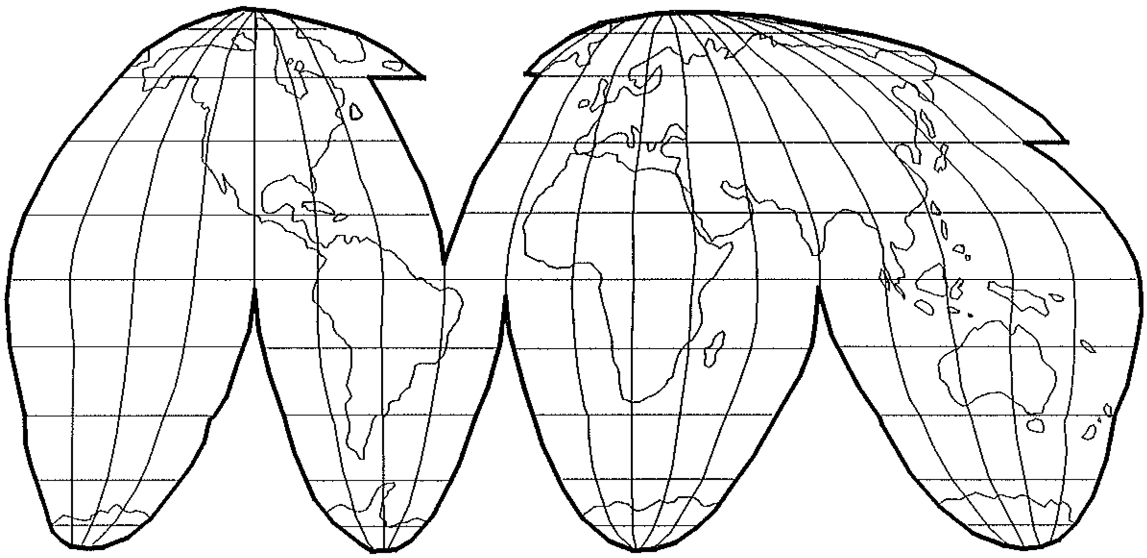
CRITICAL TECHNOLOGY ASSESSMENT OF THE U.S. OPTOELECTRONICS INDUSTRY



U.S. DEPARTMENT OF COMMERCE
BUREAU OF EXPORT ADMINISTRATION
OFFICE OF INDUSTRIAL RESOURCE ADMINISTRATION
STRATEGIC ANALYSIS DIVISION

FEBRUARY 1994

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Copies Are Available for Sale from the National Technical Information Service (NTIS) by Calling 703-487-4650 and Requesting PB93-192425.

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EXECUTIVE SUMMARY

- The main objective of this assessment is to provide policymakers in the Congress and the Executive branch with needed information and analysis on the production and technology status, economic performance and international competitiveness of private sector firms in the optoelectronics area. The primary source of information for this report was a written survey of 107 U.S. companies (and U.S. operations of foreign companies) involved in various aspects of optoelectronics. This survey was conducted by the Department of Commerce, Bureau of Export Administration (BXA) between July 1992 and February 1993.

- For the purposes of this assessment, optoelectronics was very broadly defined as all systems, equipment, or components which emit, modulate, transmit and/or sense light or are dependent on the combination of optical and electronic devices. The market applications for optoelectronics are diverse, and include consumer products, communications, transportation, information, medical and military.

Optoelectronics Technology

- Just as the invention of the transistor several decades ago led to dramatic changes in many aspects of daily life, the marriage of optics with electronics promises to lead to similar leaps in technology. Two optoelectronics advances in particular have spawned myriad advances throughout commercial and military industry: the invention of the laser in the late 1950's and optical fiber in the 1970's.

- Optical technologies combined with electronics offer smaller, faster, and smarter products and weapons that are more reliable, require less energy, and are more cost-effective than those with electronics alone. Optoelectronic technology also has the potential to unblock some of the bottlenecks that are hindering electronics, such as pin congestion on integrated circuits, tangled tracks on printed circuit boards, interference, and signal degradation.

- Optoelectronic technology is of particular advantage to the U.S. military across many application areas. These include data communications and telecommunications for command and control and high bandwidth video transmission for intelligence, reconnaissance, display and electronic warfare systems. The technology also has wide use in weapon-delivery platforms, sensors, guidance systems and optical computing. The resistance of optoelectronic components to electromagnetic and nuclear radiation interference is particularly desirable for military applications, and their lightness allow for fuel savings and greater ammunition payloads.

- The largest market for optoelectronics is in industrial and business applications, which accounts for about 28 percent of total sales. In particular, producers of optoelectronic information systems, lasers, industrial equipment, and components are dependent on this market for sales.

- The military market accounts for the second largest share of total optoelectronics sales, with about 23 percent. Over 60 percent of the companies in the BXA survey participated to some extent in the defense market. The other major market for optoelectronics is communications (18 percent of sales).

Optoelectronics Manufacturing

- BXA's survey captured nearly $6 billion in domestic optoelectronics shipments in 1991. A control group of companies providing shipment information for all years shows that total optoelectronics shipments fell by about eight percent in 1990 from 1989 levels. The drop in 1990 is also evident in the raw data figures. Since that time, however, shipments have rebounded and companies expect the upward trend to continue through 1995.

- The average production capacity utilization rate was slightly over 63 percent in 1991, with a range of just 3 percent to 100 percent. About one quarter of the firms in the survey were operating at less than 50 percent of capacity that year. In contrast, the average capacity utilization rate for industrial production as a whole was about 79 percent in 1991.

- Capacity utilization rates varied by optoelectronic product group, with the display and defense groups showing lower than average utilization rates (54.7 percent and 57.5 percent, respectively) Nearly one-half of the display companies and over one-third of the defense group were operating at less than half of their capacity production levels.

- Thirty survey respondents reported closure of 38 domestic optoelectronics production/research operations since 1972; all but one of these was since 1980 and 24 closings were since 1990. An additional seven companies reported they expect to close down a facility or product line within the next two years. Production lines that were closed ranged from semiconductor laser diodes, to flat panel display operations, to optical guided munitions equipment.

- Production lines targeted to be closed in the future include optical modulators, switches, wavelength division multiplexers, optical data communications equipment, solar cells, photodetectors, lasers, and non-active matrix and plasma displays. The most frequently cited reasons for shutting down facilities and product lines were low profitability, consolidation of operations, and declining demand for particular product. Loss of market share to imports and loss of market share to domestic competition were also mentioned.

- Twenty six survey respondents reported they expected to expand their optoelectronics operations between 1992 and 1996; three of the new facilities were planned to open overseas. Product lines to be added include video transmission equipment, transmitter/receiver modules, lasers, blue LEDs, fly-by-light flight control systems, projection displays, non-active and active matrix liquid crystal displays, optical cable TV distribution systems, bar code readers/scanners, optical military sensor equipment, optical munitions guidance equipment, and laser diodes.

- Investment in optoelectronics production facilities has followed a generally increasing trend, with a large jump between 1991 and 1992, due primarily to major investments by one or two firms. Forecasts for the future show a continuation of the increasing trend.

- The bulk of capital investment, however, is in machinery and equipment. Capital investment in machinery and equipment has been more volatile over the 1989-1992 period; forecasts for the future show a generally increasing trend. Despite the trend toward increasing capital investment, total investment in optoelectronics plant and equipment in the United States is relatively low when compared with some foreign competitors (especially Japan).

- Optoelectronics employment increased about three percent per year in 1990 and 1991, and was virtually stagnant between 1991 and 1992. Those companies making estimates for future years expect their employment to remain essentially unchanged through 1994, with a modest increase anticipated for 1995. The average size of an optoelectronics establishment is about 750 employees.

- About 54 percent of employees in optoelectronics facilities were classified as production workers, while scientists and engineers accounted for 16 percent of the total. Sales and technical service accounted for 14 percent of employees, with the remaining 16 percent classified as administrative.

Research and Development

- In 1991, the surveyed firms spent over $884 million on optoelectronics-related R&D. R&D increased between 1989 and 1991, but then fell slightly in 1992 from 1991 levels. Predictions for 1993-1995 show an increasing trend. Although the decline is small, the lagging economy in 1991 may have left fewer funds available for R&D in 1992, coupled with the start of defense budget cuts affecting federal-funded R&D.

- On average, firms spent about 11 percent of their revenues on research and development. The range was great, with one firm spending less than one percent of sales revenue on R&D, to several (start-up) firms that spent more than their revenues in certain years.

- Companies themselves funded 74 percent of the total R&D. The federal government accounted for the second greatest amount of R&D funds, with 23 percent of the total. Defense organizations were responsible for the vast majority of government-funded optoelectronics-related R&D among surveyed firms, accounting for nearly 90% of the total government funded R&D in 1991.

- The remaining few percentage points of total R&D spending were accounted for by funding provided by customers, foreign governments, and through partnerships with other firms.

- In the field of optoelectronics as in many emerging technology areas, much research and development is performed outside of private firms -- at government laboratories and in academic institutions. The majority of optoelectronics research at academic institutions was funded by the federal government; the National Science Foundation was the largest single source of funds.

- All surveyed universities and government labs indicated some degree of cooperation with private sector firms in the area of optoelectronics. Technology commercialization is a relatively new goal for both of these types of organizations, and increasingly, the assets and resources of federal labs -- personnel and equipment -- are being made available to private sector firms.

- Technology transfer to industry is achieved through personnel interchange, joint research, and joint meetings. Since these programs are relatively new, the overall success of technology commercialization programs of universities and government labs is as yet unclear.

Defense Markets and Effect of Budget Cuts

- The firms in the BXA survey group reported supplying optoelectronics products to a wide range of weapons systems and other military equipment. The items supplied ranged from optoelectronics components such as photodetectors and laser diodes, to subsystems such as optical gyroscopes, to military systems such as the LANTIRN -- a two-pod navigation/targeting system for night and under the weather ground attack.

- About 20 percent of total optoelectronics shipments were reportedly for defense applications. A substantial minority of firms (about 20 percent) are heavily dependent on defense shipments (more than 50 percent of business). Over 10 percent of the establishments were almost exclusively defense producers.

- Thirty establishments reported that defense budget cuts will likely have a significant effect on their operations. Frequently mentioned product categories that will be affected by defense budget cuts include optical sensor equipment such as FLIR and night vision, CCD's and focal plane arrays; other photodetectors; optical munitions guidance equipment; and solid state lasers.

- Because of the nature of optoelectronics, many companies do not perceive that there will be major problems in converting their manufacturing or research operations to commercial production. Many supply similar or identical products to both military and non-military applications; others said that while their products were currently geared toward defense uses, they could be dual-use (e.g., fly-by-light for use in civilian aerospace applications; military sensor work converted to production automation, industrial security, or medical sensors; use of FLIRs for border control, drug interdiction and law enforcement).

- The biggest concern/problem cited by the respondents in converting their operations from military to commercial applications was financial.

Financial Performance

- Aggregated sales by the surveyed optoelectronics firms have consistently risen over the 1989-1992 period, and are forecast by the survey respondents to continue to increase. Sales in 1992, however, were only about five percent higher than the previous year, a smaller increase than the more than 12 percent increase in each of the two previous years.

- Pretax profitability was relatively stable over the 1989-1992 period at about two percent of sales. For comparison, the average profitability for all durable manufacturing was slightly over one percent in 1991 and about three percent for the first three quarters of 1992. About one third of the companies lost money (negative profitability) in any given year 1989-1992. Firms in the laser, display, and components categories had lower than average profitabilities.

Sourcing

- Survey respondents listed specific examples of essential components for which they are dependent on sole/single sources of supply, often foreign. One material -- glass -- was by far the most frequently mentioned item. Other components mentioned include diode lasers, photomultipliers, optical fiber, electronic circuits, high reliability LED's, photodiodes, and optical switches. In most cases, firms indicated that the loss of supplies of these items would halt production until another source could be qualified, often at greatly increased costs.

