGR (%) 1990-1995	CAGR (%) 1990-2000	CAGR (%) 1990-2000	CAGR (%) 1990-2000
Total Semiconductor	13.4	12.1	8.5	8.4	4.1	8.4
Total IC	14.5	14.2	10.1	10.8	5.3	10.5
Bipolar Digital	8.8	4.8	(0.1)	(3.1)	(1.6)	(1.6)
Memory	NA	NA	NA	NA	NA	NA
Logic	NA	NA	NA	NA	NA	NA
MOS Digital	18.8	16.9	11.8	12.9	6.2	12.3
Memory	26.5	13.3	9.8	8.2	4.0	9.0
Micro	29.7	20.8	16.9	15.1	7.3	16.0
Logic	14.9	17.3	10.9	13.4	6.5	12.2
Analog	16.2	17.6	12.3	11.7	5.7	12.0
Total Discrete	12.1	11.3	7.7	7.2	3.5	7.4
Total Optoelectronic	29.0	13.4	10.4	9.5	4.6	9.9

NA = Not available
Source: Dataquest (October 1990)

Dataquest Research and Sales Offices:

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

Technology Products Group
Phone: (800) 624-3280

Dataquest Incorporated
Invitational Computer Conferences Division
3151 Airway Avenue, C-2
Costa Mesa, California 92626
Phone: (714) 957-0171
Telex: 5101002189 ICCDQ
Fax: (714) 957-0903

Dataquest Incorporated
Ledgeway Group
430 Bedford Street
Suite 340
Lexington, MA 02173
Phone: (617) 862-8500
Fax: (617) 862-8207

Dataquest Australia
Suite 1, Century Plaza
80 Berry Street
North Sydney, NSW 2060
Australia
Phone: (02) 959 4544
Telex: 25468
Fax: (02) 929 0635

Dataquest Boston
1740 Massachusetts Ave.
Boxborough, MA 01719-2209
Phone: (508) 264-4373
Telex: 171973
Fax: (508) 635-0183

Dataquest GmbH
Kronstadter Strasse 9
8000 Munich 80
West Germany
Phone: 011 49 89 93 09 09 0
Fax: 49 89 930 3277

Dataquest Europe Limited
Roussel House, Broadwater Park
Denham, Uxbridge, Middx UB9 5HP
England
Phone: 0895-835050
Telex: 266195
Fax: 0895 835260/1/2

Dataquest Europe SA
Tour Galliéni 2
36, avenue du Général-de-Gaulle
93175 Bagnolet Cedex
France
Phone: (1) 48 97 31 00
Telex: 233 263
Fax: (1) 48 97 34 00

Dataquest Hong Kong
Rm. 401, Connaught Comm. Bldg.
185 Wanchai Rd.
Wanchai, Hong Kong
Phone: 8387336
Telex: 80587
Fax: 5722375

Dataquest Israel
59 Mishmar Ha'yarden Street
Tel Aviv, Israel 69865
or
P.O. Box 18198
Tel Aviv, Israel
Phone: 52 913937
Telex: 341118
Fax: 52 32865

Dataquest Japan Limited
Shinkawa Sanko Building
1-3-17 Shinkawa, Chuo-ku
Tokyo 104 Japan
Phone: (03) 5566-0411
Fax: (03) 5566-0425

Dataquest Korea
Daeheung Bldg., Room 505
648-23 Yeoksam-dong
Kangnam-gu
Seoul, Korea 135
Phone: (02) 552-2332
Fax: (02) 552-2661

Dataquest Singapore
4012 Ang Mo Kio Industrial Park 1
Ave. 10, #03-10 to #03-12
Singapore 2056
Phone: 4597181
Telex: 38257
Fax: 4563129

Dataquest Taiwan
Room 801/8th Floor
Ever Spring Building
147, Sect. 2, Chien Kuo N. Rd.
Taipei, Taiwan R.O.C. 104
Phone: (02) 501-7960
Telex: 27459
Fax: (02) 505-4265

Dataquest West Germany
In der Schneithohl 17
6242 Kronberg 2
West Germany
Phone: 06173/61685
Telex: 418089
Fax: 06173/67901

Demographics

U.S. Demographics

Dataquest

a company of
The Dun & Bradstreet Corporation

Published by Dataquest Incorporated

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Demographic Terms

CAGR (compound annual growth rate). Calculated using the formula:

$$\text{CAGR} = \left(\frac{\text{Value in year 1+n}}{\text{Value in year 1}}\right)^{\left(\frac{1}{n}\right)} -1$$

civilian population. Resident population of the United States that does not include resident or overseas armed forces, merchant marines, or citizens living outside the United States.

corporation. A self-perpetuating body set up as a business entity separate from its owners. This means that ownership is separate from management and incurs limited liability.

desktop. Defined in Dataquest's desktop analyses as a potential location for a desktop information device.

elementary grades. Elementary grades are classified through the school district. If the district covers kindergarten through eighth grade, then up through eighth grade is considered elementary. If the district covers only through sixth grade, then only through sixth grade is considered elementary.

enterprise. An aggregation of establishments that have common ownership. This definition includes a parent company plus all of its subsidiaries and branches, as well as single establishments that have no financial links with other establishments.

establishment. A single physical location where business activity is conducted, whether or not there are any financial links to other units. Establishments include independently owned and operated businesses as well as the headquarters, subsidiaries, and branches of larger firms.

family. A group of two or more persons residing together who are related by birth, marriage, or adoption.

household. A housing unit intended as separate living quarters. A household includes all persons, either related or unrelated, living in the unit.

householder. The person in whose name the housing unit is owned or rented. The term is never applied to either husbands or wives in married-couple families, but relates only to persons in families maintained by either men or women without a spouse.

information worker. An individual who is or will be a user of an automated desktop information device.

median income. Indicates the value that divides the income distribution into two equal parts, one part having values above the median and the other having values below the median.

nonfamily. A group of two or more persons residing together who are unrelated.

occupational tenure. The cumulative number of years a person works in his or her current occupation, regardless of the number of employers, interruptions in employment, or times spent in other occupations.

other four-year colleges. A school that places its primary emphasis on undergraduate education. A four-year college can offer doctorate and professional degrees, but its graduate programs will not be as extensive as those of a university.

participation rates. Represents the proportion of the population that is in the labor force.

partnership. An association of two or more persons to carry on as co-owners of a business. Partners may be individuals, corporations, estates, trusts, or other partnerships and may be actively or passively involved in business operations.

secondary grades. Secondary grades are classified like elementary grades, by district. If the district covers eighth through twelfth grades, then grades eight through twelve are considered secondary. Likewise, if the district covers grades nine through twelve, then only nine through twelve are considered secondary.

sole proprietorship. A business that is fully owned and managed by a single individual.

total population. Includes all citizens, armed forces personnel, and merchant marines of the United States living at home or abroad.

two-year colleges. A school that offers an associate degree, but not a baccalaureate degree. Two-year colleges are also called junior colleges.

university. A school that places its primary emphasis on graduate and professional education. Universities offer doctoral studies in numerous fields and support at least two professional programs.

vocational school. A school that offers a certification in a specialized profession but does not offer classes applicable toward an associate or baccalaureate degree.

Education and Government Environments

The evolution of demographic changes in the United States has profoundly affected American society. One significant factor that has caused major shifts in school enrollment is the alteration in the fertility rate of women.

- The continuing effects of the baby boom (1946-1964) have caused enrollment at the elementary and secondary levels to:
  - Increase—1950s and 1960s
  - Decrease—1970s and early 1980s
  - Increase—Mid-1980s to late 1980s
- Higher education (postsecondary) enrollment has also been affected. Enrollment has:
  - Increased—Mid-1960s and 1970s
  - Peaked—Mid-1980s
  - Increased—Late 1980s
- Changes in the enrollment of elementary and secondary schools reflect shifts in school-age population. As women started having more children in the early 1980s, the school-age population began to increase.
- Enrollment in grades kindergarten through 8 will continue to increase well into the 1990s. However, enrollment in grades 9 through 12 is expected to decline through 1990, then begin to increase through 1997.
- Although enrollment in elementary and secondary schools was decreasing in the 1970s, the number of teachers in public elementary and secondary schools increased. Part of the increase can be attributed to a greater number of teachers required to implement special and bilingual education programs and smaller class-size policies. The number of teachers declined in the late 1970s and early 1980s. After 1983, the number of classroom teachers reached an all-time high of 2.3 million in 1987. This number is expected to reach 2.6 million by 1997.
- Although school-age population contributes to the enrollment of higher education institutions, the younger population is no longer the sole source of enrollment.
- The traditional college-age population is between 18 and 24 years old. This group declined from 30.4 million in 1981, to 27.4 million in 1987. This decline is expected to continue throughout most of the 1990s, reaching 24.0 million in 1997.
- There are several factors influencing changes in enrollment. Some of these factors are:
  - Economic conditions
  - Political and administrative decisions
  - Perceived value of a degree
  - Intrinsic value of higher education
  - College costs
- Although the traditional college-age population is declining, higher education enrollment will be supplemented by the increasing entrance of women, part-time, and older students.
- Preparing students for their post-education work experience is critical. As the required skill level to perform basic job tasks escalates, the demand on the education system to provide a solid foundation to meet these requirements is heightened.
- The 1990s will be a time for the education system and the workplace to join together and take action to keep the skill level of the work force in step with the rapid changes in technology and skill requirements.

In This Section

Tables E-1 through E-9 and G-1, and Figure 1 provide a general overview of education and government statistics. Areas covered in this section are number of schools, enrollment, expenditures, and government employment.

Table E-1. Number of U.S. Schools, Student Enrollment, and Instructional Staff

	Schools	Percent	Student Enrollment (Thousands)	Percent	Instructional Staff (Thousands)	Percent
Elementary						
Public	59,311	52.8	28,818	49.1	1,336	38.8
Private	15,303	13.6	4,097	7.0	256	7.4
Secondary						
Public	20,758	18.5	11,505	19.6	1,003	29.1
Private	2,438	2.2	1,175	2.0	96	2.8
K-12						
Public	2,179	NA	NA	NA	NA	NA
Private	4,949	NA	NA	NA	NA	NA
Other						
Public	1,000	NA	NA	NA	NA	NA
Private	2,926	NA	NA	NA	NA	NA
Subtotal	108,864	96.9	45,595	77.7	2,691	78.1
Higher Education						
Public	1,549	1.4	10,188	17.4	534	15.5
Private	1,908	1.7	2,899	4.9	221	6.4
Subtotal	3,457	3.1	13,087	22.3	755	21.9
Total	112,321	100.0	58,682	100.0	3,446	100.0

Note: Instructional staff for elementary and secondary education represents teachers exclusively.
Others includes special schools, vocational schools, and adult education schools.
Columns may not add to totals shown because of rounding.

NA = Not available

Source: Market Data Retrieval
U.S. Department of Education,
National Center for Education Statistics

Table E-2. Public School Systems and Student Enrollment by Enrollment-Size Class, 1988-1989

Enrollment Size (Students)	Number of Systems	Percent	Enrollment (Thousands)	Percent
0	195	1.3	NA	0
1 to 299	3,984	25.9	526	1.3
300 to 599	2,266	14.7	1,010	2.5
600 to 999	1,813	11.8	1,454	3.6
1,000 to 2,499	3,529	23.0	5,860	14.5
2,500 to 4,999	1,907	12.4	6,748	16.7
5,000 to 9,999	924	6.0	6,546	16.2
10,000 to 24,999	473	3.1	7,112	17.6
25,000 or more	177	1.2	11,233	27.7
Size Not Reported	108	0.7	NA	0
Total	15,376	100.0	40,489	100.0

Note: Enrollments and numbers of schools should be regarded as approximations only.
These totals differ from those in other tables because this table represents data reported by school districts rather than by states.
Columns may not add to totals shown because of rounding.

NA = Not available

Source: U.S. Department of Education, National Center for Education Statistics

Table E-3. Student Enrollment at U.S. Colleges and Universities, 1985-1995

	Total Enrollment	Four-Year Institutions	Two-Year Institutions	Percent Change
Actual				
1985	12,247	7,716	4,531	0
Estimated				
1986	12,397	7,753	4,644	1.2
1987	12,544	7,816	4,728	1.2
Projected				
1988	12,557	7,878	4,679	0.1
1989	12,570	7,857	4,713	0.1
1990	12,585	7,862	4,723	0.1
1991	12,529	7,831	4,698	(0.2)
1992	12,408	7,756	4,652	(1.3)
1993	12,300	7,679	4,621	(2.3)
1994	12,201	7,605	4,596	(2.6)
1995	12,151	7,563	4,588	(2.1)

Source: U.S. Department of Education, National Center for Education Statistics

Table E-4. Student Enrollment in Grades Kindergarten through 8 and 9 through 12 in Public and Private Elementary and Secondary Schools, 1985-1995 (Thousands of Students)

	Total Public and Private			Public			Private		
Year	K-12	K-8	9-12	K-12	K-8	9-12	K-12	K-8	9-12
Actual									
1987	45,547	32,101	13,446	40,200	27,983	12,217	5,347	4,118	1,229
Projected									
1988	45,522	32,475	13,047	40,280	28,439	11,841	5,242	4,036	1,206
1989	45,609	32,904	12,705	40,337	28,807	11,530	5,272	4,097	1,175
1990	46,092	33,542	12,550	40,752	29,366	11,386	5,340	4,176	1,164
1991	46,718	34,031	12,687	41,306	29,794	11,512	5,412	4,237	1,175
1992	47,366	34,470	12,896	41,879	30,178	11,701	5,487	4,292	1,195
1993	48,000	34,792	13,208	42,444	30,460	11,984	5,556	4,332	1,224
1994	48,635	34,980	13,655	43,014	30,624	12,390	5,621	4,356	1,265
1995	49,112	35,110	14,002	43,442	30,738	12,704	5,670	4,372	1,298

Source: U.S. Department of Education,
National Center for Education Statistics

Table E-5. Institutions of Higher Education by Control and Student Enrollment, 1987