- The companies in the survey relied on a wide range of imported machinery and equipment, parts, subcomponents and raw materials to produce their optoelectronic products. In the machinery and equipment category, test and measurement equipment was the most frequently mentioned imported item, the primary source of supply for which was Japan. The reason for importing given was that no U.S. source was available, as well as price.

Competitiveness

- U.S. firms believe that they have a technological advantage, particularly over their competitors in the Pacific Rim. U.S. firms also believe their have a slight technological edge over European firms, but ranked their Japanese competitors at or near parity for most technology-oriented competitive factors.

- Japanese firms were rated most competitive in the area of displays, and above average competitiveness in the areas of communications and optical information systems. Japanese firms were ranked below average in industrial equipment, lasers, and particularly in the defense category.

- Firms in the Pacific Rim were universally rated technologically weaker by the U.S. firms across all product groups. However, they were rated the strongest competitors in the optical information category, which includes such well commercialized items as fax machines, copiers, and printers.

- European firms were also consistently rated less technologically competitive by the U.S. survey respondents. They were, however, rated as near equals to U.S. firms in the laser category and are also fairly strong in communications.

- South Korea was named as the country with the greatest potential to become a major competitor in the future, particularly in the areas of displays and communications. Also mentioned frequently in this regard was China for communications, industrial equipment, and component categories.

- U.S. firms believe they have a substantial lead over their Pacific Rim competitors with regard to product and service performance competitive factors (e.g., price, quality, delivery and customer satisfaction). They also believe they have a slight lead over their Japanese and European rivals on these factors. Surprisingly, price does not appear to be a significant advantage or disadvantage for any particular region.

- U.S. firms considered the overall business environment in the United States their biggest disadvantage compared to their competitors in all other regions. This category includes such factors as access to and cost of capital, the legal and regulatory environment, the cost and quality of labor, and the support of government. With the exception of labor, U.S. firms uniformly rate themselves at a competitive disadvantage vis-a-vis competitors, particularly in Japan.

- Lack of access to low cost capital was perhaps the single most frequently cited obstacle to U.S. competitiveness in optoelectronics. Similarly, government policies that discourage investment and R&D were also frequently mentioned, as was the lack of a coherent U.S. government "industrial policy."

- Other obstacles to U.S. competitiveness were external, including inability to penetrate foreign markets due to trade barriers, and alleged dumping by foreign firms in the U.S. market. Some obstacles in this category are the flip side of those in the U.S. business environment, such as the close relationship between foreign governments and their industry, the ability of foreign competitors to finance high levels of R&D, lower labor and other production costs abroad, and better educated workforces overseas.

- Respondents were mostly optimistic about their competitive prospects. Over 60 percent of survey respondents expected the competitiveness of their optoelectronic products to improve somewhat or greatly over the next five years. About one fifth of the respondents anticipated no change in the competitiveness status. On the other hand, about 20 percent of firms expected their competitiveness to decline greatly or somewhat in the near term.

CHAPTER I:
INTRODUCTION

Background

This critical technology assessment of optoelectronics was initiated under Section 825 of the Defense Authorization Act for Fiscal Year 1991. Section 825 (attached as appendix A) requires the Secretary of Defense and the Secretary of Commerce to submit annual reports to the Armed Services Committees of the Senate and House of Representatives on critical technologies. Specifically, the law requires assessments of the financial and production status of industries supporting technologies deemed by the Department of Defense as critical to the performance of current and next-generation weapons systems. Within the Department of Commerce, the Bureau of Export Administration, Office of Industrial Resource Administration is responsible for this, and other, issues related to the ability of U.S. industry to support the nation's economic and military security. Optoelectronics is one of six critical technologies selected for review by the Office of Industrial Resource Administration in fiscal year 1992; the others are Advanced Ceramics, Advanced Composites, Artificial Intelligence, Flexible Computer-Integrated Manufacturing, and Superconductivity.

The objective of this assessment is to provide policymakers in the Congress and the Executive branch with needed information and analysis of the production and technology status, competitiveness, and industrial performance of private sector firms in the optoelectronics area. In accordance with the requirements of Section 825 of the FY 1991 Defense Authorization Act, specific attention was given to assessing the financial ability of U.S. firms supporting optoelectronics to: (1) conduct research and development; (2) to apply technologies to the production of goods/services; (3) to maintain a viable production base for defense-related items in the wake of defense budget/procurement cuts; and (4) to expand production in a national security emergency. To accomplish this, the followin factors were taken into consideration: (a) trends in profitability, investment, research and development; (b) international competitiveness and market trends; (c) the effect of mergers, acquisitions and takeovers; and (d) the extent and effect of dependence on foreign suppliers. In addition, the report was structured after extensive consultation with private sector trade associations and

firms, and every attempt was made to include information that will be of use to them that was not availabe from other Government or industry sources.

Scope and Methodology

For the purposes of this assessment, optoelectronics was very broadly defined as all systems, equipment, or components which emit, modulate, transmit and/or sense light or are dependent on the combination of optical and electronic devices. This definition of optoelectronics encompasses a wide variety of products, from small components to major equipment and entire systems. In the former category as such items as photodiodes, semiconductor lasers, and optical switches. THe latter categories include laser-based medical systems, fiber optic telecommunications systems, and products such as bar code scanners and laser printers. THe market applications for optoelectronics are similarly diverse, and include consumer products, communications, transportation, information, medical and military.

The primary source of information for this report was a survey of U.S. companies (and U.S. operations of foreign companies) involved in various aspects of optoelectronics. This survey was conducted between July, 1992 and February, 1993. A copy of the survey instrument is attached as Appendix B. Survey recipients represent a cross-section of firms throughout various optoelectronic categories, from small components manufacturers to major systems producers. These firms were selected because of their membership in optoelectronic-related trade associations or listings in optoelectronic-related directories. Foreign-owned firms were included in the survey if they had U.S.-base production or research facilities. Ultimately, surveys were received from 106 companies involved in various aspects of optoelectronics. While these companies do not represent the total population of all U.S. firms with optoelectronics-related research or production, they are representative of this total population.

In addition, a separate survey instrument was developed and mailed to academic institutions and U.S. Government laboratories that reportedly conducted major research projects in optoelectronics-related fields. This survey is also attached (appendix B). This survey was completed on a voluntary basis. Again, no attempt was made to capture all U.S. government and academic research related to optoelectronics. However, the survey respondents provide

a representative sample of the activities and goals of these organizations related to optoelectronics. Of particular interest was the extent of cooperation between these organizations and private firms.

In addition to the surveys, information for this assessment was obtained through published sources, such as trade periodicals, company annual reports, U.S. and foreign government statistics, and other Government and non-government studies on optoelectronics or related fields. Experts in various aspects of optoelectronics in the Department of Commerce, the Department of Defense, universities, and the private sector were also consulted. Finally, assistance was received from the Bureau of Export Administration's Office of Foreign Availability, which conducted an extensive review of the activities and technological status of foreign firms in the optoelectronics area.

The first section of the report goes into more detail on optoelectronics products and their uses, including military applications. Then, the industry survey results are presented in the section on industry performance. A profile of the survey recipients is first presented. Then, this section assess the health and viability of the U.S. optoelectronics sector by discussing recent trends in research and development, profitability, investment, employment, shipments, and exports and imports. This is followed by an analysis of the international competitiveness of the U.S. optoelectronics industry, in comparison with major foriegn competitors. The assessment ends by summarizing the major findings and recommendations.

CHAPTER II:
OPTOELECTRONICS PRODUCTS AND INDUSTRY DESCRIPTION

Overview

Optoelectronics promises to be to the 21st century what electronics was to the 20th century. Just as the invention of the transistor several decades ago led to dramatic changes in many aspects of daily life, the marriage of optics with electronics promises to lead to similar leaps in technology. Optical technologies combined with electronics offer smaller, faster, and smarter products and weapons that are more reliable, require less energy, and are more cost-effective than those with electronics alone. Optoelectronics has the potential to break through those bottlenecks that currently limit electronics to allow for more information capacity, faster transmission, energy efficiency, and immunity to electromagnetic interference (i.e. static caused by proximity to other electrical systems, lightning or nuclear blasts). Using optoelectronics, computers with "supercomputing" power may soon be able to fit on one's desk; fiber optic "super highways" will carry video, text, motion pictures, and voice concurrently and instantaneously to computer terminals in the home, office, and automobile; sensors will be powerful enough to read license plates from satellites; and lasers capable of guiding missiles will all be possible.

Optoelectronics is, generally, the combination of optical technologies and electronics; more specifically, it is those systems, equipment, and/or components that emit, modulate, transmit, and/or sense light or are dependent on the combination of optical and electronic devices. For the purpose of this study, we have broken down optoelectronics by systems, equipment, and components in seven broad application areas: 1) Communications; 2) Information; 3) Industrial and Medical; 4) Transportation; 5) Military; 6) Consumer; and 7) Other optoelectronics-based devices and subsystems. We will explain a little of the history of optoelectronics and the technical advantages of combining light with electricity, then discuss optoelectronics products within each application area.

Light vs. Electricity

Like electrons, particles of light called photons can be used to transmit information. Photons offer significant advantages over electrons, such as greater speed, capacity, energy

efficiency, and immunity to electromagnetic interference. Because electrons carry a charge and a mass, they are slower and must be guided along (usually) copper wires or cables that must be covered in protective cladding to prevent "crosstalk." Electrons also require expensive amplifiers to boost signal transmission over long distances. In contrast, photons do not have a mass or charge to restrict their travel or to necessitate frequent amplification. Since light beams do not interact with one another, they can travel freely through space or through thin strands of glass fiber, omitting the need for thick copper wiring. Moreover, since photons have no mass, they are faster than electrons; and because lightwaves don't interact, they can be superimposed onto one another, providing greater bandwidth or information carrying capacity than can copper cables.[1] Consequently, light has advantages that can unblock some of the bottlenecks that are hindering electronics, such as pin congestion on integrated circuits, tangled tracks on printed circuit boards, interference, and signal degradation.

Optoelectronic products are already beginning to shape our everyday lives, due in large part to two major breakthroughs: lasers and fiber optics. The laser (Light Amplification by Stimulated Emission of Radiation) was among the earliest optoelectronics inventions, dating to the late 1950s.[2] Particles of light, or photons, were found to emit a powerful beam when bounced back and forth between mirrors.[3] Although their first commercial use was to transmit telephone messages, lasers are now ubiquitous, doing everything from registering prices at the supermarket, to performing surgery, to aiming weapons, to "reading" music from compact disks.

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[1] "The Optical Enlightenment," The Economist Newspaper Ltd., July 6, 1991, p. 87.

[2] Chaffee, David C., The Rewiring of America: The Fiber Optics Revolution, Academic Press Inc., New York, 1988, p. 2.

[3] Larsen, Erik, "Patent Pending," INC, March 1989, p. 107.

Optical fiber was developed in the 1970s[4] as a conduit for laser-generated messages with at least 10,000 times the capacity of copper cables[5]. Deployment of the first optical telecommunications system occurred in 1977,[6] and the first U.S. coast-to-coast telephone call via fiber optic lines was made by 1986.[7] Recently, both the U.S. and Japanese governments have announced plans to bring optical fiber to the home by 2015.

These two advances in particular have spawned myriad advances throughout commercial and military industry. As a result, the U.S. optoelectronics "infrastructure" is sprawling, loosely connected, and difficult to define. With the advice of the U.S. Optoelectronics Industry Development Association (OIDA), for the purposes of this assessment we have broken-down the optoelectronics "industry" by broad application area: communications, information, industrial, medical, transportation, military, consumer, and a general category for optoelectronics subcomponents used across all of these application areas. Table II-1 lists some common optoelectronic components and products in each application area.

A. Fiber Optic Communications Equipment

Perhaps the most visible and mature market for optoelectronics is fiber optic communications. Optical fiber has wide bandwidth capacity that increases the capability not only for telecommunications but also for video communications such as high-definition television (HDTV) and interactive communications. The capabilities of fiber optic networks are constrained by the efficacy of their available components. Generally optical devices provide greater performance. For example, optical switches have the potential to massively increase fiber optic network speeds by routing light paths without first having to convert photons to electronic form -- a process that is necessary with electronic switches. Wavelength division multiplexers expand the information capacity of fiber by applying more

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[4] Chaffee, p. 11.

[5] Carey, John, "The Light Fantastic," Business Week, May 10, 1993, p. 46

[6] Chaffee, p. 28.

[7] Chaffee, p. 111.

than one wavelength. Optical amplifiers doped with the element erbium directly amplify light pulses, reducing the need for expensive electronic amplifiers.

TABLE II-1

OPTOELECTRONICS PRODUCT CATEGORIES

A. Fiber Optic Communications (e.g., Transmission, Amplifiers, Cable TV Distribution, Optical Modulators, Switches, Fibers, Multiplexers, Connectors, Transmitter/Receiver Modules)
B. Fiber Optic Information Equipment (e.g., Optical Processing Units, Memory/Storage Devices, Bar Code Readers, Printers, Image Processing, Interconnects, Faxes, Displays)
C. Industrial/Medical Equipment (e.g., Machine Vision, Optical Test & Measurement, Night Vision/Surveillance, Laser Processing Equipment, Non-laser Medical Equipment, Lasers)
D. Non-Military Transportation Equipment (e.g., Automotive Interior Displays, Traffic Control Systems, Fly-By-Light, Cockpit Displays, LIDAR/CAT, Optical Gyroscopes)
E. Military Equipment (e.g., Fiber Optic Ground/Satellite Communications, LIDAR, Optical Gyroscopes, FLIR, Night Vision, Munitions Guidance, Laser Weapons)
F. Consumer Equipment (e.g., TVs, Video Cameras, CD Players, Home Faxes, Appliance Displays)
G. Subsystems/Components (e.g., Photo Detectors, Semiconductor Light Sources, Hybrid Optical Devices)

B. Information Equipment

Optoelectronics has also permeated the information industry by way of fiber optic interconnects, optical storage disks, flat panel displays, and optical computing. Optical interconnects are important for enabling high-speed data transmission, replacing copper wires

that link chips, boards, and computers. Optical storage disks have greater storage capacity and durability than magnetic media and use lasers to "read and write" information onto tiny pits in the disks; for example, CD-ROMs (compact disk read-only-memory) can store the equivalent of 1,000 floppy disks.[8] In the future, holographic memory systems that chemically change when struck by laser beams promise higher capacities and faster access times than even CD-ROMs and certain hard drives.[9] Flat panel displays are replacing the more bulky cathode ray tube designs for computers, cockpit displays, and high definition television (HDTV) sets. Optical processors that handle images instead of data bits are on the horizon and even optical computing is in the not so distant future; the University of Colorado unveiled the world's first, albeit very basic, all-optical computer in January, 1993.[10]

C. Industrial and Medical

Medical and industrial applications also have been greatly enhanced by optoelectronics. Gas and solid state lasers are used for welding, material processing, alignment, process control, surgery, and diagnostic medicine. In the future, laser-based medical image processing could rival magnetic resonance imaging and cost "99 percent less."[11] Sensor-based machine vision systems that can track license plates, collect tolls, and control and analyze traffic are on the way. Laser-based optical test and measurement systems can improve quality control by monitoring factory processes and assuring alignment and accuracy. Night vision equipment that was successfully deployed in Operation Desert Storm also can be used for surveillance and police protection.

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[8] Schwartz, Evan I., "CD-ROM: A Mass Medium At Last," Business Week, July 19, 1993, p. 82.

[9] Carey, p. 49.

[10] Carey, pp. 44-50.

[11] Welter, Therese R., "Electronics Takes a Bride," Industry Week, May 7, 1990, p. 49.

D. Transportation Equipment (Non-Military)

Optoelectronics is only beginning to emerge in the commercial transportation marketplace. Fly-by-light (FBL) flight control systems are scheduled to replace conventional electronic fly-by-wire (FBW) systems in military and commercial airplanes. The benefits of FBL systems employing optical fibers are similar to those of other applications: their lightness, cost effectiveness, and resistance to electromagnetic interference. Flat panel displays are replacing CRTs in the cockpit and are beginning to appear in some automobiles. Optical gyroscopes can be used in the navigation systems of both automobiles and airplanes.

E. Military Equipment

Optoelectronics has particular advantages to the U.S. military across many of the application areas discussed above, including "...data communications and telecommunications for command and control and high bandwidth video transmission for intelligence, reconnaissance, display and electronic warfare systems. The technology also has wide use in weapon-delivery platforms, sensors, guidance systems and optical computing."[12] Optoelectronics' resistance to electromagnetic and nuclear radiation interference is particularly desirable for military applications, and their lightness allow for fuel savings and greater ammunition payloads. Optical transmission systems are more difficult to tap than their electronic counterparts; and optical fiber-tethered missiles enable remote controlled guidance over long distances that cannot be achieved with copper wire. Laser-guided munitions can achieve high target accuracy rates as demonstrated in Operation Desert Storm. Fiber optic sensors can record stresses and temperature levels in airplane wings and detect ripples created by submarines.[13] Forward Looking Infrared (FLIR) systems can capture real-time images of infrared scenes for display on monitors. Optical interconnects, switches, and processors promise high speed parallel processing for quick analysis of intelligence information. Night vision goggles can be particularly effective when integrated with FLIR

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[12] Schmitt, Edward J., "Photonics: A New Capability for Advanced Military and Avionics Systems," Photonics Spectra, July 1991, p. 105.

[13] Carey, p. 50.

systems as done in Operation Desert Storm.[14] Heads Up Displays were also useful during the Gulf War for allowing pilots to view information projected on their windscreens without having to look downward to an instrument display. Laser-based LIDAR (light detection and ranging) systems were used to detect chemical and biological agents during Operation Desert Storm (and are now being used to monitor atmospheric conditions, such as air pollution).

F. Consumer Equipment

The effect of optoelectronics on the consumer industry is obvious. Hand held video cameras, flat screen TVs, CD players, laser disks, fax machines, and liquid crystal displays on watches, cellular telephones, calculators, and appliances are all examples of how optoelectronics has integrated with and enhanced the consumer world. In the future, optoelectronics technologies will enable products that combine audio, text, graphics, and video.

G. Subsystems & Components

Optoelectronic components are the building blocks for the products listed above across all application areas. Light emitting diodes (LEDs) and semiconductor laser diodes, invented in the early 1960s,[15] are used in a wide variety of applications including laser printers, CD players, fiber optic transmission, and satellite communications. Tiny lasers, called microlasers, that emit light perpendicular to a chip's surface are promising for military applications, including laser radars and automatic target recognition systems.[16] Photodetectors detect light impulses generated by an LED or laser diode and convert this energy to electrical form, and are used primarily in communication systems. Charge coupled devices (CCDs) are used as image sensors in certain cameras, camcorders and fax machines. Hybrid optical devices such as optoelectronic integrated circuits (OEICs) combine photonic and electronic technologies on a single chip for faster and cheaper computing.

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[14] Scott, William B., "Night Vision Systems Yield Payoff in Persian Gulf War," Aviation Week & Space Technology, February 3, 1992, p. 42.

[15] Carey, p. 46.

[16] Leopold, George and Munro, Neil, "DOD Ponders Big Supply of Tiny Lasers," Defense News, January 6, 1992, p. 23.

Summary

The impact of optoelectronics on the way we store, process, and transmit information is gradual but no less remarkable than that of electronics. The replacement of copper wires with light to improve products is a subtle process that is no less impressive than those earlier electronics inventions; computers are faster, television images finer, and telephone conversations clearer. Over the next decade, this technology will yield smaller, faster, and smarter products and weapons that are more reliable, efficient, and more cost-effective than those with electronics alone. On the horizon is a national "superhighway" of fiber optic networks capable of transmitting words, music, movies, medical images, and blueprints; optical sensors that can monitor stresses and temperatures in planes, automobiles, and machinery; lasers that can identify military targets, brain tumors, and the substance of cells[17]; flat panel displays that can project images in cockpits, automobile dashboards, and medical equipment; holographic memories capable of replacing CD-ROMs and floppy disk drives; and optical processors that can process whole images instead of data bits, allowing quicker detections of cancers.[18]* Ultimately, this subtle infiltration of optics with electronics in vast arrays of product areas will foment a revolution that rivals that of its predecessor, electronics.

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[17] Carey, p. 44.

[18] Carey, p. 49.

CHAPTER III:
PROFILE OF SURVEY RESPONDENTS

The primary source of information for this assessment was a detailed questionnaire conducted by the Bureau of Export Administration (BXA) between July, 1992 and February, 1993 (See Appendix A). A total of 107 firms (148 establishments) active in various optoelectronics fields responded to the BXA questionnaire. Of these, 77 designated themselves as primarily manufacturers. Eleven respondents indicated that they conducted optoelectronics-related research, but did not do any manufacturing, while 17 respondents designated themselves as both research and manufacturing organizations. Note that most of those companies that designated themselves as primarily manufacturers also conduct R&D, but this was not the focus of their activities.

The firms responding to the questionnaire produced and/or conducted research in a wide variety of optoelectronics product categories, from materials, to components, to equipment and systems. Broad categories and number of survey participants active in each are listed in Table III-1 below. (Because some companies participate in more than one broad category, the total is greater than 107). As can be seen from the table, all optoelectronics categories are represented among the survey respondents, although the surveillance and consumer equipment categories have relatively few participants. Surveillance is a relatively small market sector; consumer electronics is an area where U.S. firms do not play a large role compared to foreign competitors. In fact, of the five companies responding in this category, four are U.S. operations of foreign-owned companies.

Of the 107 companies in the survey, 22 are known to be either wholly or partially foreign-owned. Of these 22, nine were Japanese; five were British; four were German; two French, and one each had owners based in Sweden and Israel. Many additional foreign companies surveyed indicated that while they have U.S. sales and/or service operations, they did not conduct research or manufacturing of optoelectronics-related products in the United States, and thus were not required to complete the questionnaire.

TABLE III-1
PROFILE OF SURVEY RESPONDENTS BY
PRODUCT CATEGORY

OPTOELECTRONIC PRODUCT CATEGORY	NUMBER OF SURVEY RESPONDENTS PARTICIPATING
Communications Systems and Equipment	23
Optical Information Equipment	14
Displays	19
Industrial Equipment	22
Lasers	18
Surveillance Equipment	4
Defense/Military Equipment, Systems & Components	26
Consumer Equipment	5
Optoelectronic Components	18

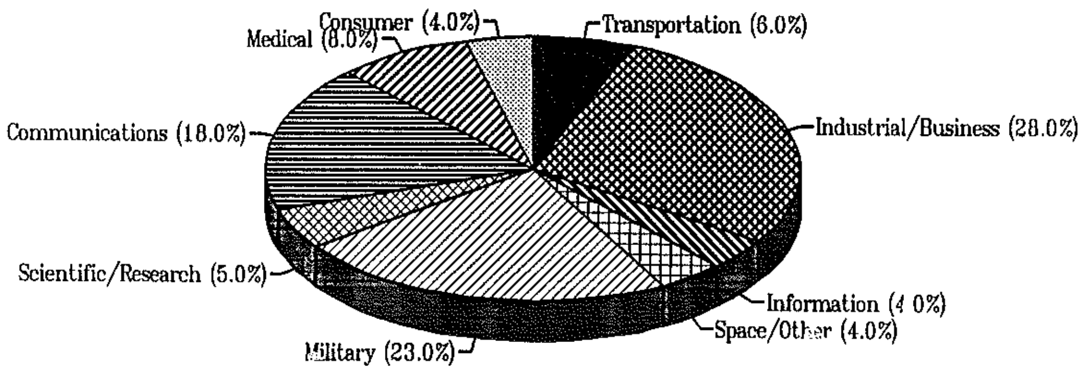
Source: BXA Optoelectronics Survey

We are unable to estimate the percentage of the total U.S. optoelectronics industry captured by the BXA survey. Although some subsectors of optoelectronics such as lasers and components are well studied and documented, there is little information on the optoelectronics sector as a whole. However, given the broad array of optoelectronics products produced, and sizes and types of optoelectronics firms represented in the BXA survey, we believe the experiences and trends of the survey group are similar to that of all optoelectronics firms.