Student Enrollment	All Institutions Number	All Institutions Enrollment (Thousands)	Universities Number	Universities Enrollment (Thousands)	Other Four-Year Colleges Number	Other Four-Year Colleges Enrollment (Thousands)	Two-Year Colleges Number	Two-Year Colleges Enrollment (Thousands)
Public Institutions								
Less than 200	7	1	0	0	1	0	6	1
200 to 499	40	15	0	0	11	4	29	11
500 to 999	131	100	0	0	29	23	102	76
1,000 to 2,499	415	713	0	0	107	189	308	524
2,500 to 4,999	319	1,137	1	5	103	376	215	756
5,000 to 9,999	316	2,208	7	59	134	930	175	1,220
10,000 to 19,999	220	2,998	30	452	91	1,222	99	1,325
20,000 to 29,999	73	1,741	34	832	18	430	21	479
30,000 or More	28	1,063	22	841	2	71	4	150
Subtotal	1,549	9,976	94	2,189	496	3,245	959	4,542
Private Institutions								
Less than 200	400	41	0	0	283	29	117	12
200 to 499	395	133	0	0	235	79	160	54
500 to 999	393	284	0	0	307	224	86	60
1,000 to 2,499	463	716	0	0	423	654	40	62
2,500 to 4,999	148	509	6	25	139	473	3	11
5,000 to 9,999	68	465	24	183	43	275	1	7
10,000 to 19,999	33	424	24	313	7	82	2	29
20,000 to 29,999	5	125	5	125	0	0	0	0
30,000 or More	3	95	3	95	0	0	0	0
Subtotal	1,908	2,792	62	741	1,437	1,816	409	235
Public and Private Institutions								
Less than 200	407	42	0	0	284	29	123	13
200 to 499	435	148	0	0	246	83	189	65
500 to 999	524	384	0	0	336	248	188	137
1,000 to 2,499	878	1,429	0	0	530	843	348	586
2,500 to 4,999	467	1,646	7	30	242	849	218	766
5,000 to 9,999	384	2,673	31	242	177	1,204	176	1,227
10,000 to 19,999	253	3,422	54	764	98	1,304	101	1,354
20,000 to 29,999	78	1,866	39	957	18	430	21	479
30,000 or More	31	1,158	25	937	2	71	4	150
Total	3,457	12,768	156	2,930	1,933	5,061	1,368	4,777

Source: U.S. Department of Education, National Center for Education Statistics

Table E-6. Expenditures of U.S. Schools, 1986 (Millions of Dollars)

Type of School	Expenditures	Percent
Public Elementary and Secondary		
Instruction	89,559	61.1
Support Services	51,905	35.4
Noninstruction	5,125	3.5
Total, Elementary and Secondary	146,589	100.0
Higher Education		
Public Institutions		
Instruction	21,881	34.6
Research	5,705	9.0
Public Service	2,516	4.0
Academic Support	4,694	7.4
Student Services	2,922	4.6
Institutional Support	5,667	9.0
Operation and Maintenance	5,177	8.2
Scholarships and Fellowships	1,576	2.5
Others	13,057	20.7
Subtotal	63,195	100.0
Private Institutions		
Instruction	9,151	26.6
Research	2,732	8.0
Public Service	604	1.8
Academic Support	1,974	5.7
Student Services	1,641	4.8
Institutional Support	3,684	10.7
Operation and Maintenance	2,428	7.1
Scholarships and Fellowships	2,584	7.5
Others	9,543	27.8
Subtotal	34,341	100.0
Total, Higher Education	97,536	
Total	244,125	

Source: U.S. Department of Education, National Center for Education Statistics

Table E-7. Ratio of Students to Microcomputers in Public Schools

	School Year				
Grade Level	1985-86*	1986-87*	1987-88	1988-89	1989-90
Elementary	55.3	43.7	36.8	32.4	28.0
Junior High	41.6	32.9	27.6	23.8	22.0
Senior High	37.9	31.1	26.3	22.8	20.5
Total	45.5	36.5	30.8	26.9	24.1

Note: Total represents all public schools including K-12, but excluding schools of special education. Data are preliminary.
*Data collection was limited to those schools with a microcomputer.

Source: Market Data Retrieval

Table E-8. Installed Base of Microcomputers in Public Elementary and Secondary Schools by Manufacturer and School Year

	School Year				
Manufacturer	1985-86	1986-87	1987-88	1988-89	1989-90
Apple	460,900	632,900	783,400	930,600	1,072,000
Tandy-Radio Shack	139,000	155,800	171,900	178,200	183,000
Commodore	116,300	130,900	140,400	141,600	138,000
IBM	42,100	68,200	108,900	147,700	189,000
Others	84,300	94,100	107,600	124,900	125,000
Total	842,600	1,081,900	1,312,200	1,523,000	1,707,000

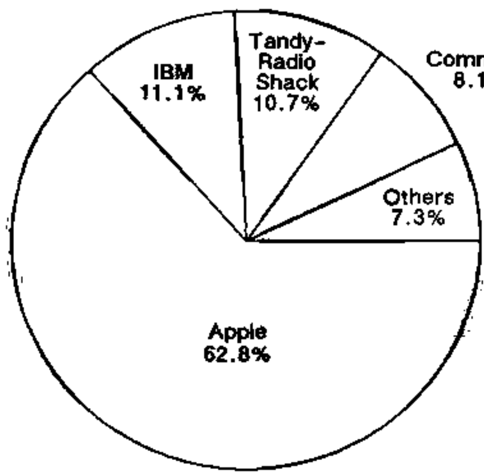
Source: Market Data Retrieval

Table E-9. Microcomputers for Student Instruction in Elementary and Secondary Schools, 1986-1988

	Number of Schools				Percent with Microcomputers			
Year	All	Elementary	Junior High	Senior High	All	Elementary	Junior High	Senior High
1986	80.5	50.7	9.7	15.1	95.6	94.9	98.5	98.7
1987	80.6	50.9	9.7	15.0	96.4	96.0	98.6	99.0
1988	80.8	51.0	9.8	15.0	97.1	96.8	98.8	99.1

Source: Market Data Retrieval

Figure 1. Installed Base of Microcomputers in School for School Year, 1989-1990



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Source: Market Data Retrieval
Dataquest
June 1990

Table G-1. Federal, State, and Local Government Employment by Industry Sector, 1988

SIC Category	Employees
Construction	188,500
Manufacturing	126,039
Transportation and Public Utilities	480,541
Retail Trade	80,655
Services	8,503,458
Hospitals	1,253,829
Social Services	285,018
Amusement and Recreation	138,445
Educational	5,525,277
Elementary and Secondary	5,087,240
Colleges and Universities	1,250,769
Public Administration	6,098,305
U.S. Postal Service	834,673
Total	16,312,171

Source: U.S. Department of Labor, Bureau of Labor Statistics

Households and Population

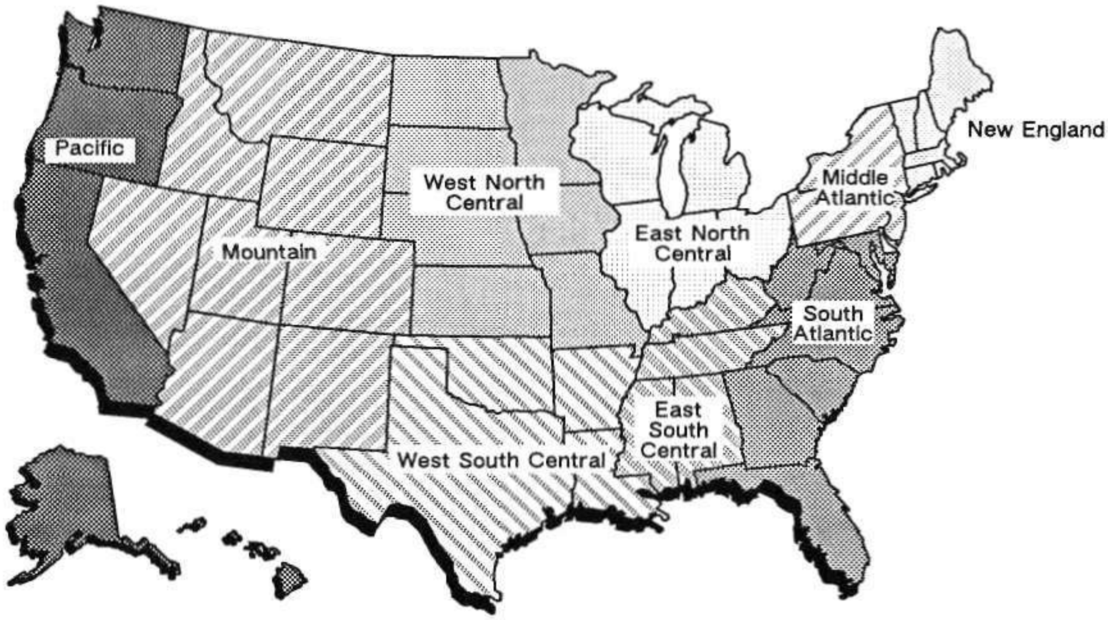
The phrase "traditional nuclear family" is rapidly becoming a sociological term describing the past in American society. As the new decade begins, the movement away from the two-parent, one-income family with children shall continue. This transition time will give rise to an increase in nonfamily, single-parent households, and dual-income marriages without children.

- The percentage of households composed of a married couple with children in the home is 26 percent, down from 31 percent in 1980.
- The fastest growing household classification is people living with nonrelatives. Although the number of households of this type has increased, it accounts for only 5 percent of total households.
- The overall number of households has grown steadily for decades. In 1910, there were 20.3 million households, increasing in number to 92.8 million in 1989.
- In 1989, 16.5 percent of all family households were maintained by women without a husband present, compared with 9.2 percent in 1950. Two contributing factors to this increase are:
  - A greater number of women participating in the work force
  - A higher incidence of divorce than ever before
- The median age for first marriages is getting older. In the late 1980s, the median age for women getting married for the first time was 23.6 and 26.0 for men. These ages compare with the 1950s, when the median age for first marriages was 20.1 and 22.5 for women and men, respectively. The rise in median age for first marriages will have implications on initial and lifetime fertility rates and marriage dissolution. Those couples who are older at the time of their first marriage have fewer children born and a lower incidence of divorce.
- Almost one-fourth of family households with children are maintained by a single parent.
- Nearly 9 out of 11 children living with a single parent are with their mothers. Unfortunately, many women in this circumstance have lower than average incomes. Subsequently, children raised in poverty are at higher risk of low educational attainment, more frequent crime involvement, and out-of-wedlock childbearing.
- The current social patterns in childbearing point to the continuation of small family units as the norm for the nineties.
- Five states have grown by at least 10 percent since 1985. These increases are significantly higher than the national rate of 4 percent. The five states are:
  - Nevada—18 percent
  - Arizona—12 percent
  - Florida and New Hampshire—11 percent
  - California—10 percent (Overall growth in California—2.7 million—accounted for more than one-fourth of the entire nation's growth since 1985.)
- Rebounding from a slight decline in the early 1980s, the East North Central States (such as Michigan and Ohio) experienced population increases in the second half of the decade.
- West Virginia, Kentucky, Mississippi, and the District of Columbia all experienced either slow growth or population declines in the mid-1980s to late 1980s.

In This Section

Figures 2, 3, and 4, and Tables H-1 through H-4 and P-1 through P-8 provide a detailed overview of the U.S. population and household demographics.

Figure 2. U.S. Census Regions and Divisions



Northeast Region

New England Division

Maine
New Hampshire
Vermont
Massachusetts
Rhode Island
Connecticut

Middle Atlantic Division

New York
New Jersey
Pennsylvania

Midwest Region

East North Central Division

Ohio
Indiana
Illinois
Michigan
Wisconsin

West North Central Division

Minnesota
Iowa
Missouri
North Dakota
South Dakota
Nebraska
Kansas

South Region

South Atlantic Division

Delaware
Maryland
District of Columbia
Virginia
West Virginia
North Carolina
South Carolina
Georgia
Florida

East South Central Division

Kentucky
Tennessee
Alabama
Mississippi

West South Central Division

Arkansas
Louisiana
Oklahoma
Texas

West Region

Mountain Division

Montana
Idaho
Wyoming
Colorado
New Mexico
Arizona
Utah
Nevada

Pacific Division

Washington
Oregon
California
Alaska
Hawaii

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Source: U.S. Department of Commerce
Bureau of the Census
Dataquest
June 1990

Table H-1. Number of U.S. Households and Average Household Size

Year	1985	1986	1987	1988	1989	1990	Estimated 1995	2000
Households (Millions)	86.8	88.4	89.5	91.1	92.8	94.2	100.3	105.9
CAGR (%)	1.6	1.8	1.2	1.8	1.9	1.7	1.3	1.2
Persons per Household	2.69	2.67	2.66	2.64	2.62	2.60	NA	2.48

NA = Not available

Source: U.S. Department of Commerce, Bureau of the Census

Table H-2. Income Distribution of U.S. Households, 1988

Income	Households (Thousands)	Percent
Less than $5,000	5,737	6.2
$5,000 to $9,999	10,006	10.8
$10,000 to $14,999	9,516	10.3
$15,000 to $19,999	9,126	9.8
$20,000 to $24,999	8,184	8.8
$25,000 to $29,999	7,891	8.5
$30,000 to $34,999	6,984	7.5
$35,000 to $39,999	6,414	6.9
$40,000 to $49,999	9,638	10.4
$50,000 to $74,999	12,455	13.4
$75,000 or More	6,877	7.4
Total	92,828	100.0
Median Income	$27,225	
Mean Income	$34,017	

Source: U.S. Department of Commerce, Bureau of the Census

Table H-3. Average U.S. Household Size

Type of Household	Persons per Household 1986	1987	1988	1989
All Households	2.67	2.66	2.64	2.62
Family Households[1]	3.28	3.22	3.21	3.16
Married Couple Households	3.32	3.27	3.25	3.23
Male Householder, No Wife	2.94	2.88	2.92	2.75
Female Householder, No Husband	3.11	3.09	3.08	2.95
Nonfamily Households[2]	1.21	1.22	1.22	NA
Male Householder	1.33	1.34	1.33	NA
Female Householder	1.13	1.13	1.13	NA

[1] Family households consist of people related to the householder by birth, marriage, or adoption.
[2] Nonfamily households consist of a person living alone or a householder living with people unrelated by birth, marriage, or adoption.
NA = Not available

Source: U.S. Department of Commerce, Bureau of the Census

Table H-4. U.S. Households by Region (Thousands of Households)

Region	1988 Households	Percent	1989 Households	Percent	CAGR
Northeast	19,137	21.0	19,158	20.6	0.11
Midwest	22,402	24.6	22,719	24.5	1.42
South	31,048	34.1	31,962	34.4	2.94
West	18,480	20.3	19,078	20.5	3.24
Total	91,067	100.0	92,917	100.0	2.03

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

Source: U.S. Department of Commerce, Bureau of the Census

Table P-1. Population of the United States, 1987-2000 (Thousands of People)

	Actual			Estimated			
	1987	1988	1989	1991	1994	1997	2000
Population	244,425	246,048	248,241	252,502	258,338	263,543	268,266
CAGR (%)	1.39	0.66	0.89	0.85	0.76	0.67	0.59

Source: U.S. Department of Commerce,
Bureau of the Census
Dataquest
June 1990

Table P-2. Distribution of U.S. Population by Age (Percent)

	Actual		Estimated		
Age	1989	1991	1994	1997	2000
Less than 10 Years	14.7	14.6	14.2	13.7	13.0
10-19 Years	14.0	13.7	13.9	14.2	14.3
20-29 Years	16.4	15.7	14.4	13.5	13.2
30-44 Years	23.7	24.6	24.7	24.4	23.6
45-64 Years	18.7	18.7	19.9	21.2	22.9
65 Years and Over	12.5	12.7	12.9	13.0	13.0
	100.0	100.0	100.0	100.0	100.0

Source: U.S. Department of Commerce, Bureau of the Census

Table P-8. U.S. Population by Census Regions, Divisions, and States

Region	Population (Thousands)	Percent
Northeast Region		
New England Division		
Maine	1,222	0.5
New Hampshire	1,107	0.4
Vermont	567	0.2
Massachusetts	5,913	2.4
Rhode Island	998	0.4
Connecticut	3,239	1.3
Subtotal	13,046	5.3
Middle Atlantic Division		
New York	17,950	7.2
New Jersey	7,736	3.1
Pennsylvania	12,040	4.9
Subtotal	37,726	15.2
Midwest Region		
East North Central Division		
Ohio	10,907	4.4
Indiana	5,593	2.3
Illinois	11,658	4.7
Michigan	9,273	3.7
Wisconsin	4,867	2.0
Subtotal	42,298	17.0
West North Central Division		
Minnesota	4,353	1.8
Iowa	2,840	1.1
Missouri	5,159	2.1
North Dakota	660	0.3
South Dakota	715	0.3
Nebraska	1,611	0.6
Kansas	2,513	1.0
Subtotal	17,851	7.2

(Continued)

Table P-8 (Continued). U.S. Population by Census Regions, Divisions, and States

Region	Population (Thousands)	Percent
South Region		
South Atlantic Division		
Delaware	673	0.3
Maryland	4,694	1.9
District of Columbia	604	0.2
Virginia	6,098	2.5
West Virginia	1,857	0.7
North Carolina	6,571	2.6
South Carolina	3,512	1.4
Georgia	6,436	2.6
Florida	12,671	5.1
Subtotal	43,116	17.4
East South Central Division		
Kentucky	3,727	1.5
Tennessee	4,940	2.0
Alabama	4,118	1.7
Mississippi	2,621	1.1
Subtotal	15,406	6.2
West South Central Division		
Arkansas	2,406	1.0
Louisiana	4,382	1.8
Oklahoma	3,224	1.3
Texas	16,991	6.8
Subtotal	27,003	10.9
West Region		
Mountain Division		
Montana	806	0.3
Idaho	1,014	0.4
Wyoming	475	0.2
Colorado	3,317	1.3
New Mexico	1,528	0.6
Arizona	3,556	1.4
Utah	1,707	0.7
Nevada	1,111	0.4
Subtotal	13,514	5.4

(Continued)

Table P-8 (Continued). U.S. Population by Census Regions, Divisions, and States

Region	Population (Thousands)	Percent
West Region (Continued)		
Pacific Division		
Washington	4,761	1.9
Oregon	2,820	1.1
California	29,063	11.7
Alaska	527	0.2
Hawaii	1,112	0.4
Subtotal	38,283	15.4
Total	248,241	100.0

Note: Includes armed forces residing in each state. Columns may not add to totals shown because of rounding.

Source: U.S. Department of Commerce, Bureau of the Census
Dataquest
June 1990

Business

The business sector of the U.S. economy is faced with responding to a multitude of high-impact trends occurring simultaneously in our society. The production orientation of American business is transforming into a service-providing framework. As the structure of business is rebuilt, a new set of challenges await businesses in the nineties.

- Over the next decade, service-producing industries are projected to reach 79.0 percent of all nonfarm wage and salary jobs, compared with 75.9 percent in 1988.
- Employment within the services segment of service-producing industries will account for nearly one-half of all new jobs added over the next 10 years.
- In health and business services alone, employment is expected to reach 18 million by the year 2000. The fastest growing business service industry will be computer services. The business starts of computer-related services have been increasing at an accelerating level.
- The installation of automatic processing equipment in industries such as food production and automotive has raised productivity levels while reducing employment.
- Increased demand for printed material has augmented growth in both employment in this field and the establishment of new small firms. Printing and publishing is one of the few manufacturing sectors where growth has increased to accommodate these new opportunities.
- Strong migration to western states such as Nevada, Arizona, and California has spawned opportunities. The market for opening new businesses in response to this population movement is widening.
- The results of The Dun & Bradstreet Corporation's Dun's 5000 Survey show that 40.9 percent of the companies surveyed expect to increase capital spending in 1990 over their 1989 level. This is a positive economic development in light of rising interest rates.
- Capital equipment expenditures, within the information industry sector, are less dependent on interest rates because of the pace of technological change. The average life-cycle of a computer is shorter than that of a turbine, tractor, or desk.
- There is a strong correlation between the size of the company and plans to increase capital spending. Over half of the companies with greater than 10,000 employees plan to increase capital equipment expenditures. Only 31.7 percent of the companies with less than 20 employees plan to spend more.
- The implementation of technologically advanced equipment in the workplace will foster a continued need for businesses to train and retrain existing employees.

In This Section

Tables B-1 through B-5 and Figures 5 through 7 provide a detailed overview of the overall composition of U.S. business.

Table B-1. Distribution of U.S. Establishments by Detailed Industry Sector and Employment-Size Class, 1990

Industry Sector	0-9	10-19	20-49	50-99	100-499	500-999	1,000+	Total	Percent of Total
	Number of Establishments by Employment-Size Class								
Agriculture, Forestry, Fisheries									
Agricultural Production	206,669	7,775	4,473	1,154	743	52	19	220,885	2.5
Agricultural Services	85,386	6,648	2,965	704	360	19	5	96,087	1.1
Forestry	3,213	274	159	47	48	10	1	3,752	0
Fishing, Hunting, and Trapping	2,315	174	103	29	6	0	0	2,627	0
Subtotal	297,583	14,871	7,700	1,934	1,157	81	25	323,351	3.7
Percent	92.0	4.6	2.4	0.6	0.4	0	0	100.0	
Mining									
Oil and Gas Extraction	29,653	4,176	2,852	876	587	58	45	38,247	0.4
Other Mining	8,180	1997	1756	579	675	91	47	13,325	0.2
Subtotal	37,833	6,173	4,608	1,455	1,262	149	92	51,572	0.6
Percent	73.4	12.0	8.9	2.8	2.4	0.3	0.2	100.0	
Contract Construction									
General Contractors and Builders	271,208	20,894	11,356	2,900	1,458	58	27	307,901	3.5
Heavy Construction Contractors	30,870	6,306	5,114	1,946	1,197	60	39	45,532	0.5
Special Trade Contractors	432,107	42,268	24,537	6,060	2,563	54	16	507,605	5.8
Subtotal	734,185	69,468	41,007	10,906	5,218	172	82	861,038	9.9
Percent	85.3	8.1	4.8	1.3	0.6	0	0	100.0	
Manufacturing									
Food and Kindred Products	15,565	4,852	5,142	2,888	3,704	488	238	32,877	0.4
Tobacco Manufactures	97	29	28	32	63	10	16	275	0
Textile Mill Products	5,805	1,612	1,894	1,127	1,743	309	112	12,602	0.1
Apparel and Other Textile Products	16,668	4,061	4,438	2,613	3,028	261	52	31,121	0.4
Lumber and Wood Products	30,805	5,713	4,693	1,946	1,527	84	30	44,798	0.5

(Continued)

Table B-1 (Continued). Distribution of U.S. Establishments by Detailed Industry Sector and Employment-Size Class, 1990

Industry Sector	Number of Establishments by Employment-Size Class								
	0-9	10-19	20-49	50-99	100-499	500-999	1,000+	Total	Percent of Total
Manufacturing (Continued)									
Furniture and Fixtures	11,041	2,599	2,353	1,179	1,239	129	41	18,581	0.2
Paper and Allied Products	2,708	1,326	1,958	1,327	1,891	169	112	9,491	0.1
Printing and Publishing	76,496	12,146	8,673	3,463	2,791	260	167	103,996	1.2
Chemicals and Allied Products	10,881	3,780	3,810	1,916	2,086	335	258	23,066	0.3
Petroleum and Coal Products	2,167	621	611	265	343	60	58	4,125	0
Rubber and Miscellaneous Plastics Products	7,861	2,812	3,555	2,238	2,283	160	74	18,983	0.2
Leather and Leather Products	2,336	455	469	278	377	39	12	3,966	0
Stone, Clay, and Glass Products	14,065	3,781	3,411	1,353	1,262	145	54	24,071	0.3
Primary Metal Industries	4,497	1,834	2,158	1,226	1,586	215	137	11,653	0.1
Fabricated Metal Products	24,325	8,292	8,718	4,086	3,361	219	141	49,142	0.6
Machinery, except Electrical	52,140	13,206	10,872	4,311	3,829	466	319	85,143	1.0
Electric and Electronic Equipment	14,118	4,269	4,754	2,647	3,677	612	430	30,507	0.3
Transportation Equipment	10,623	2,461	2,414	1,321	1,976	349	439	19,583	0.2
Instruments and Related Products	10,972	2,943	2,794	1,418	1,683	255	209	20,274	0.2
Miscellaneous Manufacturing Industries	27,242	4,079	3,187	1,276	966	80	29	36,859	0.4
Subtotal	340,412	80,871	75,932	36,910	39,415	4,645	2,928	581,113	6.7
Percent	58.6	13.9	13.1	6.4	6.8	0.8	0.5	100.0	
Transportation, Communications, Utilities									
Railroad Transportation	1,653	409	415	208	364	73	69	3,191	
Local and Interurban Passenger Transportation	13,677	3,902	3,991	1,530	905	72	36	24,113	0.3
Trucking and Warehousing	111,081	17,206	13,570	4,542	2,737	199	89	149,424	1.7
Water Transportation	8,778	1,177	940	300	265	20	12	11,492	0.1
Transportation by Air	10,293	1,864	1,803	808	642	78	88	15,576	0.2
Pipe Lines, except Natural Gas	497	182	163	58	41	3	0	944	0
Transportation Services	39,418	5,854	2,794	741	495	42	20	49,364	0.6

(Continued)

Table B-1 (Continued). Distribution of U.S. Establishments by Detailed Industry Sector and Employment-Size Class, 1990

	Number of Establishments by Employment-Size Class								
Industry Sector	0-9	10-19	20-49	50-99	100-499	500-999	1,000+	Total	Percent of Total
Transportation, Communications, Utilities (Continued)									
Communication									
Telephone	5,644	2,139	1,837	880	951	168	209	11,828	0.1
Telegraph	857	134	57	19	31	1	4	1,103	0
Broadcasting	4,347	3,608	3,049	835	521	16	15	12,391	0.1
Others	6,416	1,416	1,229	425	475	39	18	10,018	0.1
Electric, Gas, and Sanitary Services	19,632	4,557	4,386	2,189	1,799	259	175	32,997	0.4
Subtotal	222,293	42,448	34,234	12,535	9,226	970	735	322,441	3.7
Percent	68.9	13.2	10.6	3.9	2.9	0.3	0.2	100.0	
Wholesale Trade									
Durable Goods	333,253	56,051	31,782	7,364	3,438	169	110	432,167	5.0
Nondurable Goods	188,211	29,225	18,292	5,480	3,282	209	75	244,774	2.8
Subtotal	521,464	85,276	50,074	12,844	6,720	378	185	676,941	7.8
Percent	77.0	12.6	7.4	1.9	1.0	0.1	0	100.0	
Retail Trade									
Building Materials and Garden Supplies	99,721	11,764	5,653	1,440	526	11	4	119,119	1.4
General Merchandise Stores									
Department Stores	3,453	1,644	2,769	3,458	7,784	285	90	19,483	0.2
Others	29,702	3,505	1,813	873	592	41	9	36,535	0.4
Food Stores									
Grocery Stores	136,435	17,557	15,628	9,472	5,823	86	42	185,043	2.1
Others	57,540	6,348	2,603	377	126	9	0	67,003	0.8
Automotive Dealers and Service Stations									
New and Used Car Dealers	13,516	8,129	13,818	6,547	1,711	0	3	43,724	0.5

(Continued)

Table B-1 (Continued). Distribution of U.S. Establishments by Detailed Industry Sector and Employment-Size Class, 1990

Industry Sector	0-9	10-19	20-49	50-99	100-499	500-999	1,000+	Total	Percent of Total
	Number of Establishments by Employment-Size Class								
Retail Trade (Continued)									
Used Car Dealers	31,583	858	204	25	5	0	0	32,675	0.4
Auto and Home Supply	52,347	5,677	1,445	137	68	3	3	59,680	0.7
Gasoline Service Stations	96,454	7,443	1,505	409	207	1	1	106,020	1.2
Others	22,572	2,287	720	103	24	0	0	25,706	0.3
Apparel and Accessory Stores	172,455	15,417	4,406	879	545	42	24	193,768	2.2
Furniture and Home Furnishings Stores									
Household Appliances Stores	20,657	1,484	690	96	38	0	1	22,966	0.3
Radio, TV, and Music Stores	29,380	1,570	522	125	71	7	0	31,675	0.4
Others	124,489	11,150	3,891	582	264	13	6	140,395	1.6
Eating and Drinking Places	260,440	76,014	74,413	22,087	3,798	109	46	436,907	5.0
Miscellaneous Retail									
Drug Stores	36,831	11,931	5,743	652	189	13	8	55,367	0.6
Liquor Stores	38,043	2,040	411	39	7	1	1	40,542	0.5
Used Merchandise Stores	46,388	720	409	77	32	0	1	47,627	0.5
Miscellaneous Shopping Goods	310,257	14,202	4,400	1,006	351	24	17	330,257	3.8
Nonstore Retailers	64,950	3,812	2,170	731	474	41	34	72,212	0.8
Others	180,890	5,172	2,009	365	137	11	2	188,586	2.2
Subtotal	1,828,103	208,724	145,222	49,480	22,772	697	292	2,255,290	25.9
Percent	81.1	9.3	6.4	2.2	1.0	0	0	100.0	
Finance, Insurance, Real Estate									
Banking	45,860	27,441	16,259	4,626	2,831	316	326	97,659	1.1
Credit Agencies, Except Banks	29,997	4,379	2,706	825	655	73	36	38,671	0.4
Securities, Commodities Brokers, and Services	23,305	4,075	3,485	1,229	814	80	90	33,078	0.4
Insurance Carriers	12,423	4,555	5,142	2,280	2,537	411	406	27,754	0.3
Insurance Agents, Brokers and Services	120,529	9,292	5,658	1,668	991	95	35	138,268	1.6

(Continued)

Table B-1 (Continued). Distribution of U.S. Establishments by Detailed Industry Sector and Employment-Size Class, 1990