Market Applications

The optoelectronics companies in the BXA survey group produce a wide variety of products for use in a multitude of applications. Figure III-1 below shows how the surveyed companies estimated the share of their production that goes to specific markets.

Figure III-1
Markets for Optoelectronic Products
(102 Establishments Reporting)



Source: BXA Optoelectronics Survey

The largest market for optoelectronics was industrial/business, accounting for about 28 percent of sales. In particular, producers of optoelectronic information systems, lasers, industrial equipment, and components are dependent on this market for sales. Although it would have been useful to further break down this category into its industrial and business subsets, this was not possible due to the structure of the survey question. There was also some confusion and overlap regarding the "information" category and the "business/industrial" category.

The military market accounts for the second largest share of optoelectronics sales, with about 23 percent. Nearly three quarters of the companies (71 out of 102) in the survey participated to some extent in the defense market. The other major market for optoelectronics is

communications (18 percent). Optoelectronics are used in a variety of other applications (medical, scientific research) to a lesser extent. However, for some companies, these markets are the major source of demand.

Geographical Distribution

Survey recipients were asked to identify the location of their optoelectronic manufacturing and research establishments in the United States and abroad. They were also asked to indicate the category of optoelectronic production or research, the number of employees, and the year of establishment of each site. In general, optoelectronics facilities were found to be spread throughout the United States, with no one region dominating in any particular technology or application area (See Figure III-2).

-- Manufacturing Establishments

Ninety-five companies reported 139 domestic and 28 foreign manufacturing establishments in 27 states and 12 countries. California accounted for the greatest number of manufacturing establishments, with 35, followed by Massachusetts (13) and New Jersey (11). Multiple foreign facilities of U.S. optoelectronics companies were found in Germany (7), Mexico (5), and the United Kingdom (5).

Eighty-nine manufacturing companies provided employment information by establishment. New York employed the highest number of manufacturing workers (due in large part to one very large facility). California ranked second, followed by Connecticut and Florida. Outside of the United States, employment was concentrated in Latin America (especially Mexico), followed by Asia (including Singapore, Malaysia, China, Korea and Philippines) and Europe (Germany, U.K., Italy, Ireland) (See Figure III-3).

The reported focus of optoelectronics manufacturing varied widely across those twenty-seven states. Fiber optic communications equipment was reported manufactured in fourteen states as well as France, Germany, and Singapore; information systems, displays, and industrial/medical equipment each were manufactured in eleven different states, plus the United Kingdom, Germany, Italy, Korea, and Malaysia. Most of those firms produced optical input equipment (scanners, mice, and bar code readers) and optical data

communications; plasma and non-active matrix liquid crystal displays; and optical test and measurement equipment. Lasers were manufactured in seven different states and Germany with firms focusing equally on solid state and gas types. Defense-use optoelectronics equipment was manufactured in eight different states and no foreign locations with most firms providing unique military equipment, optical sensor (e.g. FLIR, night vision equipment), and munitions guidance equipment. Optoelectronic components were reported manufactured in seven different states and eight different countries (including Canada, Ireland, Singapore, the Philippines, Malaysia, Korea, China, and the United Kingdom) with most firms focusing on laser diodes and CCDs/focal plane arrays.

Respondents also listed some products which were manufactured only overseas. Overseas production included the manufacture of components and passive matrix displays in Asia, video equipment in Latin America (Mexico), and telecommunications, information and industrial/medical (non-laser) equipment in Europe.

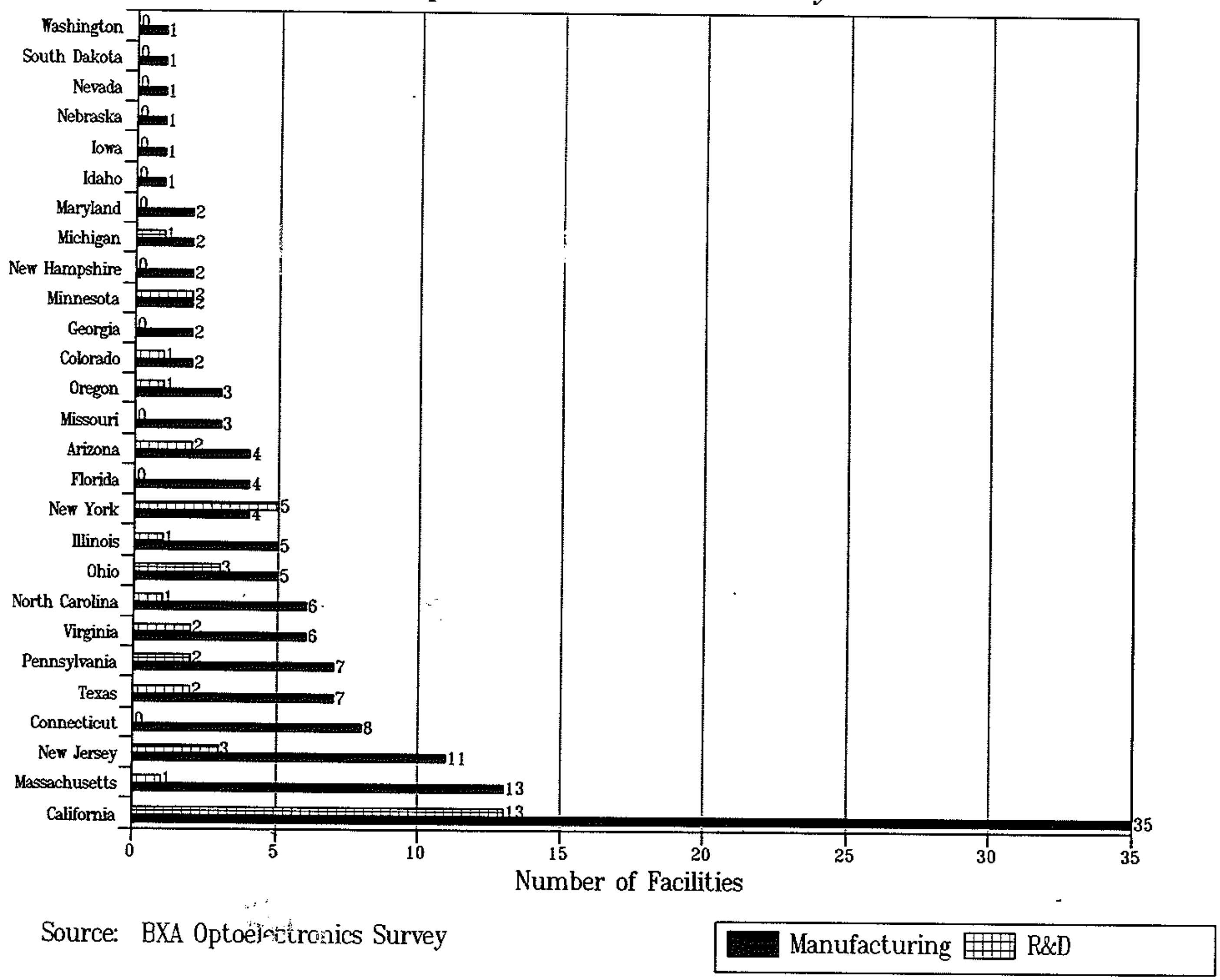
About 60 percent of respondents reported that they had established their manufacturing facilities since 1980; one third of those facilities were built in the last three years. This is not surprising, given the nascent nature of optoelectronics.

-- Research Establishments

While most surveyed optoelectronic firms did not maintain R&D facilities separate from their main manufacturing operations, 23 companies, including nine research-only organizations, reported a total of 43 research-only facilities (40 in the United States and three in Europe). As with manufacturing establishments, California had the most optoelectronics research facilities with 13, followed by New York with four research establishments. A full eighty percent of research facilities were established since 1980.

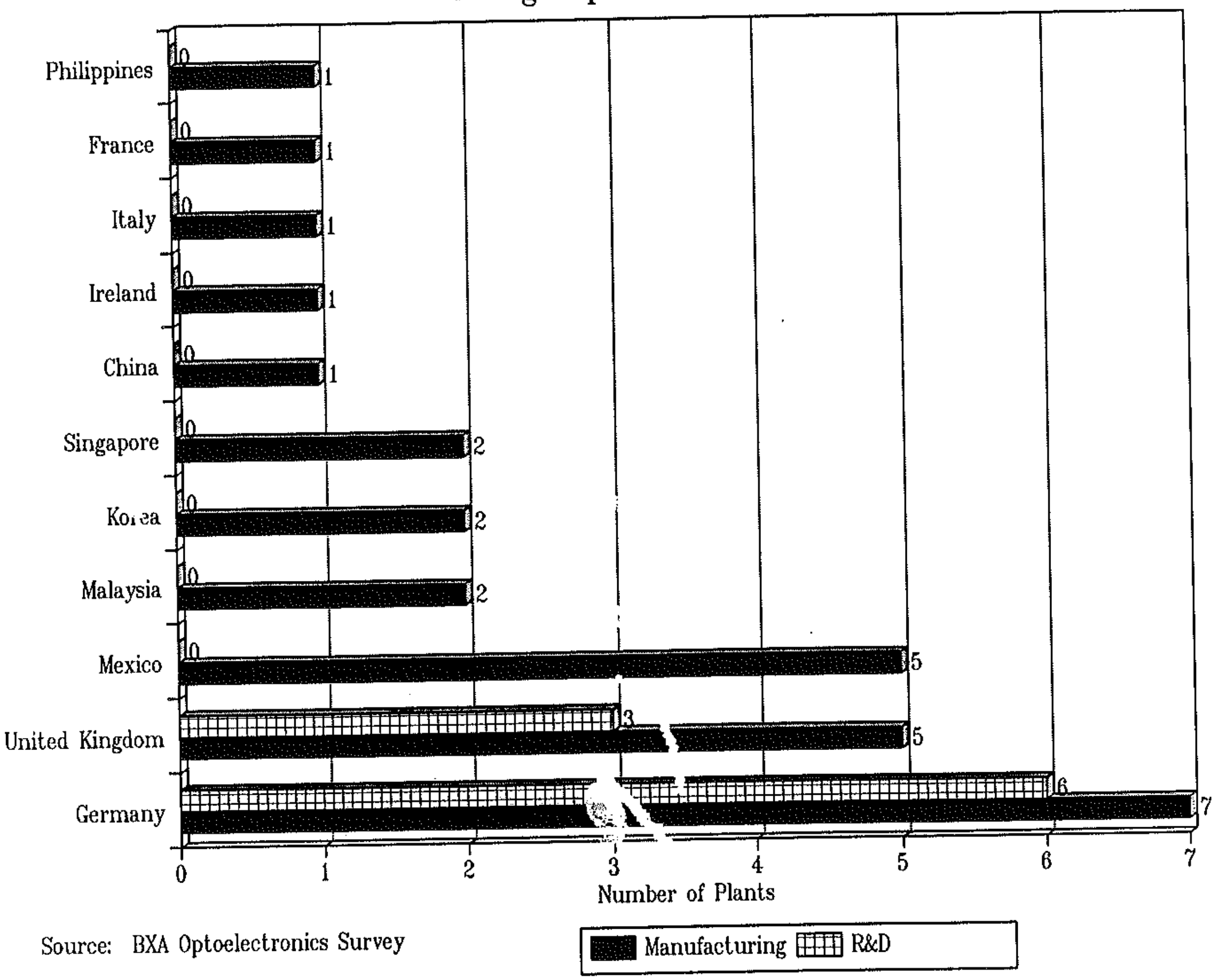
Companies were also asked to indicate the primary areas of their research concentrations by establishment. In California, these included fiber optic communications, military fly-by-light, optical satellite communications, optical information systems, and displays. In New York, research was reported on optical input systems (such as printers and scanners), fiber optic communications, production automation, laser diodes, and high definition television

Figure III-2
Optoelectronics Facilities By State



Source: BXA Optoelectronics Survey

Figure III-3
Foreign Optoelectronics Facilities



Source: BXA Optoelectronics Survey

(HDTV). Research in Ohio and New Jersey included fiber optic telecommunications, HDTV, and construction alignment equipment.