	Number of Establishments by Employment-Size Class								
Industry Sector	0-9	10-19	20-49	50-99	100-499	500-999	1,000+	Total	Percent of Total
Finance, Insurance, Real Estate (Continued)									
Real Estate	313,425	27,955	16,421	3,814	1,771	72	29	363,487	4.2
Holding and Other Investment Offices	28,915	2,197	1,359	531	381	60	36	33,479	0.4
Subtotal	574,454	79,894	51,030	14,973	9,980	1,107	958	732,396	8.4
Percent	78.4	10.9	7.0	2.0	1.4	0.2	0.1	100.0	
Services									
Hotels and Other Lodging Places	55,361	7,981	7,430	3,729	3,802	306	136	78,745	0.9
Personal Services									
Laundry, Cleaning, Garment Services	70,370	4,942	2,337	824	476	6	2	78,957	0.9
Photographic Studios	18,947	472	139	38	28	5	1	19,630	0.2
Beauty and Barber Shops	152,746	6,405	1,220	102	16	0	0	160,489	1.8
Shoe Repair, Hat Cleaning	8,280	40	6	1	0	0	0	8,327	0.1
Funeral Services	19,532	1,245	315	38	16	0	0	21,146	0.2
Miscellaneous Personal Services	34,981	1,175	542	154	107	9	4	36,972	0.4
Business Services									
Advertising	26,517	3,210	1,634	498	307	30	15	32,211	0.4
Credit Collection and Reporting	5,414	1,361	994	266	130	6	6	8,177	0.1
Mailing, Reproduction, Stenography	15,728	1,682	1,155	363	268	9	1	19,206	0.2
Services to Buildings	40,825	6,710	4,303	1,513	1,529	143	82	55,105	0.6
News Syndicates	586	122	114	35	30	5	0	892	0
Personnel Supply Services	17,721	3,148	1,651	679	939	110	73	24,321	0.3
Computer and Data Processing Services	41,041	6,224	4,405	1,678	1,471	153	114	55,086	0.6
Miscellaneous Business Services	195,790	14,234	8,529	2,873	2,461	210	82	224,179	2.6
Auto Repair, Services, Garages									
Auto Rental, without Drivers	18,372	2,267	1,396	419	227	9	7	22,697	0.3
Auto Parking	2,258	378	319	103	74	4	1	3,137	0

(Continued)

Table B-1 (Continued). Distribution of U.S. Establishments by Detailed Industry Sector and Employment-Size Class, 1990

Industry Sector	Number of Establishments by Employment-Size Class								Percent
	0-9	10-19	20-49	50-99	100-499	500-999	1,000+	Total	of Total
Services (Continued)									
Auto Repair Shops	193,843	8,757	2,181	218	85	6	3	205,093	2.4
Auto Services, except Repair	23,053	1,926	1,055	104	28	2	2	26,170	0.3
Miscellaneous Repair Services	170,398	5,903	2,670	602	311	13	8	179,905	2.1
Motion Pictures	34,961	3,145	1,387	334	219	16	9	40,071	0.5
Amusement and Recreation Services	71,427	10,648	8,263	2,663	1,231	57	63	94,352	1.1
Health Services									
Offices of Physicians	169,628	15,109	6,702	1,329	685	51	41	193,545	2.2
Offices of Dentists	89,783	5,023	943	93	16	0	0	95,858	1.1
Offices of Osteopathic Physicians	5,849	309	87	5	1	1	0	6,252	0.1
Offices of Other Health Practitioners	50,951	1,585	468	107	76	2	0	53,189	0.6
Nursing and Personal Care Facilities	2,649	1,283	3,870	6,416	5,817	97	40	20,172	0.2
Hospitals	1,075	613	1,087	1,555	4,384	1,588	1,899	12,201	0.1
Medical and Dental Laboratories	14,340	1,694	1,024	321	230	17	13	17,639	0.2
Outpatient Care Facilities	3,801	1,728	1,645	627	322	13	18	8,154	0.1
Other Health and Allied Services	4,457	1,831	1,838	844	807	52	17	9,846	0.1
Legal Services	112,716	10,193	6,039	1,722	1,038	91	10	131,809	1.5
Educational Services									
Elementary and Secondary Schools	14,700	12,431	38,378	23,086	9,175	592	296	98,658	1.1
Colleges and Universities	570	346	563	360	1,034	249	335	3,457	0
Libraries and Information Centers	16,467	1,104	914	310	162	18	6	18,981	0.2
Correspondence and Vocational Schools	3,049	791	849	388	238	15	7	5,337	0.1
Other Schools and Educational Services	10,741	1,885	1,757	793	1,030	167	72	16,445	0.2
Social Services	89,954	16,785	10,750	3,333	2,133	115	41	123,111	1.4
Museums, Botanical, Zoological Gardens	3,998	573	550	200	145	9	4	5,479	0.1

(Continued)

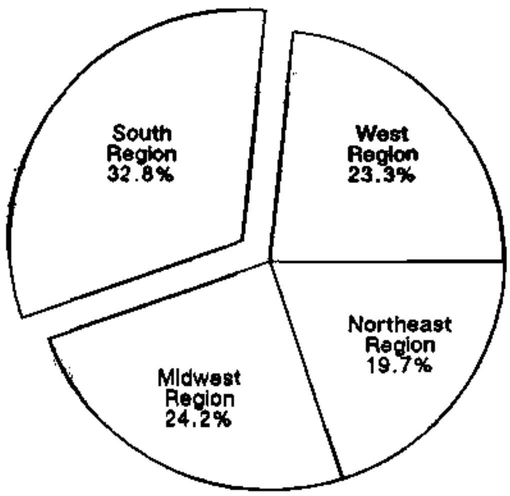
Table B-1 (Continued). Distribution of U.S. Establishments by Detailed Industry Sector and Employment-Size Class, 1990

	Number of Establishments by Employment-Size Class								
Industry Sector	0-9	10-19	20-49	50-99	100-499	500-999	1,000+	Total	Percent of Total
Services (Continued)									
Membership Organizations	186,483	16,667	11,025	3,420	1,720	130	52	219,497	2.5
Miscellaneous Services	212,405	26,299	16,960	5,466	4,375	470	395	266,370	3.1
Subtotal	2,211,767	208,224	157,494	67,609	47,143	4,776	3,855	2,700,868	31.0
Percent	81.9	7.7	5.8	2.5	1.7	0.2	0.1	100.0	
Total	6,768,094	795,949	567,301	208,646	142,893	12,975	9,152	8,505,010	97.6
Percent	79.6	9.4	6.7	2.5	1.7	0.2	0.1	100.0	
Other Government									
Federal								42,047	0.5
Military								13,462	0.2
State								52,656	0.6
Local								99,893	1.1
Subtotal								208,058	2.4
Percent								100.0	
Total								8,713,068	100.0
Percent								100.0	

Note: Columns may not add to totals shown due to rounding.

Source: Dun's Marketing Services
Dataquest
June 1990

Figure 5. Percent Distribution of Business Establishments by Industry Sector



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Source: Dun's Marketing Services
Dataquest
June 1990

Table B-2. Distribution of U.S. Establishments by State and Employment-Size Class

Census Regions and Divisions	Number of Establishments by Employment-Size Class							
	0-9	10-19	20-49	50-99	100-499	500-999	1,000+	Total
Northeast Region								
New England Division								
Maine	34,147	4,115	2,835	1,016	637	64	43	42,857
New Hampshire	31,334	4,130	2,981	1,031	740	79	36	40,331
Vermont	20,046	2,335	1,619	543	299	16	12	24,870
Massachusetts	147,121	21,047	15,540	5,834	4,569	482	354	194,947
Rhode Island	24,794	3,514	2,431	920	616	79	42	32,396
Connecticut	111,443	13,918	9,887	3,336	2,376	233	175	141,368
Subtotal	368,885	49,059	35,293	12,680	9,237	953	662	476,769
Middle Atlantic Division								
New York	460,645	57,846	40,904	14,966	10,801	1,086	855	587,103
New Jersey	192,813	27,712	20,645	7,480	5,795	543	417	255,405
Pennsylvania	278,179	35,217	25,121	10,075	7,414	796	469	357,271
Subtotal	931,637	120,775	86,670	32,521	24,010	2,425	1,741	1,199,779
Midwest Region								
East North Central Division								
Ohio	238,075	31,741	24,151	9,245	6,662	603	451	310,927
Indiana	120,415	15,789	11,526	4,431	3,278	287	197	155,923
Illinois	335,450	38,554	29,319	11,037	8,050	770	507	423,687
Michigan	208,395	27,432	19,871	7,220	4,882	373	342	268,515
Wisconsin	125,275	15,196	11,153	4,198	3,026	272	191	159,311
Subtotal	1,027,610	128,712	96,020	36,131	25,898	2,305	1,688	1,318,363

(Continued)

Table B-2 (Continued). Distribution of U.S. Establishments by State and Employment-Size Class

Census Regions and Divisions	Number of Establishments by Employment-Size Class							
	0-9	10-19	20-49	50-99	100-499	500-999	1,000+	Total
West North Central Division								
Minnesota	139,330	14,598	10,223	4,180	2,955	253	175	171,714
Iowa	141,791	9,503	6,878	2,463	1,589	140	101	162,465
Missouri	130,109	15,178	11,181	4,078	2,917	284	192	163,939
North Dakota	25,450	2,363	1,472	527	289	20	13	30,134
South Dakota	30,675	2,527	1,739	630	368	18	17	35,974
Nebraska	57,557	5,429	3,927	1,388	873	91	45	69,310
Kansas	87,412	8,536	5,761	2,054	1,322	110	76	105,271
Subtotal	612,324	58,134	41,181	15,320	10,313	916	619	738,807
South Region								
South Atlantic Division								
Delaware	15,310	2,161	1,520	568	431	58	44	20,092
Maryland	100,460	15,460	10,773	3,996	2,728	243	177	133,837
District of Columbia	20,578	3,331	2,541	962	717	108	125	28,362
Virginia	147,099	18,422	12,724	4,832	3,486	361	277	187,201
West Virginia	39,585	4,444	3,362	1,104	732	81	53	49,361
North Carolina	153,380	18,936	13,583	5,318	4,007	411	255	195,890
South Carolina	74,752	8,982	6,272	2,522	1,936	232	132	94,828
Georgia	143,907	19,688	13,461	5,438	3,800	383	247	186,924
Florida	308,145	39,942	26,388	10,067	6,581	530	354	392,007
Subtotal	1,003,216	131,366	90,624	34,807	24,418	2,407	1,664	1,288,502
East South Central Division								
Kentucky	84,731	9,245	6,955	2,692	1,702	174	104	105,603
Tennessee	108,148	14,103	9,859	3,681	2,738	298	179	139,006
Alabama	81,663	10,225	7,559	2,915	2,148	254	128	104,892
Mississippi	60,539	6,396	4,445	1,827	1,287	162	61	74,717
Subtotal	335,081	39,969	28,818	11,115	7,875	888	472	424,218

(Continued)

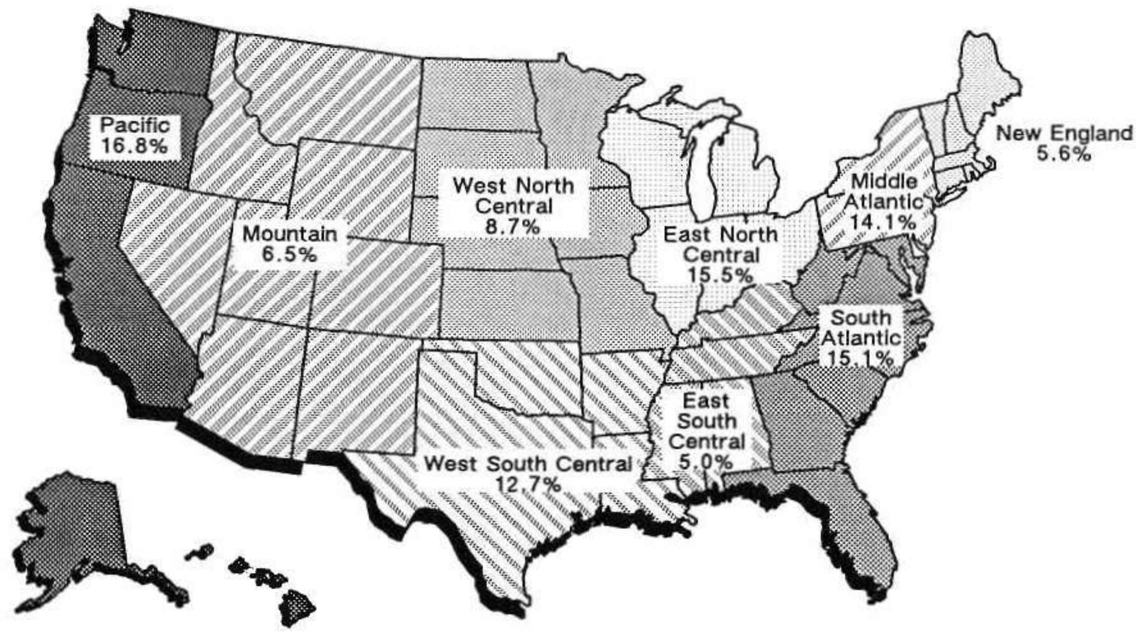
Table B-2 (Continued). Distribution of U.S. Establishments by State and Employment-Size Class

	Number of Establishments by Employment-Size Class							
Census Regions and Divisions	0-9	10-19	20-49	50-99	100-499	500-999	1,000+	Total
West South Central Division								
Arkansas	65,053	6,094	4,227	1,625	1,189	125	74	78,387
Louisiana	94,255	11,336	8,370	3,023	1,890	178	116	119,168
Oklahoma	97,605	9,446	6,585	2,368	1,408	114	78	117,604
Texas	652,001	53,912	36,213	13,395	9,214	796	648	766,179
Subtotal	908,914	80,788	55,395	20,411	13,701	1,213	916	1,081,338
West Region								
Mountain Division								
Montana	36,726	3,098	2,103	585	319	25	11	42,867
Idaho	37,383	3,427	2,261	723	386	52	31	44,263
Wyoming	22,284	1,865	1,348	443	250	12	8	26,210
Colorado	127,495	12,601	9,018	3,119	1,941	160	138	154,472
New Mexico	43,628	4,712	3,241	1,078	660	59	29	53,407
Arizona	115,191	12,474	8,473	2,986	1,935	166	108	141,333
Utah	42,021	4,890	3,322	1,296	858	69	63	52,519
Nevada	29,232	3,624	2,460	834	602	65	86	36,903
Subtotal	453,960	46,691	32,226	11,064	6,951	608	474	551,974
Pacific Division								
Washington	144,554	15,348	10,572	3,765	2,202	172	143	176,756
Oregon	98,859	9,954	7,092	2,328	1,439	140	71	119,883
California	877,279	94,360	66,445	24,198	15,722	1,309	1,063	1,080,376
Alaska	15,674	1,566	998	323	253	21	13	18,848
Hawaii	22,419	3,225	2,272	813	583	52	33	29,397
Subtotal	1,158,785	124,453	87,379	31,427	20,199	1,694	1,323	1,425,260
Total	6,800,419	779,946	553,605	205,475	142,601	13,408	9,557	8,505,010

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

Source: Dun's Marketing Services
Dataquest
June 1990

Figure 6. Distribution of Business Establishments by Census Divisions



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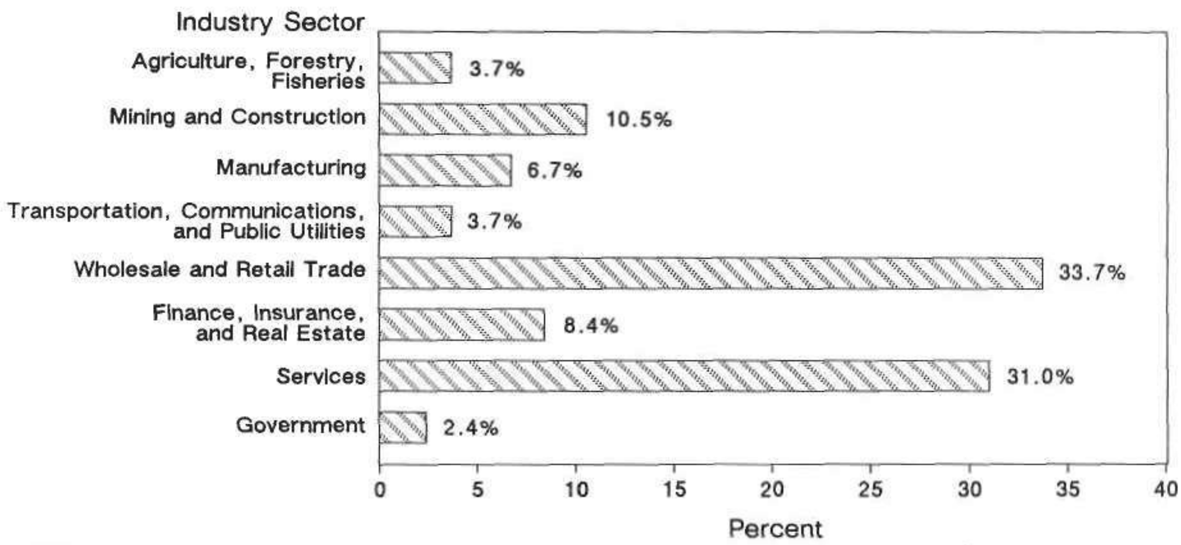
Source: U.S. Department of Commerce
Bureau of the Census
Dataquest
June 1990

Table B-3. Establishment Data by Census Region, 1990

Census Regions and Divisions	Total	Percent of Total
Northeast Region		
New England Division	476,769	5.6
Middle Atlantic Division	1,199,779	14.1
Midwest Region		
East North Central Division	1,318,363	15.5
West North Central Division	738,807	8.7
South Region		
South Atlantic Division	1,288,502	15.1
East South Central Division	424,218	5.0
West South Central Division	1,081,338	12.7
West Region		
Mountain Division	551,974	6.5
Pacific Division	1,425,260	16.8
Total	8,505,010	100.0

Source: Dun's Marketing Services
Dataquest
June 1990

Figure 7. Distribution of Establishments by Census Region



Source: Dun's Marketing Services
Dataquest
June 1990

Table B-4. Distribution of Establishments by Sales Volume and Industry Sector

Industry	Number of Establishments by Sales Volume							
	0-99.9m	100-499.9m	500-999.9m	1-4.9mm	5-9.9mm	10-49.9mm	50mm+	Total
Agriculture, Forestry, and Fisheries	90,637	196,803	17,744	13,071	1,382	1,036	184	320,857
Percent of Subtotal	28.2	61.3	5.5	4.1	0.4	0.3	0.1	100.0
Mining	8,099	24,356	7,252	8,039	1,268	1,439	721	51,175
Percent of Subtotal	15.8	47.6	14.2	15.7	2.5	2.8	1.4	100.0
Construction	224,862	416,314	88,551	100,809	13,219	9,247	1,382	854,385
Percent of Subtotal	26.3	48.7	10.4	11.8	1.5	1.1	0.2	100.0
Manufacturing	94,813	225,669	73,437	119,700	26,078	27,327	9,598	576,622
Percent of Subtotal	16.4	39.1	12.7	20.8	4.5	4.7	1.7	100.0
Transportation, Public Utilities, and Communication	67,962	129,025	47,825	55,656	8,818	7,679	2,982	319,947
Percent of Subtotal	21.2	40.3	14.9	17.4	2.8	2.4	0.9	100.0
Wholesale Trade	49,593	280,769	111,150	165,290	32,468	27,291	5,151	671,712
Percent of Subtotal	7.4	41.8	16.5	24.6	4.8	4.1	0.8	100.0
Retail Trade	519,621	1,272,072	221,955	176,104	21,962	22,532	3,620	2,237,865
Percent of Subtotal	23.2	56.8	9.9	7.9	1.0	1.0	0.2	100.0
Banking	4,780	15,596	11,157	36,922	11,435	12,095	4,920	96,904
Percent of Subtotal	4.9	16.1	11.5	38.1	11.8	12.5	5.1	100.0
Finance, Insurance, and Real Estate	139,113	330,992	68,650	63,482	10,711	12,126	4,760	629,833
Percent of Subtotal	22.1	52.6	10.9	10.1	1.7	1.9	0.8	100.0
Services	1,083,624	1,240,714	186,449	187,216	22,137	19,822	5,749	2,745,711
Percent of Subtotal	39.5	45.2	6.8	6.8	0.8	0.7	0.2	100.0
Total	2,283,103	4,132,309	834,170	926,289	149,478	140,593	39,067	8,505,010
Percent of Total	26.8	48.6	9.8	10.9	1.8	1.7	0.5	100.0

Note: Columns may not add to totals shown because of rounding.
m = Thousands
mm = Millions

Source: Dun's Marketing Services
Dataquest
June 1990

Table B-5. Primary Mainframe Installation Sites of IBM/PCM* by Vertical Market

Vertical Market	Total	IBM	Amdahl	Others
Natural Resources/Construction	223	207	14	2
Process Manufacturing	1,073	1,034	15	24
Discrete Manufacturing	1,467	1,404	26	37
Transportation	203	185	9	9
Communications	119	111	7	1
Utilities	223	212	9	2
Wholesale Trade	572	546	11	15
Retail Trade	444	419	7	18
Finance	821	788	21	12
Insurance	727	694	16	17
Real Estate	68	63	1	4
Health Care	407	397	7	3
Hotels and Lodging	18	17	0	1
Business Services	1,339	1,219	68	52
Other Services	484	459	12	13
Education	707	677	11	19
Government	783	677	67	39
Others	61	59	1	1
Total	9,739	9,168	302	269

*Plug-compatible mainframe

Source: Dataquest
June 1990

Work Force

Labor force opportunities in the 1990s will be challenged by industry employment trends, technological change, worker displacement, and education and training needs for workers. Technology and changes in business practices are two factors, in particular, that will play a key role in the ability to achieve and maintain job stability in this new decade.

- Three of the nine major occupational groups are expected to grow more rapidly than the average for total employment over the next 10 years—executive, administrative, and managerial; professional specialty; and technicians and related support. In addition to being the fastest growing groups, these fields also require the highest level of educational attainment to fulfill job requirements.
- An exception to the growth pattern of the top three occupational categories lies in the service workers. Although this category is projected to grow faster than average, it has relatively few workers with college degrees and a rather high incidence of workers with less than a high-school education.
- Occupations within the professional specialty category growing most in this growth segment are:
  - Engineers
  - Computer specialists
  - Lawyers
  - Health-diagnosing and treatment occupations
  - Teachers (except college and university)
- Technological changes and advancements have been key in furthering the demand for several occupations, including engineers and computer specialists.
- The service occupations group will add more than 4 million jobs by the year 2000, an increase of 23 percent. This category will add more new jobs than any other major occupational group.
- Technological innovation and use of office automation will encourage a slowing trend in the growth in the administrative support occupations. However, this technological movement will affect certain occupations positively, such as computer operators.
- Very low employment growth is expected in agriculture, forestry, and fishing. An increase of less than 100,000 jobs is projected through the year 2000.
- A negative result of declining industries is worker displacement. Some of these workers may be reemployed in their same occupation in a growing industry or retrained for a similar position in the declining industry. However, those workers displaced because of technological change, regardless of whether they are in growing or declining industries, will have a more difficult time finding reemployment.

In This Section

Tables W-1 through W-7 and Figures 8 through 11 highlight the work force by job classification, white-collar segmentation, and employment growth by industry.

Table W-1. Distribution of U.S. Work Force by Detailed Occupational Category (Thousands of Workers)

Occupational Category	1988 Number of Workers	1988 Percent of Total	1989 Number of Workers	1989 Percent of Total	1988-1989 Percent Change
Managerial and Professional Specialty	29,190	25.39	30,398	25.91	4.1
Executive, Administrative, and Managerial	14,216	12.37	14,848	12.65	4.4
Officials and Administrators, Public Administration	472	0.41	519	0.44	10.0
Financial Managers	502	0.44	472	0.40	(6.0)
Personnel and Labor Relations Managers	130	0.11	128	0.11	(1.5)
Purchasing Managers	99	0.09	110	0.09	11.1
Managers, Marketing, Advertising, and PR	482	0.42	514	0.44	6.6
Administrators, Education and Related Fields	562	0.49	585	0.50	4.1
Managers, Medicine and Health	163	0.14	188	0.16	15.3
Managers, Properties and Real Estate	433	0.38	451	0.38	4.2
Management-Related Occupations	3,772	3.28	3,908	3.33	3.6
Accountants and Auditors	1,329	1.16	1,416	1.21	6.5
Underwriters and Other Financial Officers	741	0.64	103	0.09	(86.1)
Management Analysts	199	0.17	183	0.16	(8.0)
Personnel, Training, Labor Relations	390	0.34	426	0.36	9.2
Buyers, Wholesale and Retail Except Farm Production	233	0.20	214	0.18	(8.2)
Construction Inspectors	60	0.05	61	0.05	1.7
Inspectors and Compliance Officers, Except Construction	194	0.17	196	0.17	1.0
Others (Includes Other Financial Officers)	626	0.54	1309	1.12	109.1
Executive, Administrative, and Managerial NEC	7601	6.61	7973	6.79	4.9
Professional Specialty	14,974	13.02	15,550	13.25	3.8
Architects	143	0.12	157	0.13	9.8
Engineers	1,805	1.57	1,823	1.55	1.0
Aerospace	115	0.10	112	0.10	(2.6)
Chemical	65	0.06	67	0.06	3.1
Civil	218	0.19	249	0.21	14.2
Electrical and Electronic	573	0.50	571	0.49	(0.3)

(Continued)

Table W-1 (Continued). Distribution of U.S. Work Force by Detailed Occupational Category (Thousands of Workers)

	1988		1989		
Occupational Category	Number of Workers	Percent of Total	Number of Workers	Percent of Total	1988-1989 Percent Change
Industrial	221	0.19	199	0.17	(10.0)
Mechanical	297	0.26	310	0.26	4.4
Engineers NEC	316	0.27	315	0.27	(0.3)
Mathematical and Computer Scientists	732	0.64	853	0.73	16.5
Computer Systems Analysts and Scientists	479	0.42	566	0.48	18.2
Operations and Systems Researchers and Analyst	210	0.18	239	0.20	13.8
Mathematical and Computer Scientists NEC	43	0.04	48	0.04	11.6
Natural Scientists	395	0.34	413	0.35	4.6
Chemists, except Biochemists	125	0.11	122	0.10	(2.4)
Biological and Life Scientists	75	0.07	77	0.07	2.7
Natural Scientists NEC	195	0.17	214	0.18	9.7
Health Diagnosing Occupations	818	0.71	854	0.73	4.4
Physicians	541	0.47	548	0.47	1.3
Dentists	152	0.13	170	0.14	11.8
Health Diagnosing Occupations NEC	125	0.11	136	0.12	8.8
Health Assessment and Treating Occupations	2,154	1.87	2,242	1.91	4.1
Registered nurses	1,559	1.36	1,599	1.36	2.6
Pharmacists	168	0.15	174	0.15	3.6
Dietitians	74	0.06	83	0.07	12.2
Therapists	298	0.26	324	0.28	8.7
Inhalation	65	0.06	63	0.05	(3.1)
Physical	82	0.07	90	0.08	9.8
Speech	66	0.06	63	0.05	(4.5)
Others	85	0.07	108	0.09	27.1
Health Assessment and Treating Occupations NEC	140	0.12	62	0.05	(55.7)
Teachers, College and University	700	0.61	709	0.60	1.3
Teachers, except College and University	3,773	3.28	3,936	3.35	4.3
Prekindergarten and Kindergarten	393	0.34	431	0.37	9.7

(Continued)

Table W-1 (Continued). Distribution of U.S. Work Force by Detailed Occupational Category (Thousands of Workers)

Occupational Category	1988 Number of Workers	1988 Percent of Total	1989 Number of Workers	1989 Percent of Total	1988-1989 Percent Change
Elementary School	1,424	1.24	1,489	1.27	4.6
Secondary School	1,187	1.03	1,220	1.04	2.8
Special Education	246	0.21	257	0.22	4.5
Teachers, NEC	524	0.46	539	0.46	2.9
Counselors, Educational and Vocational	206	0.18	214	0.18	3.9
Librarians, Archivists and Curators	219	0.19	212	0.18	(3.2)
Librarians	196	0.17	188	0.16	(4.1)
Librarians, Archivists and Curators NEC	23	0.02	24	0.02	4.3
Social Scientists and Urban Planners	343	0.30	374	0.32	9.0
Economists	116	0.10	122	0.10	5.2
Psychologists	196	0.17	210	0.18	7.1
Social Scientists and Urban Planners NEC	31	0.03	42	0.04	35.5
Social, Recreation, and Religious Workers	1,052	0.92	1,043	0.89	(0.9)
Social Workers	537	0.47	527	0.45	(1.9)
Recreation Workers	92	0.08	101	0.09	9.8
Clergy	348	0.30	336	0.29	(3.4)
Religious Workers NEC	75	0.07	79	0.07	5.3
Lawyers and Judges	757	0.66	774	0.66	2.2
Lawyers	724	0.63	741	0.63	2.3
Lawyers and Judges NEC	33	0.03	33	0.03	0
Writers, Artists, Entertainers, Athletes	1,855	1.61	1,921	1.64	3.6
Authors	82	0.07	82	0.07	0
Technical Writers	58	0.05	65	0.06	12.1
Designers	510	0.44	534	0.46	4.7
Musicians and Composers	151	0.13	170	0.14	12.6
Actors and Directors	100	0.09	96	0.08	(4.0)
Painters, Sculptors, Craft Artists and Artist Printmakers	215	0.19	229	0.20	6.5
Photographers	117	0.10	112	0.10	(4.3)

(Continued)

Table W-1 (Continued). Distribution of U.S. Work Force by Detailed Occupational Category (Thousands of Workers)