Production Closings and Expansions

--Closings

Thirty survey respondents reported closure of 38 domestic optoelectronics production/research operations since 1972; all but one of these have closed since 1980 and 24 closings have occurred since 1990. An additional seven companies reported they expect to close down a facility or production line within the next two years.

The most frequently cited reasons for shutting down facilities and production lines were low profitability, consolidation of operations, and declining demand for particular products. Loss of market share to imports and loss of market share to domestic competition were also mentioned by several companies. Additional reasons included "elimination of low priority work," "inability to produce," and "too many unpredictable and onerous administrative burdens" -- referring to the requirements for participation in defense contracts.

Production lines that have been closed included those manufacturing semiconductor laser diodes, flat panel displays, and optical guided munitions equipment. Production lines targeted to be closed in the future include those which manufacture optical modulators, switches, wavelength division multiplexers, optical data communications equipment, solar cells, photodetectors, lasers, and non-active matrix and plasma displays. A summary of the ceased production lines/operations is presented in Table III-2.

--Expansions

Twenty-six survey respondents reported they expected to expand their optoelectronics operations between 1992 and 1996; three of the new facilities were planned to open overseas. Product lines to be added include video transmission equipment, transmitter/receiver modules, lasers, blue LEDs, fly-by-light flight control systems, projection displays, non-active and active matrix liquid crystal displays, optical cable TV distribution systems, bar code readers/scanners, optical military sensor equipment, optical munitions guidance equipment, and laser diodes.

TABLE III-2
OPTOELECTRONIC PRODUCTION CLOSINGS
SINCE 1972
(U.S. ONLY)

Year	# of Product Lines/ Facilities	Product Lines
1992	9	Semiconductor Diode Lasers, Color Printers, LED Printheads, Photodetectors, Solar Cells, Optical Munitions Guidance Eq., TVs, Optical Satellite-to-Satellite Communications Equipment
1991	12	PIN Photodiodes, Surveillance Systems, Optical Cable Distribution, Flat Panel Displays, Optical Test & Measurement, Fiber Optic Communications, Optical Switches, CW YAG Lasers
1990	3	Optical Storage Devices, CCDs/Focal Plane Arrays, Projection Lithography
1987-89	4	Fiber Optic Control Equipment, Wavelength Division Multiplexers, Gas Lasers, Photo Interrupters
1984-86	5	Flat Panel Displays, Gas Lasers, Military Fiber Optic Cable Systems, Automotive (e.g., Interior Displays, Exterior Lighting), TV Components
1980-83	4	Production Automation, Laser Processing, Optical Test & Measurement, TVs, Optical Amplifiers
1972	1	Military Communications Equipment, Video Equipment
Total:	38	

Source: BXA Optoelectronics Survey

Cooperative Relationships

The companies in the BXA survey group were involved in a wide variety of relationships with other domestic and international firms, universities, and government organizations. A sampling of the types of these cooperative relationships are described here, and it is believed to be representative of the overall nature of domestic and international cooperation in the optoelectronics field. The cooperative agreements described here are by no means an exhaustive list of cooperation in this industry.

The most common type of agreement among domestic organizations was collaborative research/joint development efforts. Fourteen companies reported involvement in 36 such agreements ranging from high-speed fiber optic transmission technologies to optoelectronic integrated circuits to HDTV. Of the 35 reported research programs, twelve involved university participants, one included a federal agency, and one involved a state agency. The remaining 22 agreements were among private sector firms, including divisional partnerships within the same corporation. Domestic marketing agreements were far fewer with 11 companies reporting only 14 such efforts.

By far, the most commonly reported foreign cooperative agreements were marketing/sales and distribution. Approximately 124 agreements were reported with the great majority in Europe (roughly 55 percent) and the Pacific Rim (10 percent in Japan and 12 percent all other Pacific Rim nations). The remaining agreements were with firms in the Middle East, Australia/New Zealand, China, India, South America and Mexico.

Nine surveyed companies identified 17 cooperative research/joint development efforts with European and Japanese partners. Ten of these agreements were with European companies and universities, including two U.S. subsidiaries and two university research scientists on sabbatical visits to the U.S. for one year. Seven agreements were with Japanese companies, involving two U.S. subsidiaries in Japan and one Japanese parent company of a U.S. firm. Licensing agreements were the second most frequently reported type of domestic and foreign arrangement, including 36 foreign and 30 domestic agreements. The majority of licenses were with Europe (17) and Japan (9), followed by the Middle East (4). Additionally, a

Japanese subsidiary in the U.S. agreed to license "software and a manufacturing process" to its parent company.

The vast majority of these licensing agreements involved use of U.S. technology abroad. However, reported license agreements to obtain technology from abroad included LCD displays, a scanning system, and optical material from Japan; night vision equipment from France; and fiber optic communications systems, optical sensors, and recording equipment from Canada. Domestic license agreements included royalties for patents, two cross licenses, and licenses to four universities. These included touch technologies, optical guided vehicles, solid state and gas laser systems, and multimedia players.

Companies in the BXA survey sample indicated involvement in 12 international and five domestic joint ventures. The majority of joint ventures were with European and Japanese firms and focused on optical integrated circuits, fiber optics, and LED arrays. Additionally, a joint venture agreement was reported with a factory in China to manufacture liquid crystal displays. U.S. joint ventures ranged from marketing application specific integrated circuits for active matrix liquid crystal displays, to distributing of CO_2 lasers, to developing indium arsenide focal planes and IR cameras.

Companies also identified 22 cooperative supplier agreements including nine foreign and 13 U.S. partnerships. Companies reported original equipment manufacturer (OEM) agreements, subcontractors, or vendor agreements for products ranging from laser beam printers, to medical equipment, to television integrated circuit design. Reported foreign subcontractor agreements included fiber pigtails, optical processing equipment, and laser diodes. OEM agreements were for "optical systems" and supplier arrangements for LCD modules and picture tubes.

Additional agreements included minority investments in U.S. companies to "bring fiber to the curb" and to build local area networks; foreign subsidiaries for distribution and sales efforts, product standardization, servicing agreements; and management consulting.

Not surprisingly, industry participants were involved in far more U.S. than foreign consortia. Two companies indicated they were members of or contractors to the European initiatives to RACE (Research in Advanced Communications in Europe) and EUREKA (the European Research Coordinating Agency). Industry participants reported being involved in several U.S. Government supported consortia including the Optoelectronic Technology Consortium, the American and U.S. Display Consortia, and certain university and university-government-industry cooperative initiatives such as the Alliance for Photonic Technology and a consortium on optical network architectures ("ACORN") at Columbia University.

Additionally, companies reported memberships in the Optoelectronics Industry Development Association -- a group companies formed to advance the competitiveness of the U.S. optoelectronics industry -- and the Advanced Display Manufacturers Association -- 10 companies promoting development of the flat panel display industry. Members from the Laser Electro-Optic Manufacturers' Association, a trade association established in 1985 to represent the laser and electro-optics industries, were also participants.

TABLE III-4
FOREIGN BUSINESS ARRANGEMENTS

Foreign Relationships:	# of Agreements	# of Companies	Areas of Focus
Marketing/Distribution	124	19	Distributorships including LCDs, IR Imaging Systems, IR detectors
Supplier	9	6	Fiber Optic Pigtails, Optical Processing and Manufacturing Equipment, Laser Diodes, Picture Tubes, LCD Modules (3 Korea, 2 Japan, 2 Europe, 1 Scotland, 1 Hong Kong)
Joint Venture	13	9	Optical Circuits, Micro Machining, Fiber Optics, LCD, LED Arrays, etc. (4 Japan, 6 Europe, 1 Australia, 1 China, 1 Korea)
Collaborative Research/ Joint Development	17	9	Laser Packaging, Fiber Optic Transmission, Optical Networks, Optical Interconnects, Acousto-Optical Wave-Guides, Fly-By-Light, Optical Receivers, Photonic Instruments, Flat Panel Displays (10 Europe, 7 Japan)
Licensing	36	14	LANTIRN, Fiber Optic Communications Systems, Liquid Crystal Displays, Night Vision Eq., Fiber Optic Scanners & Sensors, Optical Recording Eq., IR Fiber Optic Control Subsystems (17 Europe; 9 Japan; 4 Middle East; 4 Pacific Rim; 1 Canada; 1 Indonesia)
Investor/ Subsidiary	6	5	Sales Offices, Distribution of Fiber Optic Systems, Flat Panels (5 Europe)
Consortia/ Memberships	3	2	FACE, EUREKA -- Flat Panels ([illegible] Europe)
Other	4	2	Product Standardization (2 Japan, 2 Europe)
Total:	183	50	

Source: BXA Optoelectronics Survey

TABLE III-3
DOMESTIC BUSINESS ARRANGEMENTS

Domestic Relationships:	# of Agreements	# of Companies	Areas of Focus
Marketing	14	11	Laser Diodes, Telecommunications Equipment, Medical Cameras
Supplier	13	7	Laser Printers, Medical Equipment, Fiber Optic Lighting, IC Design
Joint Venture	5	5	Lasers, ASICs, Focal Plane Arrays, IR Cameras
Collaborative Research/ Joint Development	36	14	High-Speed Fiber Optic Transmission, Optical Amplifiers, Fly-By-Light, LIDAR, Optical Memory, Photovoltaics, Medical and High-Powered Diode-Pumped Lasers, Optoelectronic Packaging and Integrated Circuits, Optical Interconnects, Color Electroluminescent Displays, High Definition Television (HDTV), Video Compression, Semiconductor Materials, Optical Waveguides
Licensing	30	16	Military Datalinks, Optical Guided Vehicles, Bar Code Readers, Spectrometers, Lasers, Plasma and "Touch" Technologies, Printer Devices, LANTIRN, Medical Equipment, Multimedia Players
Investment	2	1	Fiber to the Curb, LAN
Consortia/ Memberships	13	10	Optical Interconnects, Data Communications, Optical Network Architectures, Laser Diodes, Materials, Displays, Manufacturing Automation
Other	4	4	FDDI Standardization, Servicing Agreements, Management Consulting
Total:	117	45	