Occupational Category	1988 Number of Workers	1988 Percent of Total	1989 Number of Workers	1989 Percent of Total	1988-1989 Percent Change
Editors and Reporters	260	0.23	253	0.22	(2.7)
Public Relations Specialists	151	0.13	159	0.14	5.3
Announcers	52	0.05	51	0.04	(1.9)
Athletes	73	0.06	74	0.06	1.4
Writers, Artists, Entertainers, Athletes NEC	86	0.07	96	0.08	11.6
Other Professional Specialty	22	0.02	25	0.02	13.6
Technical, Sales, and Administrative Support	35,532	30.91	36,127	30.79	1.7
Technicians and Related Support	3,521	3.06	3,645	3.11	3.5
Health Technologists and Technicians	1,226	1.07	1,276	1.09	4.1
Clinical Laboratory Technologists and Technicians	272	0.24	308	0.26	13.2
Dental Hygienists	78	0.07	80	0.07	2.6
Radiologic Technicians	133	0.12	124	0.11	(6.8)
Licensed Practical Nurses	423	0.37	414	0.35	(2.1)
Health Technicians and Related Support NEC	320	0.28	350	0.30	9.4
Engineering and Related Technologists and Technicians	930	0.81	937	0.80	0.8
Electrical and Electronic Technicians	322	0.28	326	0.28	1.2
Drafting Occupations	290	0.25	296	0.25	2.1
Surveying and Mapping Technicians	78	0.07	70	0.06	(10.3)
Engineering and Related Technologists and Technicians NEC	240	0.21	245	0.21	2.1
Science Technicians	216	0.19	217	0.18	0.5
Biological Technicians	55	0.05	59	0.05	7.3
Chemical Technicians	81	0.07	74	0.06	(8.6)
Science Technicians NEC	80	0.07	84	0.07	5.0
Technicians, except Health, Engineering, and Science	1,149	1.00	1,216	1.04	5.8
Airplane Pilots and Navigators	88	0.08	109	0.09	23.9
Computer Programmers	570	0.50	561	0.48	(1.6)
Legal Assistants	203	0.18	210	0.18	3.4
Technicians, except Health, Engineering, and Science	288	0.25	336	0.29	16.7

(Continued)

Table W-1 (Continued). Distribution of U.S. Work Force by Detailed Occupational Category (Thousands of Workers)

Occupational Category	1988 Number of Workers	1988 Percent of Total	1989 Number of Workers	1989 Percent of Total	1988-1989 Percent Change
Sales Occupations	13,747	11.96	14,065	11.99	2.3
Supervisors and Proprietors	3,658	3.18	3,828	3.26	4.6
Sales Representatives, Finance and Business Service	2,410	2.10	2,371	2.02	(1.6)
Insurance Sales	545	0.47	535	0.46	(1.8)
Real Estate Sales	792	0.69	772	0.66	(2.5)
Securities and Financial Services Sales	319	0.28	302	0.26	(5.3)
Advertising and Related Sales	168	0.15	156	0.13	(7.1)
Sales Occupations, Other Business Services	585	0.51	607	0.52	3.8
Sales Representatives, Commodities, except Retail	1,551	1.35	1,612	1.37	3.9
Sales Workers, Retail and Personal Services	6,068	5.28	6,186	5.27	1.9
Sales Workers, Motor Vehicles and Boats	294	0.26	300	0.26	2.0
Sales Workers, Apparel	462	0.40	449	0.38	(2.8)
Sales Workers, Shoes	112	0.10	107	0.09	(4.5)
Sales Workers, Furniture and Home Furnishings	166	0.14	152	0.13	(8.4)
Sales Workers, Radio, Television, Hi-Fi, and Appliances	180	0.16	203	0.17	12.8
Sales Workers, Hardware, and Building Supplies	198	0.17	206	0.18	4.0
Sales Workers, Parts	169	0.15	160	0.14	(5.3)
Sales Workers, Other Commodities	1,537	1.34	1,522	1.30	(1.0)
Sales Counter Clerks	189	0.16	190	0.16	0.5
Cashiers	2,337	2.03	2,473	2.11	5.8
Street and Door-to-Door Sales Workers	318	0.28	323	0.28	1.6
News Vendors	108	0.09	101	0.09	(6.5)
Sales-Related Occupations	59	0.05	68	0.06	15.3
Administrative Support, Including Clerical	18,264	15.89	18,416	15.69	0.8
Supervisors	764	0.66	736	0.63	(3.7)
General Office	458	0.40	446	0.38	(2.6)
Financial Records Processing	91	0.08	82	0.07	(9.9)

(Continued)

Table W-1 (Continued). Distribution of U.S. Work Force by Detailed Occupational Category (Thousands of Workers)

Occupational Category	1988 Number of Workers	1988 Percent of Total	1989 Number of Workers	1989 Percent of Total	1988-1989 Percent Change
Supervisors, Distributing, Scheduling, and Adjusting	165	0.14	169	0.14	2.4
Supervisors NEC	50	0.04	39	0.03	(22.0)
Computer Equipment Operators	869	0.76	876	0.75	0.8
Computer Operators	865	0.75	870	0.74	0.6
Computer Equipment Operators NEC	4	0	6	0.01	50.0
Secretaries, Stenographers, and Typists	4,876	4.24	4,788	4.08	(1.8)
Secretaries	4,030	3.51	4,010	3.42	(0.5)
Stenographers	48	0.04	47	0.04	(2.1)
Typists	798	0.69	731	0.62	(8.4)
Information Clerks	1,479	1.29	1,451	1.24	(1.9)
Interviewers	163	0.14	183	0.16	12.3
Hotel Clerks	103	0.09	89	0.08	(13.6)
Transportation Ticket and Reservation Agents	114	0.10	112	0.10	(1.8)
Receptionists	848	0.74	815	0.69	(3.9)
Information Clerks NEC	251	0.22	252	0.21	0.4
Records Processing Occupations, Except Financial	827	0.72	851	0.73	2.9
Order Clerks	197	0.17	199	0.17	1.0
Personnel Clerks, except Payroll and Timekeeping	65	0.06	77	0.07	18.5
Library Clerks	143	0.12	144	0.12	0.7
File Clerks	271	0.24	284	0.24	4.8
Records Clerks	132	0.11	116	0.10	(12.1)
Records Processing Occupations, except Financial	19	0.02	31	0.03	63.2
Financial Records Processing	2,414	2.10	2,394	2.04	(0.8)
Bookkeepers, Accounting, and Auditing Clerks	1,970	1.71	1,926	1.64	(2.2)
Payroll and Timekeeping Clerks	173	0.15	177	0.15	2.3
Billing Clerks	157	0.14	159	0.14	1.3
Cost and Rate Clerks	75	0.07	83	0.07	10.7
Financial Records Processing NEC	39	0.03	49	0.04	25.6

(Continued)

Table W-1 (Continued). Distribution of U.S. Work Force by Detailed Occupational Category (Thousands of Workers)

	1988		1989		
Occupational Category	Number of Workers	Percent of Total	Number of Workers	Percent of Total	1988-1989 Percent Change
Duplicating, Mail, and Other Office Machine Operators	68	0.06	65	0.06	(4.4)
Communications Equipment Operators	218	0.19	210	0.18	(3.7)
Telephone Operators	210	0.18	201	0.17	(4.3)
Communications Equipment Operators NEC	8	0.01	9	0.01	12.5
Mail and Message Distributing Occupations	936	0.81	952	0.81	1.7
Postal Clerks, except Mail Carriers	313	0.27	313	0.27	0
Mail Carriers, Postal Service	320	0.28	327	0.28	2.2
Mail Clerks, except Postal Service	163	0.14	179	0.15	9.8
Messengers	141	0.12	133	0.11	(5.7)
Material Recording, Scheduling, and Distributing	1,681	1.46	1,745	1.49	3.8
Dispatchers	171	0.15	189	0.16	10.5
Production Coordinators	192	0.17	196	0.17	2.1
Traffic, Shipping and Receiving Clerks	521	0.45	550	0.47	5.6
Stock and Inventory Clerks	559	0.49	561	0.48	0.4
Weighers, Measurers, and Checkers	72	0.06	76	0.06	5.6
Expediters	95	0.08	96	0.08	1.1
Material Clerks NEC	71	0.06	77	0.07	8.5
Adjusters and Investigators	949	0.83	1,079	0.92	13.7
Insurance Adjusters, Examiners, and Investigators	287	0.25	325	0.28	13.2
Investigators and Adjusters, except Insurance	466	0.41	546	0.47	17.2
Eligibility Clerks, Social Welfare	65	0.06	72	0.06	10.8
Bill and Account Collectors	130	0.11	136	0.12	4.6
Miscellaneous Administrative Support	3,183	2.77	3,269	2.79	2.7
General Office Clerks	833	0.72	810	0.69	(2.8)
Bank Tellers	478	0.42	503	0.43	5.2
Data Entry Keyers	362	0.31	414	0.35	14.4
Statistical Clerks	85	0.07	86	0.07	1.2

(Continued)

Table W-1 (Continued). Distribution of U.S. Work Force by Detailed Occupational Category (Thousands of Workers)

Occupational Category	1988 Number of Workers	1988 Percent of Total	1989 Number of Workers	1989 Percent of Total	1988-1989 Percent Change
Teachers' Aides	423	0.37	440	0.37	4.0
Miscellaneous Administrative Support NEC	1002	0.87	1,016	0.87	1.4
Service Occupations	15,332	13.34	15,556	13.26	1.5
Private Household	909	0.79	872	0.74	(4.1)
Child Care Workers	378	0.33	358	0.31	(5.3)
Cleaners and Servants	476	0.41	464	0.40	(2.5)
Private Household NEC	55	0.05	50	0.04	(9.1)
Protective Service	1,944	1.69	1,960	1.67	0.8
Supervisors, Protective Services	174	0.15	169	0.14	(2.9)
Supervisors, Police and Detectives	93	0.08	83	0.07	(10.8)
Supervisors, Protective Services NEC	81	0.07	86	0.07	6.2
Firefighting and Fire Prevention	218	0.19	208	0.18	(4.6)
Firefighting Occupations	195	0.17	188	0.16	(3.6)
Firefighting and Fire Prevention NEC	23	0.02	20	0.02	(13.0)
Police and Detectives	755	0.66	803	0.68	6.4
Police and Detectives, Public Service	427	0.37	461	0.39	8.0
Sheriffs, Bailiffs, and Other Law Enforcement Officers	111	0.10	112	0.10	0.9
Correctional Institution Officers	217	0.19	230	0.20	6.0
Guards	796	0.69	781	0.67	(1.9)
Guards and Police, except Public Service	675	0.59	658	0.56	(2.5)
Guards, NEC	121	0.11	123	0.10	1.7
Service Occupations, except Private Household, Protective Service	12,479	10.85	12,724	10.84	2.0
Food Preparation and Service Occupations	5,182	4.51	5,351	4.56	3.3
Supervisors	325	0.28	356	0.30	9.5
Bartenders	324	0.28	322	0.27	(0.6)
Waiters and Waitresses	1,363	1.19	1,389	1.18	1.9
Cooks, except Short Order	1,634	1.42	1,713	1.46	4.8

(Continued)

Table W-1 (Continued). Distribution of U.S. Work Force by Detailed Occupational Category (Thousands of Workers)

	1988		1989		
Occupational Category	Number of Workers	Percent of Total	Number of Workers	Percent of Total	1988-1989 Percent Change
Short-Order Cooks	95	0.08	91	0.08	(4.2)
Food Counter, Fountain, and Related Occupations	325	0.28	354	0.30	8.9
Kitchen Workers, Food Preparation	132	0.11	126	0.11	(4.5)
Waiters' and Waitresses' Assistants	339	0.29	352	0.30	3.8
Miscellaneous Food Preparation	645	0.56	648	0.55	0.5
Health Service Occupations	1,977	1.72	2,042	1.74	3.3
Dental Assistants	165	0.14	187	0.16	13.3
Health Aides, except Nursing	407	0.35	416	0.35	2.2
Nursing Aides, Orderlies, and Attendants	1,404	1.22	1,439	1.23	2.5
Cleaning and Building Service Occupations	2,994	2.60	2,997	2.55	0.1
Supervisors	159	0.14	154	0.13	(3.1)
Maids and Housemen	644	0.56	646	0.55	0.3
Janitors and Cleaners	2,133	1.86	2,148	1.83	0.7
Cleaning and Building Service Occupations, NEC	58	0.05	49	0.04	(15.5)
Personal Service Occupations	2,327	2.02	2,333	1.99	0.3
Barbers	94	0.08	81	0.07	(13.8)
Hairdressers and Cosmetologists	769	0.67	736	0.63	(4.3)
Attendants, Amusement and Recreation Facilities	130	0.11	133	0.11	2.3
Public Transportation Attendants	77	0.07	86	0.07	11.7
Welfare Service Aides	92	0.08	95	0.08	3.3
Child Care Workers	853	0.74	861	0.73	0.9
Personal Service Occupations, NEC	312	0.27	341	0.29	9.3
Precision Production, Craft and Repair	13,664	11.88	13,818	11.78	1.1
Mechanics and Repairers	4,454	3.87	4,550	3.88	2.2
Supervisors	256	0.22	285	0.24	11.3
Mechanics and Repairers, except Supervisors	4,198	3.65	4,265	3.63	1.6

(Continued)

Table W-1 (Continued). Distribution of U.S. Work Force by Detailed Occupational Category (Thousands of Workers)

Occupational Category	1988 Number of Workers	1988 Percent of Total	1989 Number of Workers	1989 Percent of Total	1988-1989 Percent Change
Vehicle and Mobile Equipment Mechanics and Repairers	1,811	1.58	1,793	1.53	(1.0)
Automobile Mechanics	879	0.76	880	0.75	0.1
Bus, Truck, and Stationery Engine Mechanics	325	0.28	320	0.27	(1.5)
Aircraft Engine Mechanics	131	0.11	122	0.10	(6.9)
Small-Engine Repairers	70	0.06	65	0.06	(7.1)
Automobile Body and Related Repairers	194	0.17	191	0.16	(1.5)
Heavy Equipment Mechanics	159	0.14	160	0.14	0.6
Vehicle and Mobile Equipment	53	0.05	55	0.05	3.8
Industrial Machinery Repairers	547	0.48	539	0.46	(1.5)
Electrical and Electronic Equipment Repairers	677	0.59	680	0.58	0.4
Electronic Repairers, Communications and Industrial Equipment	165	0.14	165	0.14	0
Data Processing Equipment Repairers	140	0.12	152	0.13	8.6
Telephone Line Installers and Repairers	61	0.05	54	0.05	(11.5)
Telephone Installers and Repairers	202	0.18	193	0.16	(4.5)
Electronic and Electronic Equipment NEC	109	0.09	116	0.10	6.4
Heating, Air Conditioning, and Refrigeration Mechanics	262	0.23	279	0.24	6.5
Miscellaneous Mechanics and Repairers	874	0.76	948	0.81	8.5
Office Machine Repairers	60	0.05	67	0.06	11.7
Millwrights	96	0.08	101	0.09	5.2
Miscellaneous Mechanics NEC	718	0.62	780	0.66	8.6
Mechanics and Repairers, NEC	27	0.02	26	0.02	(3.7)
Construction Trades	5,098	4.43	5,142	4.38	0.9
Supervisors	617	0.54	662	0.56	7.3
Construction Trades, except Supervisors	4,481	3.90	4,479	3.82	0
Brickmasons and Stonemasons	202	0.18	219	0.19	8.4
Carpet Installers	108	0.09	109	0.09	0.9
Carpenters	1,427	1.24	1,369	1.17	(4.1)

(Continued)

Table W-1 (Continued). Distribution of U.S. Work Force by Detailed Occupational Category (Thousands of Workers)

Occupational Category	1988 Number of Workers	1988 Percent of Total	1989 Number of Workers	1989 Percent of Total	1988-1989 Percent Change
Drywall Installers	149	0.13	155	0.13	4.0
Electricians	701	0.61	702	0.60	0.1
Electrical Power Installers and Repairers	101	0.09	104	0.09	3.0
Painters, Construction, and Maintenance	525	0.46	543	0.46	3.4
Plumbers, Pipefitters, and Steamfitters	494	0.43	456	0.39	(7.7)
Concrete and Terrazzo Finishers	85	0.07	77	0.07	(9.4)
Insulation Workers	54	0.05	64	0.05	18.5
Roofers	156	0.14	178	0.15	14.1
Structural Metal Workers	48	0.04	63	0.05	31.3
Construction Trade NEC	431	0.37	440	0.37	2.1
Extractive Occupations	144	0.13	138	0.12	(4.2)
Precision Production Occupations	3,968	3.45	3,988	3.40	0.5
Supervisors	1,361	1.18	1,353	1.15	(0.6)
Precision Metalworking	896	0.78	911	0.78	1.7
Tool and Die Makers	145	0.13	148	0.13	2.1
Machinists	497	0.43	479	0.41	(3.6)
Sheet-Metal Workers	126	0.11	141	0.12	11.9
Precision Metalworking, NEC	128	0.11	143	0.12	11.7
Precision Woodworking Occupations	106	0.09	95	0.08	(10.4)
Cabinet Makers and Bench Carpenters	66	0.06	56	0.05	(15.2)
Precision Woodworking, NEC	40	0.03	39	0.03	(2.5)
Precision Textile, Apparel, Furnishings Machine Workers	296	0.26	277	0.24	(6.4)
Dressmakers	126	0.11	117	0.10	(7.1)
Upholsterers	84	0.07	71	0.06	(15.5)
Precision Textile, NEC	86	0.07	89	0.08	3.5
Precision Workers, Assorted Materials	529	0.46	565	0.48	6.8
Optical Goods Workers	60	0.05	80	0.07	33.3

(Continued)

Table W-1 (Continued). Distribution of U.S. Work Force by Detailed Occupational Category (Thousands of Workers)

Occupational Category	1988 Number of Workers	1988 Percent of Total	1989 Number of Workers	1989 Percent of Total	1988-1989 Percent Change
Dental Laboratory and Medical Appliance Technicians	49	0.04	51	0.04	4.1
Electrical and Electronic Equipment Assemblers	305	0.27	316	0.27	3.6
Precision Workers Assorted NEC	115	0.10	118	0.10	2.6
Precision Food Production Occupations	418	0.36	414	0.35	(1.0)
Butchers and Meat Cutters	258	0.22	266	0.23	3.1
Bakers	126	0.11	113	0.10	(10.3)
Precision Food Production NEC	34	0.03	35	0.03	2.9
Precision Inspectors, Testers, and Related Workers	126	0.11	125	0.11	(0.8)
Inspectors, Testers and Graders	113	0.10	113	0.10	0
Precision Inspectors, NEC	13	0.01	12	0.01	(7.7)
Plant and System Operators	236	0.21	249	0.21	5.5
Stationary Engineers	103	0.09	109	0.09	5.8
Plant and System Operators NEC	133	0.12	140	0.12	5.3
Operators, Fabricators, and Laborers	17,814	15.49	18,022	15.36	1.2
Machine Operators, Assemblers, and Inspectors	8,117	7.06	8,248	7.03	1.6
Machine Operators and Tenders, except Precision	5,362	4.66	5,381	4.59	0.4
Metalworking and Plastic Working Machine Operators	465	0.40	470	0.40	1.1
Lathe and Turning Machine Operators	63	0.05	55	0.05	(12.7)
Punching and Stamping Press Machine Operators	123	0.11	120	0.10	(2.4)
Grinding, Abrading, Buffing, and Polishing Machine Operators	141	0.12	143	0.12	1.4
Metalworking and Plastic Operators NEC	138	0.12	152	0.13	10.1
Metal and Plastic Processing Machine Operators	170	0.15	160	0.14	(5.9)
Molding and Casing Machine Operators	102	0.09	97	0.08	(4.9)
Metal and Plastic Processing, NEC	68	0.06	63	0.05	(7.4)
Woodworking Machine Operators	159	0.14	165	0.14	3.8
Sawing Machine Operators	105	0.09	96	0.08	(8.6)
Other Woodworking, NEC	54	0.05	69	0.06	27.8

(Continued)

Table W-1 (Continued). Distribution of U.S. Work Force by Detailed Occupational Category (Thousands of Workers)

	1988		1989		
Occupational Category	Number of Workers	Percent of Total	Number of Workers	Percent of Total	1988-1989 Percent Change
Printing Machine Operators	505	0.44	474	0.40	(6.1)
Printing Machine Operators	339	0.29	324	0.28	(4.4)
Typesetters and Compositors	67	0.06	66	0.06	(1.5)
Printing Machine Operators, NEC	99	0.09	84	0.07	(15.2)
Textile, Apparel, and Furnishings Machine Operators	1,355	1.18	1,356	1.16	0.1
Winding and Twisting Machine Operators	76	0.07	77	0.07	1.3
Textile Sewing Machine Operators	749	0.65	757	0.65	1.1
Pressing Machine Operators	146	0.13	134	0.11	(8.2)
Laundering and Dry Cleaning Machine Operator	222	0.19	220	0.19	(0.9)
Textile, Apparel, and Furnishings, NEC	162	0.14	168	0.14	3.7
Machine Operators, Assorted Materials	2,680	2.33	2,736	2.33	2.1
Packaging and Filling Machine Operators	414	0.36	442	0.38	6.8
Mixing and Blending Machine Operators	102	0.09	110	0.09	7.8
Separating, Filtering, and Clarifying Machine Operators	56	0.05	62	0.05	10.7
Painting and Paint Spraying Machine Operator	200	0.17	186	0.16	(7.0)
Furnace, Kiln, and Oven Operators, except Food	102	0.09	96	0.08	(5.9)
Slicing and Cutting Machine Operators	215	0.19	219	0.19	1.9
Photographic Process Machine Operators	98	0.09	91	0.08	(7.1)
Machine Operators, Assorted Materials, NEC	1493	1.30	1530	1.30	2.5
Other Machine Operators and Tenders	28	0.02	20	0.02	(28.6)
Fabricators, Assemblers, and Hand-Working Occupations	1,906	1.66	2,011	1.71	5.5
Welders and Cutters	555	0.48	612	0.52	10.3
Assemblers	1,141	0.99	1,177	1.00	3.2
Fabricators, Assemblers, NEC	210	0.18	222	0.19	5.7
Production Inspectors, Testers, Samplers, and Weighers	849	0.74	856	0.73	0.8
Production Inspectors, Checkers, and Examiners	683	0.59	688	0.59	0.7
Production Testers	63	0.05	60	0.05	(4.8)

(Continued)

Table W-1 (Continued). Distribution of U.S. Work Force by Detailed Occupational Category (Thousands of Workers)

Occupational Category	1988 Number of Workers	1988 Percent of Total	1989 Number of Workers	1989 Percent of Total	1988-1989 Percent Change
Graders and Sorters, except Agricultural	96	0.08	102	0.09	6.3
Production Inspectors, NEC	7	0.01	6	0.01	(14.3)
Transportation and Material-Moving Occupations	4,831	4.20	4,886	4.16	1.1
Motor Vehicle Operators	3,592	3.12	3,602	3.07	0.3
Truck Drivers, Heavy	1,826	1.59	1,850	1.58	1.3
Truck Drivers, Light	782	0.68	766	0.65	(2.0)
Drivers-Sales Workers	201	0.17	192	0.16	(4.5)
Bus Drivers	450	0.39	440	0.37	(2.2)
Taxi-Cab Drivers and Chauffeurs	218	0.19	220	0.19	0.9
Motor Vehicle Operators, NEC	115	0.10	134	0.11	16.5
Transportation Occupations, except Motor Vehicle	195	0.17	177	0.15	(9.2)
Rail Transportation Occupations	137	0.12	129	0.11	(5.8)
Locomotive Operating Occupations	51	0.04	0	0	(100.0)
Rail NEC	86	0.07	129	0.11	50.0
Water Transportation Occupations	58	0.05	0	0	(100.0)
Material Moving Equipment Operators	1,043	0.91	1,107	0.94	6.1
Operating Engineers	210	0.18	220	0.19	4.8
Crane and Tower Operators	88	0.08	99	0.08	12.5
Excavating and Loading Machine Operators	108	0.09	128	0.11	18.5
Grader, Dozer, and Scraper Operators	92	0.08	98	0.08	6.5
Industrial Truck and Tractor Equipment Operators	431	0.37	452	0.39	4.9
Material Moving, NEC	114	0.10	110	0.09	(3.5)
Handlers, Equipment Cleaners, Helpers and Laborers	4,866	4.23	4,888	4.17	0.5
Helpers, Construction and Extractive Occupations	156	0.14	133	0.11	(14.7)
Helpers, Construction Trades	141	0.12	123	0.10	(12.8)
Helpers, NEC	15	0.01	10	0.01	(33.3)
Construction Laborers	799	0.69	755	0.64	(5.5)
Production Helpers	64	0.06	82	0.07	28.1

(Continued)

Table W-1 (Continued). Distribution of U.S. Work Force by Detailed Occupational Category (Thousands of Workers)

	1988		1989		
Occupational Category	Number of Workers	Percent of Total	Number of Workers	Percent of Total	1988-1989 Percent Change
Freight, Stock, and Material Handlers	1,756	1.53	1,743	1.49	(0.7)
Stock Handlers and Baggers	891	0.77	900	0.77	1.0
Machine Feeders and Offbearers	110	0.10	91	0.08	(17.3)
Freight, Stock, Material, NEC	755	0.66	752	0.64	(0.4)
Garage and Service Station Related Occupations	246	0.21	230	0.20	(6.5)
Vehicle Washers and Equipment Cleaners	253	0.22	281	0.24	11.1
Hand Packers and Packagers	298	0.26	327	0.28	9.7
Laborers, except Construction	1,248	1.09	1,288	1.10	3.2
Handlers, Equipment Cleaners, Helpers, and Laborers	46	0.04	49	0.04	6.5
Farming, Forestry, and Fishing	3,437	2.99	3,421	2.92	(0.5)
Farm Operators and Managers	1,286	1.12	1,269	1.08	(1.3)
Farmers	1,154	1.00	1,118	0.95	(3.1)
Farm Managers	133	0.12	150	0.13	12.8
Other Agricultural and Related Occupations	1,978	1.72	1,976	1.68	(0.1)
Farm Occupations, except Managerial	1,020	0.89	964	0.82	(5.5)
Farm Workers	949	0.83	893	0.76	(5.9)
Farm Occupations, NEC	71	0.06	71	0.06	0
Related Agricultural Occupations	958	0.83	1,012	0.86	5.6
Supervisors	76	0.07	73	0.06	(3.9)
Groundskeepers and Gardeners, except Farmers	765	0.67	816	0.70	6.7
Animal Caretakers, except Farmers	101	0.09	104	0.09	3.0
Related Agriculture Occupations, NEC	16	0.01	19	0.02	18.8
Forestry and Logging Occupations	117	0.10	118	0.10	0.9
Timber Cutting and Logging	84	0.07	82	0.07	(2.4)
Forestry and Logging, NEC	33	0.03	36	0.03	9.1
Fishers, Hunters, and Trappers	56	0.05	59	0.05	5.4
Total	114,969	100.00	117,342	100.00	2.1

Note: Columns may not add to totals shown because of rounding.
NEC = Not elsewhere classified

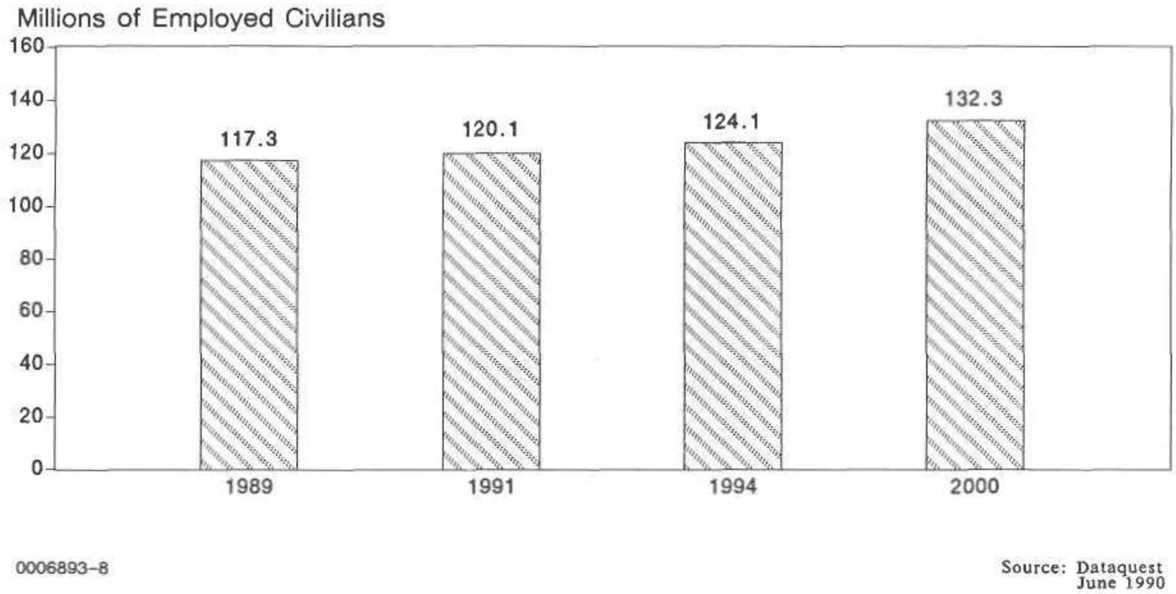
Source: U.S. Department of Labor, Bureau of Labor Statistics

Table W-2. Distribution of U.S. Work Force by Major Occupational Category (Thousands of Workers)