Source: BXA Optoelectronics Survey

CHAPTER IV:
INDUSTRY PERFORMANCE

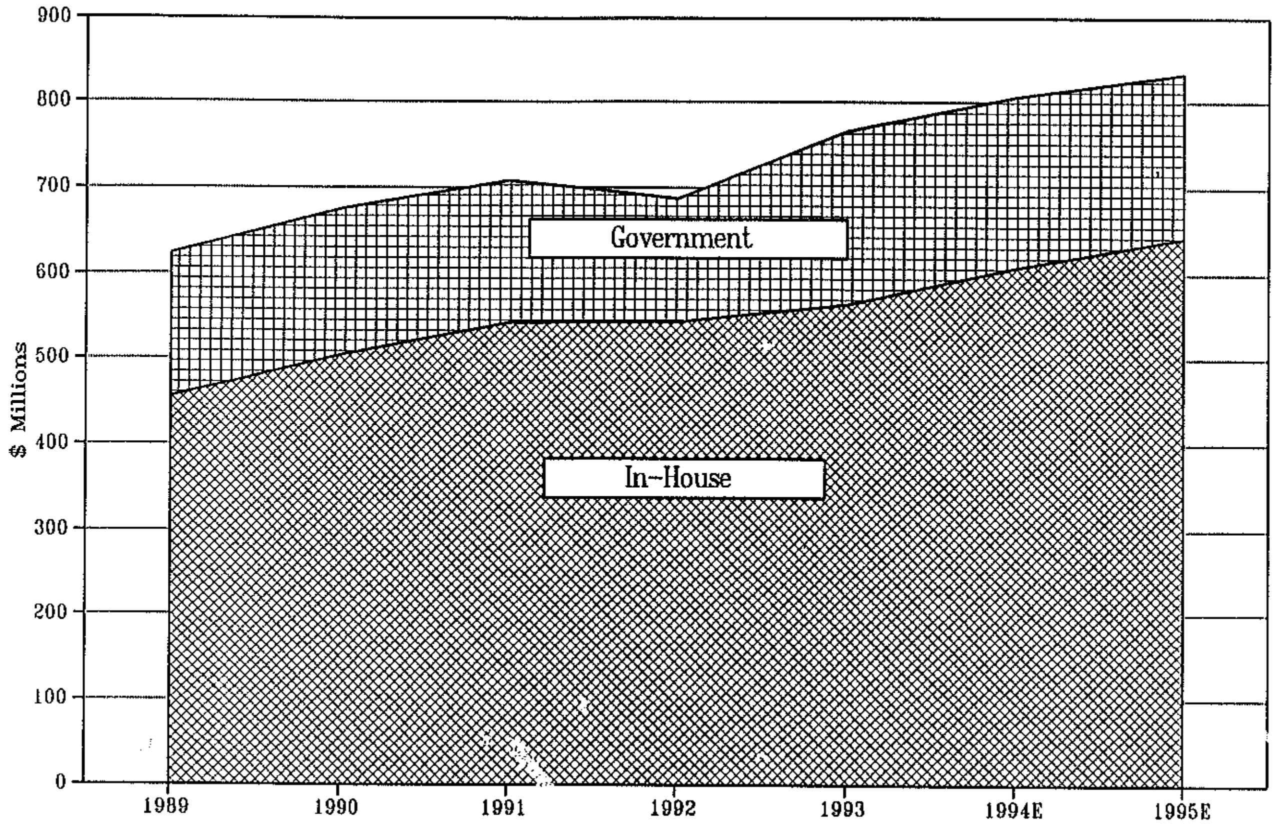
This section presents various measures of economic performance of the U.S. optoelectronics companies responding to the BXA survey. Research and development (R&D), shipments, employment, and financial measures are all presented. In most cases, information is provided for the 1989-1992 period, with forecasts made for 1993 through 1995. The overall performance of the industry on these measures is a major determinant of its international competitiveness as well as its ability to continue to produce and develop technologies for use in next generation weapons systems.

Research & Development

Companies were asked to report their annual expenditures on optoelectronics-related research and development for the period 1989-1992, and to project their expenditures for 1993-1995. The results are presented in the table below. In 1991, the surveyed firms (113 establishments reporting) spent over $882 million on optoelectronics-related R&D. Figures for other years must be carefully interpreted, since not all companies provided figures for every year. As with other quantitative portions of the survey, small firms (those with less than 50 employees) were required to report their R&D expenditures for 1991 only. In addition, some companies were unable to forecast their R&D spending for all or part of the 1993-1995 period, while other companies did not have records of historical (1989-1990) spending. Some companies were unable to provide any information on optoelectronics-related R&D at all, particularly large, diverse manufacturers who were unable to separate R&D by technology area.

Sixty-five establishments provided a complete picture/forecast of their R&D spending for the entire 7-year period; these data were used to identify any trends in R&D spending, as presented in Figure IV-1. As can be seen from the graph, R&D increased between 1989 and 1991, but then fell slightly in 1992 from 1991 levels. Predictions for 1993-1995 show an increasing trend. Although the decline is small, the lagging economy in 1991 may have left fewer funds available for R&D in 1992, coupled with the start of defense budget cuts affecting federal-funded R&D.

Figure IV-1
R&D Expenditures
(65 Establishments Reporting)



Source: BXA Optoelectronics Survey

In addition, R&D spending as a percentage of total sales was calculated, using the financial statements provided by the respondents to the BXA survey. On average, firms spent about 11 percent of their revenues on research and development; this percentage was essentially unchanged over the 1989-1995 period. The range was great, with one firm spending less than one percent of sales revenue on R&D, to several (start-up) firms that spent more than their revenues in certain years. Of the 55 establishments providing a response for 1991, eight spent less than five percent of sales on R&D; 25 spent between five and 10 percent; 11 spent between 10 and 15 percent, eight spent between 15 and 25 percent, and five spent over 25 percent (four of which were over 50 percent) (See Figure IV-2). In general, however,

optoelectronics firms in our survey spent a much greater percentage of sales on R&D than the average for U.S. industry as a whole, which was 3.6 percent in 1991.[1]

From Table IV-1, the survey respondents appear to be optimistic about their future R&D spending, projecting steady increases for 1993-1995. Their actual R&D spending also increase over the 1989-1991 period, with a slight decline in 1992 due partly to a fall in government-funded R&D. This decline in government R&D that year may be a result of the end of the Cold War and corresponding decline in the defense budget, including defense-related R&D. Their projections for future Government R&D show that they expect a steep increase beginning in 1993, perhaps as a result of the change in Governing parties to one that has espoused a firm belief in the role of the federal government (and government money) in funding research in critical technology areas or in the belief that money formerly channelled into developing and producing weaponry will now be available for "dual-use" R&D.

There also appears to be a trend toward increased customer funding of R&D in the actual figures (1989-1992), albeit customer funding still accounts for a relatively small proportion of total R&D spending. The increase could be a reflection of the trend toward strategic partnerships/strategic alliances among vertical groups of firms. One example of such a strategic alliance in the optoelectronics sector is Motorola's small equity investment in In-Focus Systems. In Focus produces liquid crystal displays that are used in Motorola's line of cellular phones and other consumer/business products. Subsequently Motorola and In Focus formed a 50-50 joint venture, Motif, to develop technology to manufacture improved passive liquid crystal displays.[2]

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[1] "R&D Scoreboard," Business Week, June 28, 1993, p. 102.

[2] "A New Motif for Flat Screens", Photonics Spectra, December 1992, p. 72.

TABLE IV-1
RESEARCH & DEVELOPMENT EXPENDITURES*
1989-1995 (projected)
(In $ Millions, with 113 Establishments Reporting)

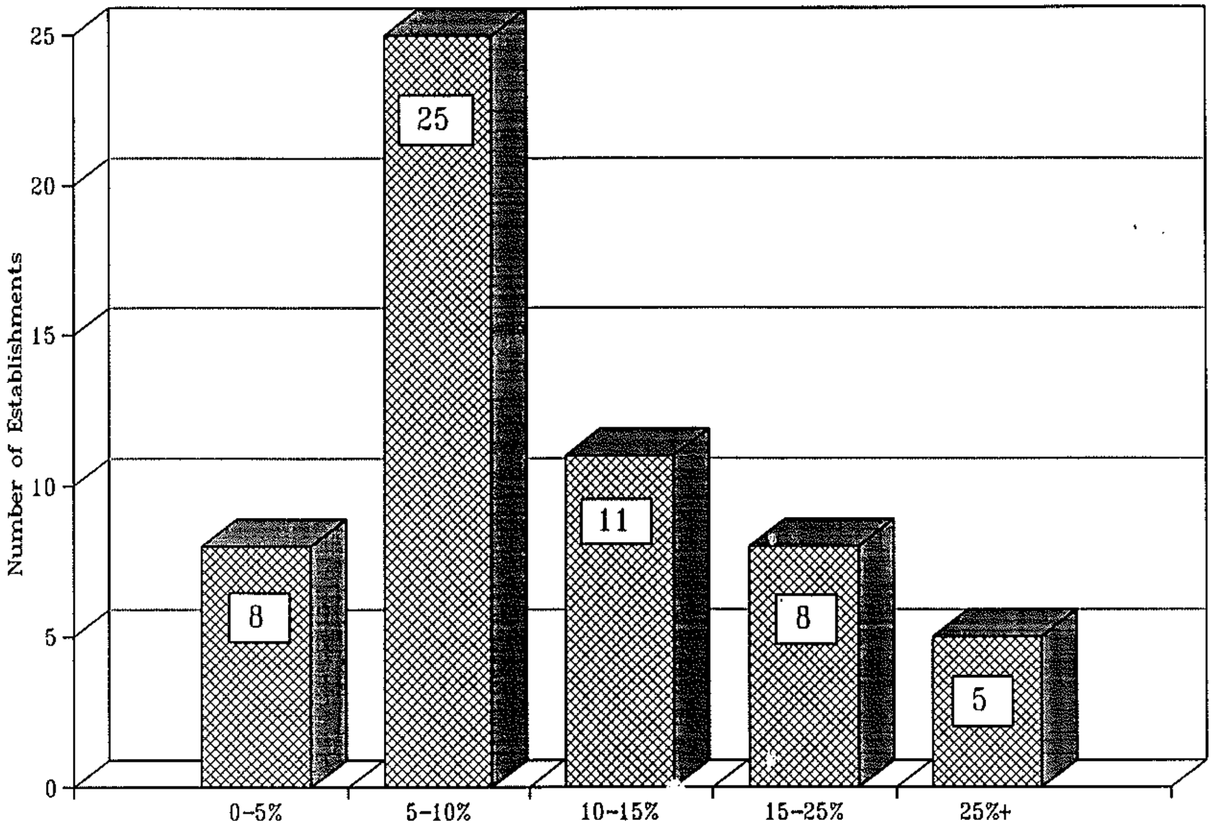
SOURCE OF FUNDING (# Companies)	1989	1990	1991	1992	1993E	1994E	1995E
In-House (113)	$533.5	$598.9	$651.3	$615.7	$619.8	$643.1	$673.6
Federal Gov't (49)	189.7	200.1	204.8	178.6	219.7	207.8	195.4
Customer (31)	8.7	11.6	15.3	17.1	20.4	18.8	14.5
Joint Venture (6)	0.5	2.5	7.8	0.4	5.2	8.0	9.0
Other (11)	3.2	2.2	3.5	3.0	2.6	2.6	3.0
TOTAL	$735.5	$815.3	$882.4	$814.8	$867.6	$880.3	$895.5

* Note that figures for 1991 are inflated by the inclusion of small businesses, and that not all respondents provided data for all years, particularly forecasts.

Source: BXA Optoelectronics Survey

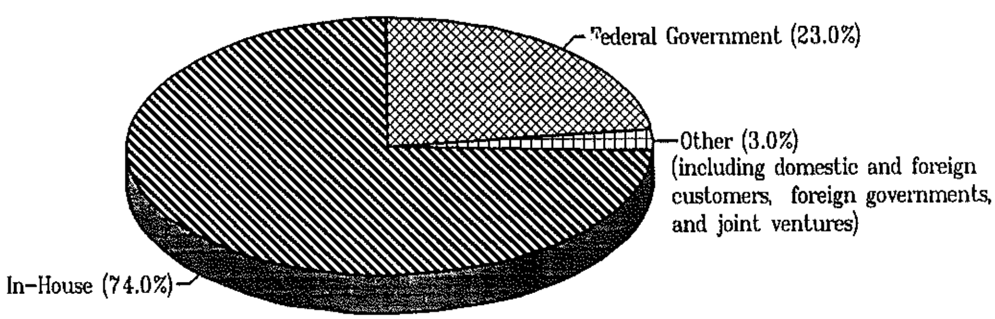
R&D spending was also broken down into several funding sources: in-house, federal government, state/local government, customer, joint venture, and other. Not surprisingly, most R&D spending is accounted for by in-house funds (see Figure IV-3). In 1991, the 113 establishments themselves funded $651 million, or 74 percent, of the total R&D. The federal government accounted for the second greatest amount of R&D funds, with $205 million in 1991 (23 percent). The remaining few percentage points of total R&D spending were accounted for by funding provided by customers ($15 million), and negligible amounts

Figure IV-2
R&D Spending as a Percentage of Sales
(55 Establishments Reporting)



Source: BXA Optoelectronics Survey

Figure IV-3
Sources of R&D Funding (1991)



Source: BXA Optoelectronics Survey

from other sources (including foreign governments, joint ventures, and R&D partnerships). Only one company reported receiving R&D funds from a state or local government in 1991. Sixteen establishments received funding from a foreign source in 1991; of these 16, the average percentage of total funding from the foreign source was just over 20 percent.

-- Government Funding of R&D

Government-funded R&D was further broken down by originating agency, as shown in Table IV-2.

TABLE IV-2
GOVERNMENT-FUNDED RESEARCH & DEVELOPMENT
BY FUNDING ORGANIZATION*
1989-1995 (projected)
(In $ Millions, with 49 Establishments Reporting)

SOURCE OF FUNDING (# Companies)	1989	1990	1991	1992	1993E	1994E	1995E
Department of Defense/ Unspecified (25)	$122.0	$120.0	$116.6	$107.8	$145.6	$135.1	$128.6
ARPA (23)	4.5	6.7	9.0	22.5	21.7	11.4	6.8
Armed Services (Navy, Army, Air Force) (26)	48.1	55.3	57.5	33.3	38.1	46.6	45.6
NASA (9)	10.7	12.4	15.0	8.0	5.9	5.2	6.0
DOE/National Lab (7)	2.4	1.6	1.5	0.7	0.3	0.1	0.1
NIH (4)	0.6	0.6	1.1	1.2	1.0	1.2	0.5
NSF (3)	0.3	0.4	0.4	0.3	0.3	0.4	0.2
NIST (4)	--	--	--	0.9	3.1	3.3	2.9
OTHER (6)	1.4	2.0	2.2	2.4	3.6	4.5	4.8
TOTAL	$189.9	$198.8	$203.4	$177.2	$219.6	$207.8	$195.4

* Note that figures for 1991 are inflated by the inclusion of small businesses, and that not all respondents provided data for all years, particularly forecasts.

Source: BXA Optoelectronics Survey

Defense organizations -- including the Advanced Research Projects Agency (ARPA), the various Armed Services, and other Department of Defense agencies -- were responsible for the vast majority of Government-funded optoelectronics-related R&D among surveyed firms, accounting for nearly 90 percent of the total in 1991. The only major non-Defense funding organization was the National Aeronautics and Space Administration (NASA), which accounted for about seven percent of total Government-funded R&D in 1991. Commercially-oriented government organizations, including the National Science Foundation (NSF) and the National Institute of Standards and Technology (NIST), accounted for a negligible percentage of the total.

NIST is a small, but growing, source of Government-funded R&D. Its Advanced Technology Program (ATP), which was launched in 1990, provides matching funds to U.S. businesses or consortia to commercialize significant new scientific discoveries and to refine manufacturing technologies. Projects are selected based on their technical merit, as well as their potential for broad commercial and economic benefits for the nation as a whole. Since its inception, a number of projects funded through ATP have involved optoelectronics, including flat panel displays, LEDs, optical memories, and many more. ATP's funding has increased steadily in its few years of existence, and there are proposals to increase it much more in the future. If these proposals are adopted, the federal share of non-defense oriented research could increase substantially from its current modest level.

As with total R&D funding, Government-funded R&D is down somewhat in 1992 from 1991 levels, mostly due to declines in Department of Defense and Armed Services funding. This is perhaps related to the end of the Cold War. Projections for the future are uncertain; many firms were unsure of the status of funding. With the increase in emphasis on "dual-use" technologies, of which optoelectronics is surely one, government-funded R&D will likely increase.

-- Focus of R&D

Finally, R&D expenditures were broken down by the firms' objectives: basic research, applied research, process development, or product development. Basic research was defined as that which is original and for the purpose of the advancement of scientific knowledge,

with no specific immediate commercial objectives. Applied research is also directed toward discovery of new scientific knowledge, but has in addition specific commercial objectives for products or processes. Process and product development involve the systematic use of knowledge. Over half of the total R&D money spent by the surveyed firms in 1992 was devoted directly to product development. About thirty percent of expenditures went toward applied research. Process development accounted for about 15 percent of total R&D expenditures, and only about five percent of R&D was classified as "basic." There do not appear to have been major shifts in these percentages over the 1989-1992 period, and shifts are not foreseen for the years 1993-1995.

-- R&D by Optoelectronic Product Groups

R&D was also examined after dividing the surveyed establishments into groups that are involved in similar optoelectronics product categories in order to determine differences among the various groups. Table IV-3 highlights the differences among 10 different optoelectronics product groups. From the table, it can be seen that telecommunications firms are responsible for a disproportionate share of all research and development. While they account for only 20 percent of all establishments, they account for 37 percent of total R&D. Moreover, they spend on average nearly 16 percent of sales revenue on R&D, compared to the average of 11.6 percent for the optoelectronics database as a whole. This R&D was overwhelmingly funded through in-house funds, with government funding accounting for only one percent of the total, compared to the average of 23 percent of R&D derived from government funds for the optoelectronics database as a whole.

Companies active in optical information systems and optoelectronics components also account for a disproportionate share of total R&D. As with telecommunications companies, they receive less than average amount of R&D funds from government sources. However, they spend slightly less than average on R&D as a percentage of sales than the database as a whole, indicating that their sales volumes are larger than average.

On the other hand, display companies account for about 19 percent of all establishments, but a tiny three percent of total R&D. This can be explained by the fact that many display

companies are very small operations with limited ability to fund extensive R&D projects. They do spend a very large share of sales revenue on R&D, a full 20 percent in 1991. This is in part possible because these companies heavily on government funds to support R&D (30 percent of their total R&D funds).

TABLE IV-3
R&D BY MAJOR PRODUCT CATEGORY:
1991

PRODUCT GROUP	# of Estabs.*	% of All Estabs.	R&D ($Millions)	% of All R&D	R&D as % of Sales Revenue	% of R&D Gov't-Funded
A. TELECOMMUNICATIONS	23	20%	$322.7	37%	14.6%	1%
B. OPTICAL INFO SYSTEMS	9	8%	101.7	12%	9.1%	17%
C. DISPLAYS	21	19%	26.1	3%	20.0%	30%
D. INDUSTRIAL EQUIPMENT	17	15%	60.1	7%	9.2%	3%
E. LASERS	16	14%	67.6	8%	15.7%	20%
F. SURVEILLANCE	4	4%	7.1	1%	6.3%	1%
G. DEFENSE	33	29%	253.6	29%	7.9%	58%
H. CONSUMER PRODUCTS	3	3%	61.4	7%	NA	10%
I. OPTOELECTRONIC COMPONENTS	18	16%	238.4	27%	10.1%	8%
ALL GROUPS	113	100%	882.4	100%	11.6%	23%

* Note that some establishments participate in more than one product category; for this reason, sum of the product categories exceeds that of the optoelectronics database as a whole.

Source: BXA Optoelectronics Survey

The defense category is a diverse group of establishments that produce a wide variety of optoelectronics-related products. The unifying feature of this group is that all of its members are heavily dependent on defense for business (more than 50 percent of sales). These establishments account for 29 percent of all establishments responding to the survey, and a

similar percentage of all R&D by surveyed firms. However, they account for over two-thirds of all government funded R&D. In fact, government funds account for the bulk of their total R&D spending (58 percent). With regard to R&D as a percent of sales, these companies are below average at 7.9 percent; again, this is due in part to the large sales volumes of the companies in this group.

-- Impact of Defense Cuts on R&D

Firms were asked about the impact of defense budget cuts on their optoelectronics-related R&D. Forty-five establishments reported that they expected little or no impact from defense budget cuts on their R&D operations. Most of the 45 did not participate in defense markets; one such firm hypothesized that defense budget cuts may in fact help them if Government R&D funding were channelled into non-defense areas in which they participate (e.g., NIH funding increases).

Thirty establishments reported that defense budget cuts will likely have a significant effect on the R&D operations. A wide variety of optoelectronics products were mentioned as being affected, including cathode ray tubes, flat panel displays, military communications systems, and rotary and nodding scanners. Other frequently mentioned product categories that will be affected by defense budget cuts include optical sensor equipment such as FLIR and night vision; CCDs and focal plane arrays; other photodetectors; optical munitions guidance equipment; and solid state lasers.

A few firms did not expect defense budget cuts to affect their particular optoelectronics product lines (e.g., laser-based sensors). Another company involved in fiber optic military communications equipment said that defense budget and personnel cutbacks could benefit them because advances in this technology would be needed to compensate for loss of military manpower.

Firms were also asked to discuss the convertibility of their defense-related optoelectronics research and development to commercial/civilian applications. Only a few of the very defense dependent establishments reported no possibility of conversion. Most respondents reported that there was a great deal of applicability of their defense R&D to the commercial

sector. Many supply similar or identical products to both military and non-military applications; others said that while their products were currently geared toward defense uses, they could be dual-use (e.g., fly-by-light for use in civilian aerospace applications; military sensor work converted to production automation, industrial security, or medical sensors; use of FLIRs for border control, drug interdiction, and law enforcement).

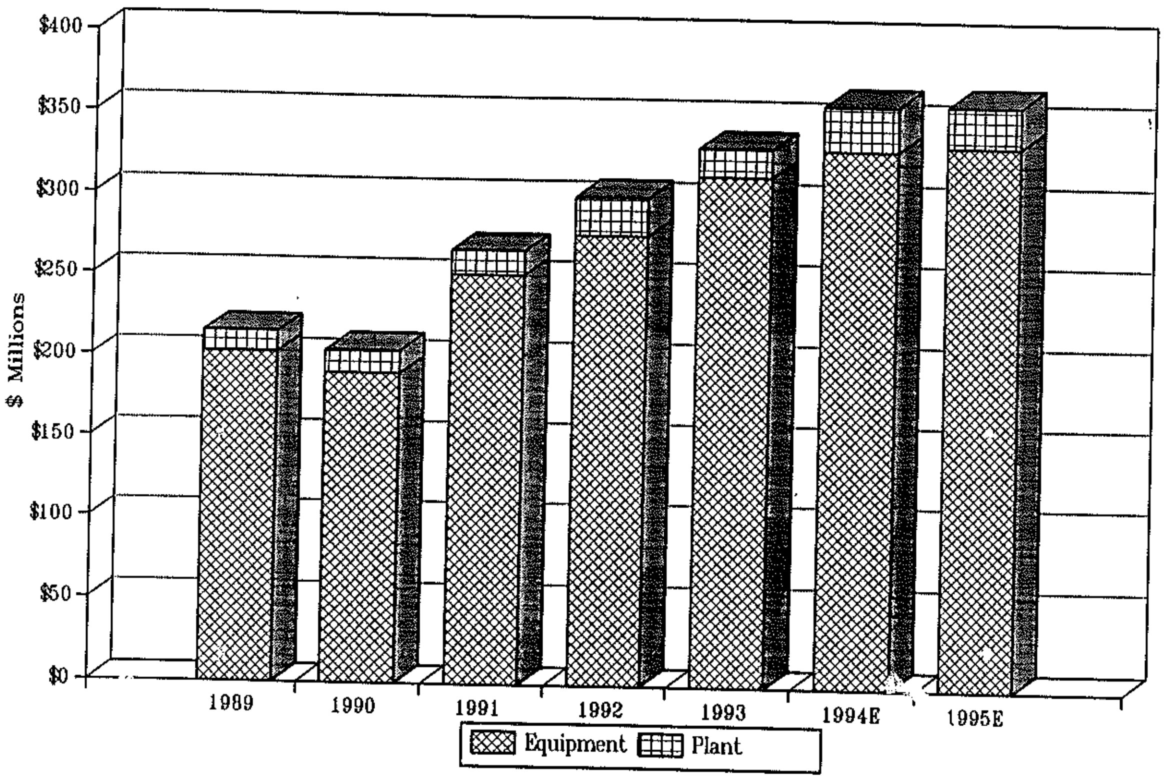
According to the respondents, the biggest concern/problem to converting their R&D from military to commercial applications was financial. Companies receiving funding from the government for the most part received it from military organizations; they anticipate that defense spending cuts would result in potentially dual-use projects being terminated. Firms reported that they could not afford to maintain the same level of funding of R&D for commercial applications without government support. As one firm put it, "the DOD pays for new product development; commercial customers do not." Other barriers to conversion mentioned include developing a product that can be produced for a cost effective price, the time to market, low volume approach, and the differences in military and commercial accounting practices and corporate cultures.