Occupational Classification	Actual 1988	Actual 1989	Actual 1991	Estimated 1994	Estimated 1997	Estimated 2000
Executive, Administrative, and Managerial	14,216	14,848	15,302	15,982	16,663	17,344
Professional Specialty	14,974	15,550	16,099	16,922	17,745	18,568
Technicians and Related Support	3,521	3,645	3,825	4,094	4,364	4,634
Sales Occupations	13,747	14,065	14,497	15,145	15,793	16,441
Administrative Support, Including Clerical	18,264	18,416	18,780	19,327	19,873	20,419
Private Household	909	872	871	868	866	864
Protective Service	1,944	1,960	2,037	2,152	2,268	2,383
Service, except Private Household and Protective	12,479	12,724	13,192	13,895	14,597	15,299
Precision Production, Craft, and Repair	13,664	13,818	14,036	14,363	14,690	15,017
Operators, Fabricators, and Laborers	17,814	18,022	18,026	18,033	18,039	18,046
Farming, Forestry, and Fishing	3,437	3,422	3,394	3,354	3,313	3,272
Total	114,969	117,342	120,059	124,135	128,211	132,287

Source: U.S. Department of Labor, Bureau of Labor Statistics
Dataquest
June 1990

Figure 8. Actual and Estimated Number of Employed U.S. Civilian Workers



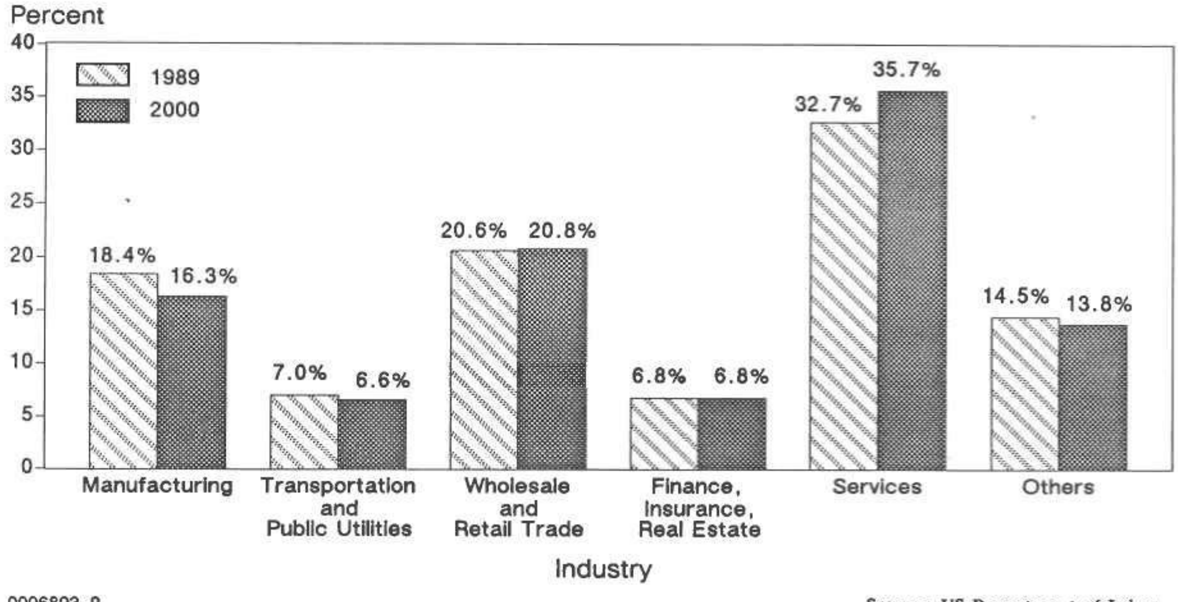
Source: Dataquest
June 1990

Table W-3. Employment Growth by Industry for 1988 and 1989 Annual Estimates through 2000 (Thousands of Workers)

	Actual		Estimated			
Industry	1988	1989	1991	1994	1997	2000
Agriculture	3,169	3,199	3,195	3,187	3,180	3,173
Mining	753	719	718	717	715	714
Construction	7,603	7,680	7,838	8,075	8,312	8,549
Manufacturing	21,320	21,652	21,626	21,590	21,555	21,523
Transportation and Public Utilities	8,064	8,094	8,203	8,367	8,531	8,695
Wholesale and Retail Trade	23,664	24,229	24,824	25,717	26,611	27,504
Finance	7,921	7,989	8,168	8,436	8,705	8,974
Services	37,043	38,227	39,871	42,334	44,794	47,251
Private Household	1,163	1,108	1,106	1,103	1,100	1,098
Public Administration	5,432	5,553	5,616	5,712	5,808	5,904
Total	114,969	117,342	120,059	124,135	128,211	132,287

Source: U.S. Department of Labor, Bureau of Labor Statistics
Dataquest
June 1990

Figure 9. Actual and Estimated Employment Growth by Industry, 1989-2000



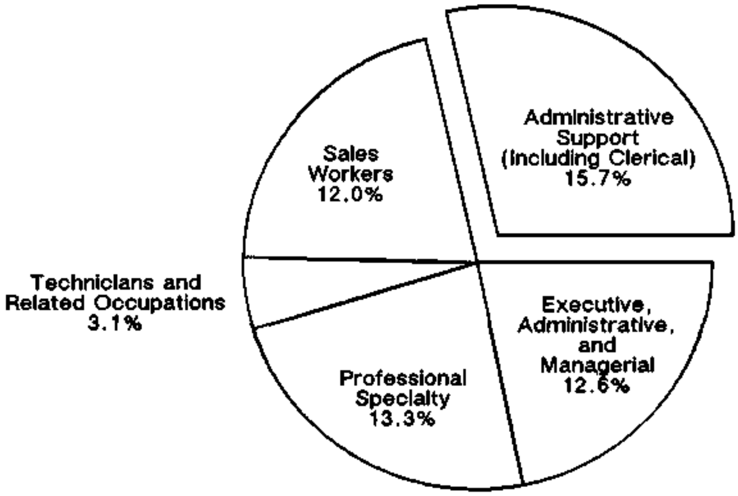
Source: US Department of Labor
Bureau of Labor Statistics
Dataquest
June 1990

Table W-4. Estimated U.S. White-Collar Workers by Job Classification

Job Function	1988 Total White-Collar Workers (Millions)	1988 Percent Total Work Force	1989 Total White-Collar Workers (Millions)	1989 Percent Total Work Force	1994 Total White-Collar Workers (Millions)	1994 Percent Total Work Force
Executive, Administrative, and Managerial	14.2	12.4	14.8	12.6	16.0	12.9
Professional Specialty	15.0	13.0	15.6	13.3	16.9	13.6
Technicians and Related Occupations	3.5	3.0	3.6	3.1	4.1	3.3
Sales Workers	13.7	11.9	14.1	12.0	15.2	12.2
Administrative Support (Including Clerical)	18.3	15.9	18.4	15.7	19.3	15.5
Total White Collar	64.7	56.2	66.5	56.7	71.5	57.5
Total Work Force	114.9	100.0	117.3	100.0	124.2	100.0

Source: U.S. Department of Labor, Bureau of Labor Statistics
Dataquest
June 1990

Figure 10. 1989 White-Collar Workers by Job Classification as a Percentage of Total Work Force



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Source: US Department of Labor
Bureau of Labor Statistics
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Table W-5. Estimated U.S. White-Collar Workers by Industry Sector

Industry Sector	1988 Total White-Collar Workers (Millions)	1988 Percent Total White Collar	1989 Total White-Collar Workers (Millions)	1989 Percent Total White Collar	1994 Total White-Collar Workers (Millions)	1994 Percent Total White Collar
Services	24.4	37.7	25.4	38.2	29.3	41.0
Wholesale and Retail Trade	14.8	22.9	15.1	22.7	16.0	22.4
Manufacturing	8.1	12.5	8.3	12.5	7.9	11.0
Finance, Insurance, and Real Estate	7.3	11.3	7.4	11.1	8.0	11.2
Transportation, Communication, and Utilities	4.1	6.3	4.2	6.3	4.2	5.9
Others*	6.0	9.3	6.1	9.2	6.1	8.5
Total White Collar	64.7	100.0	66.5	100.0	71.5	100.0

*Includes agriculture, mining, construction, and public administration.

Source: U.S. Department of Labor, Bureau of Labor Statistics
Dataquest
June 1990

Table W-6. Estimated U.S. White-Collar Workers as a Percent of Total Work Force by Industry Sector

	1988		1989		1994	
Industry Sector	Total Work Force (Millions)	Percent White Collar	Total Work Force (Millions)	Percent White Collar	Total Work Force (Millions)	Percent White Collar
Services	37.0	65.6	38.2	66.6	42.3	69.1
Wholesale and Retail Trade	23.7	65.8	24.2	62.2	25.7	62.1
Manufacturing	21.3	38.0	21.6	38.2	21.6	36.6
Finance, Insurance, and Real Estate	7.9	92.9	8.0	93.2	8.4	94.7
Transportation, Communication, and Utilities	8.1	50.8	8.1	51.9	8.4	50.9
Others*	16.9	35.8	17.2	35.0	17.7	33.8
Total Work Force	114.9	56.3	117.3	56.7	124.1	57.6

*Includes agriculture, mining, construction, and public administration; average of all four industries.

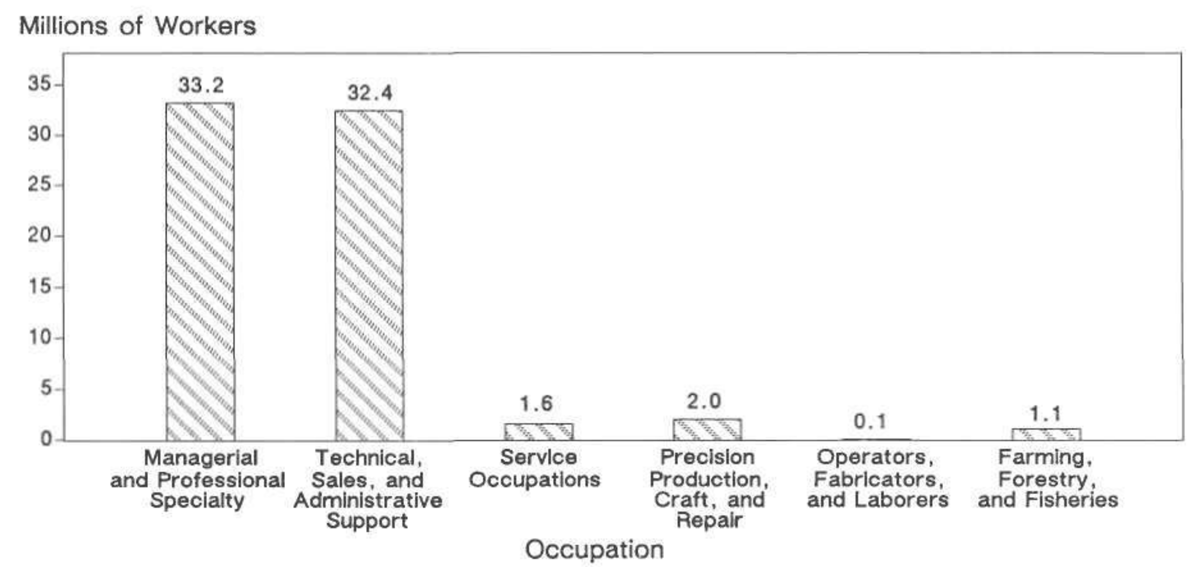
Source: U.S. Department of Labor,
Bureau of Labor Statistics
Dataquest
June 1990

Table W-7. Number of Desktops by Job Classification (Thousands)

			Estimated		
Occupational Classification	1989	1990	1992	1994	1996
Managerial and Professional Specialty	33,179	33,747	34,885	36,022	37,160
Technical, Sales, and Administrative Support	32,394	32,827	33,694	34,561	35,428
Service Occupations	1,620	1,648	1,703	1,758	1,814
Precision Production, Craft, and Repair	2,044	2,058	2,085	2,113	2,141
Operators, Fabricators, and Laborers	114	117	123	130	136
Farming, Forestry, and Fishing	1,092	1,088	1,081	1,074	1,067
Total	70,443	71,485	73,571	75,658	77,746

Source: Dataquest
June 1990

Figure 11. Number of Desktops by Major Occupational Category, 1989



Source: Dataquest
June 1990

Dataquest
a company of
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Dataquest Research and Sales Offices:

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

Technology Products Group
Phone: (800) 624-3280

Dataquest Incorporated
Invitational Computer Conferences Division
3151 Airway Avenue, C-2
Costa Mesa, California 92626
Phone: (714) 957-0171
Telex: 5101002189 ICCDQ
Fax: (714) 957-0903

Dataquest Incorporated
Ledgeway Group
430 Bedford Street
Suite 340
Lexington, MA 02173
Phone: (617) 862-8500
Fax: (617) 862-8207

Dataquest Australia
Suite 1, Century Plaza
80 Berry Street
North Sydney, NSW 2060
Australia
Phone: (02) 959 4544
Telex: 25468
Fax: (02) 929 0635

Dataquest Boston
1740 Massachusetts Ave.
Boxborough, MA 01719-2209
Phone: (508) 264-4373
Telex: 171973
Fax: (508) 635-0183

Dataquest Europe GmbH
Rosenkavalierplatz 17
D-8000 Munich 81
West Germany
Phone: (089) 91 1064
Telex: 5218070
Fax: (089) 91 2189

Dataquest Europe Limited
Roussel House, Broadwater Park
Denham, Uxbridge, Middx UB9 5HP
England
Phone: 0895-835050
Telex: 266195
Fax: 0895 835260/1/2

Dataquest Europe SA
Tour Gallieni 2
36, avenue Gallieni
93175 Bagnolet Cedex
France
Phone: (1) 48 97 31 00
Telex: 233 263
Fax: (1) 48 97 34 00

Dataquest Hong Kong
Rm. 401, Connaught Comm. Bldg.
185 Wanchai Rd.
Wanchai, Hong Kong
Phone: 8387336
Telex: 80587
Fax: 5722375

Dataquest Israel
59 Mishmar Ha'yarden Street
Tel Aviv, Israel 69865
or
P.O. Box 18198
Tel Aviv, Israel
Phone: 52 913937
Telex: 341118
Fax: 52 32865

Dataquest Japan Limited
Shinkawa Sanko Building
1-3-17 Shinkawa, Chuo-ku
Tokyo 104 Japan
Phone: (03) 5566-0411
Fax: (03) 5566-0425

Dataquest Korea
Daeheung Bldg., Room 505
648-23 Yeoksam-dong
Kangnam-gu
Seoul, Korea 135
Phone: (02) 552-2332
Fax: (02) 552-2661

Dataquest Singapore
4012 Ang Mo Kio Industrial Park 1
Ave. 10, #03-10 to #03-12
Singapore 2056
Phone: 4597181
Telex: 38257
Fax: 4563129

Dataquest Taiwan
Room 801/8th Floor
Ever Spring Building
147, Sect. 2, Chien Kuo N. Rd.
Taipei, Taiwan R.O.C. 104
Phone: (02) 501-7960
Telex: 27459
Fax: (02) 505-4265

Dataquest West Germany
In der Schneithohl 17
6242 Kronberg 2
West Germany
Phone: 06173/61685
Telex: 418089
Fax: 06173/67901