Investment in Plant and Equipment

Seventy-one survey respondents provided information on their capital investments in plant and machinery and equipment. Fifty-seven respondents provided this information for the entire 1989-1995 period, and their responses were used to discern trends in investment for the optoelectronics industry as a whole. Their aggregated responses are displayed in Figure IV-4.

Investment in plant has followed a generally increasing trend, with a large jump between 1991 and 1992, due primarily to major investments by one or two firms. It should be noted that telecommunications firms, which tend to be large operations, account for the majority of investment in plant (nearly 75 percent in 1991), and almost half of the investment in machinery and equipment. Forecasts for the future show a continuation of the increasing trend. The bulk of capital investment is in machinery and equipment. Capital investment in machinery and equipment has been more volatile over the 1989-1992 period; forecasts for the future show a generally increasing trend.

Figure IV-4
Investment in Plant and Equipment
(57 Establishments Reporting)



Sou :e: BXA Optoelectronics Survey

Note: 34 establishments pro ded plant investment data; 56 provided equipment inves ment figures.

Despite t trend toward increasing capital investment, total inv n nt in optoelectronics plant and equipment in the United States is relatively low when compa ed with some foreign competitors. While detailed statistics are not readily available, anecdotal information serves as a stark example: one Japanese company invested $2 billion in flat panel display facilities in 1991.[3] In contrast, the 12 U.S. display producers in the BXA survey spent a total of only $456 thousand in plant (by two firms) and $6.5 million in equipment in 1991. Total

[3] Report of the Japan Technology Evaluation Center, Loyola College in Maryland, June, 1992.

investment in plant and equipment captured by the BXA survey was only $302 million that year.

Financial Performance

Survey recipients were also asked to provide information on their firms' financial performance; they provided their income statements for the 1989-1992 period and forecasts for 1993 through 1995 as well as balance sheet information for fiscal year 1991. Companies were asked to provide income statement data on both a corporate and optoelectronic divisional level. Some large companies were unable to provide optoelectronic divisional information, while small companies in general reported the same information for both categories. The financial tables appearing in this section represent the optoelectronic divisions of medium-sized and large companies, combined with the corporate information for those companies whose primary line of business was optoelectronics-related. Once again, companies with 50 or fewer employees were only required to provide data for 1991, and others were unable to provide complete information for all years (particularly for 1993-1995).

In general, the optoelectronics firms participating in the OIRA survey show some financial weaknesses, particularly in the display and laser sectors. However, the financial ratios and profitability for optoelectronics are about the same, and in some cases better, than for the manufacturing sector as a whole.

-- Sales and Profitability

Table IV-4 below presents net sales (or revenues), operating income before taxes, and pretax profitability (calculated here as operating income/net sales) for the optoelectronics companies or divisions. Only those companies providing data for all years are included in this table so that any trends would be discernible; this reduced the number of respondents to 38. Thus, there is a bias toward medium and larger firms, since small firms were not required to provide data for all years.

Aggregated sales by the surveyed firms have consistently risen over the 1989-1992 period, and are forecast by the survey respondents to continue to increase. Sales in 1992, however,

were only about five percent higher than the previous year, a smaller increase than the more than 12 percent increase in each of the two previous years. Aggregated profits (operating income) of the surveyed firms actually declined last year from 1991 levels, after posting strong gains in 1990 and 1991. Again, the firms are optimistic about the future, predicting more than 30 percent increases in profits in 1993, 1994, and 1995.

TABLE IV-4
SALES, OPERATING INCOME, AND PROFITABILITY
(38 Responses)

	1989	1990	1991	1992	1993	1994	1995
NET SALES ($ Millions)	$4412	$4974	$5576	$5873	$6430	$7134	$7921
% CHANGE FROM PREVIOUS YEAR	--	+12.8%	+12.1%	+5.3%	+9.5%	+10.9%	+11.0%
OPERATING INCOME ($ Millions)	$85.2	$106.9	$149.8	$136.4	$188.2	$247.4	$333.1
% CHANGE FROM PREVIOUS YEAR	--	+25.5%	+40.2%	-9.0%	+38.0%	+31.4%	+34.6
PROFITABILITY (O.I./SALES)	**1.9%**	**2.1%**	**2.7%**	**2.3%**	**2.9%**	**3.5%**	**4.2%**

Source: BXA Optoelectronics Survey

Pretax profitability, calculated here as the aggregated operating income of the survey respondents as a percentage of their aggregated sales, was relatively stable over the 1989-1992 period at about two percent of sales. For comparison, the average profitability for all durable manufacturing was slightly over one percent in 1991 and about three percent for the first three quarters of 1992 based on data collected by the Census Bureau.[4] Once again, the inherent optimism of the survey respondents is evident in their predictions for profitability in the future.

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[4] "Financial Ratios for Manufacturing Corporations, Third Quarter 1992," U.S. Department of Commerce, Economic and Statistics Administration, Office of Business Analysis.

We also calculated profitability for each survey respondent individually; this information is broken down by profitability range and average in Table IV-5. Whereas the figures in the Table IV-4 above tend to be heavily influenced by the larger companies (with larger sales and income), Table IV-5 presents profitability figures in which each company is treated equally, regardless of size. It also makes it possible to use all survey responses for a given year, despite the fact that the number of responses varies by year.

TABLE IV-5
AFTER TAX PROFITS

Percentage of Survey Respondents :	1989	1990	1991	1992	1993	1994	1995
> 10% Profitability	14%	17%	10%	10%	6%	9%	19%
0-10% Profitability	57%	48%	57%	58%	66%	72%	71%
<0% Profitability	30%	35%	34%	32%	29%	18%	10%
Average Profitability (Number of Survey Responses)	**4.2%** (44)	**2.4%** (47)	**3.1%** (62)	**2.9%** (41)	**4.4%** (41)	**5.6%** (33)	**6.8%** (31)

Source: BXA Optoelectronics Survey

About one third of the companies lost money (negative profitability) in any given year between 1989 and 1992, while the majority earned between a zero and ten percent return on sales. About 10 percent of the respondents achieved a greater than 10 percent return on sales.

The optimistic outlook for the future is also evident in Table IV-5. The percentage of companies losing money is forecast to decline in 1994 and 1995. Surprisingly, the number of companies predicting exceptionally high profit margins (more than 10 percent) also declines in the future.

-- Profitability by Optoelectronic Product Group

Finally, profitability was examined by optoelectronic product groups to determine if there were meaningful differences among the various subsectors of this industry. These data (for 1991 only) are presented in Table IV-6. The strongest-performing group was communications, with an average profitability of 7.5 percent. The communications sector was bipolar, however, with strong gains posted by six companies outweighing losses by eight companies.

TABLE IV-6
PROFITABILITY BY OPTOELECTRONIC PRODUCT GROUPS: 1991
(OPERATING INCOME AS PERCENTAGE OF NET SALES)

	# Of Estabs.	Average Profit	% < 0%	%0-5%	%5-10%	% > 10
A. COMMUNICATIONS	18	7.5%	44%	17%	5%	33%
B. INFORMATION SYSTEMS	5	3.1%	0%	40%	20%	40%
C. DISPLAYS	15	1.5%	47%	33%	7%	13%
D. INDUSTRIAL EQUIPMENT	12	3.0%	8%	50%	25%	17%
E. LASERS	16	-0.4%	38%	31%	31%	0%
F. SURVEILLANCE	4	INSUFFICIENT DATA				
G. DEFENSE	15	3.2%	7%	20%	40%	33%
H. CONSUMER	--	INSUFFICIENT DATA				
I. COMPONENTS	14	1.1%	43%	29%	14%	14%
OVERALL AVERAGE	**73**	**4.9%**	**35%**	**24%**	**22%**	**19%**

Source: BXA Optoelectronics Survey

Three product groups (information systems, industrial equipment, and the defense group) posted virtually identical profitability ratios, at around 3 percent of net sales. Few of the companies in these sectors posted losses in 1991. Three product groups had below average profitabilities, including the laser category; the 16 companies in this group actually averaged a net loss. For comparison, according to Census figures, the profitability of non-electrical machinery producers (which includes industrial and medical lasers) averaged -0.9 percent in

1991.[5] None of the laser companies returned a profit in excess of 10 percent of sales. The display group showed profit margins of only 1.5 percent of sales, with half of the companies losing money in 1991. Similarly, the optoelectronic components group had a below average profitability of 1.1 percent, with six out of 14 companies posting losses in that year. In contrast, Census figures show that the profitability of the electrical/electronic equipment industries averaged 3.7 percent in 1991, and the instruments sector averaged 8.4 percent that year.[6] Each category contains some optoelectronics products.

-- Balance Sheet

Key financial performance ratios were calculated for the survey respondents that provided balance sheet information for fiscal year 1991 (See Table IV-7). The information is presented for the optoelectronics database as a whole, and also for the individual product groupings.

The current ratio, defined as current assets (including cash and accounts receivable) divided by current liabilities (including short term debt, accounts payable, and the current portion of long term debt) is a common measure of a company's ability to pay its debts quickly. The higher the ratio, the more assurance exists that debts can be paid. It is generally accepted in the business community that the current ratio should exceed 2:1 for a financially sound company. For the optoelectronics database, the current ratio averaged a healthy 3.9:1. However, 42 out of the 76 respondents had current ratios less than 2; these companies were offset by a few companies with very high current ratios (very low or no liabilities). For comparison, the average current ratio for all durable manufacturing was 1.5 in 1991, so optoelectronics companies appear to be doing better than average.[7]

By sector, three product groups -- information, surveillance, and consumer products -- have current ratios below the 2:1 minimum. It should be noted that in each of these cases, the

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[5] Ibid.

[6] Ibid.

[7] Ibid.

number of establishments responding is small, so averages should be viewed with caution. The display group has a current ratio of 2:1 exactly, with more than half of the companies below the minimum level. This sector is thus only marginally financially sound according to this test. However, some product groups with current ratio averages well above the 2:1 level have a number of individual companies below that level. For example, although the average current ratio for communications is 2.74, two-thirds of the companies had ratios below 2, as did 12 out of 19 defense group respondents and seven out of 13 components respondents, seven out of 16 industrial equipment producers, and four out of 14 laser producers.

TABLE IV-7
FINANCIAL PERFORMANCE RATIOS (FY 1991)

PRODUCT GROUP	# of Estabs.	CURRENT RATIO	DEBT RATIO	CURRENT LIABILITIES/ NET WORTH
A. COMMUNICATIONS	15	2.74	0.16	1.04
B. INFORMATION	6	1.93	0.21	1.74
C. DISPLAYS	13	2.00	0.34	2.50
D. INDUSTRIAL EQUIPMENT	16	6.65	0.19	1.06
E. LASERS	14	6.02	0.18	1.33
F. SURVEILLANCE	4	1.97	0.25	1.65
G. DEFENSE	19	3.30	0.23	0.81
H. CONSUMER	3	1.50	0.28	3.05
I. COMPONENTS	13	2.39	0.19	0.80
AVERAGE, ALL GROUPS	**76**	**3.90**	**0.21**	**1.36**

Source: BXA Optoelectronics Survey

The debt ratio measures the percentage of a company's assets financed through debt; lower is usually better. In this report, the debt ratio was calculated as short term and long term debt divided by total assets. The average debt ratio for the 76 companies responding was 21

percent; about one-third of the respondents had debt in excess of 25 percent of assets. The average debt ratio for all durable manufacturing was about 27 percent in 1991.[8] By product group, the displays group is particularly burdened by high debt in comparison to assets, with a debt ratio of 34 percent. In contrast, the communications sector has a relatively low debt ratio. The comparable figures for some major industry sectors that include optoelectronics products are: non-electrical machinery, 25 percent; electrical/electronic equipment, 28 percent; and instruments, 27 percent.[9]

Finally, current liabilities were compared with each survey respondent's net worth (equity). This comparison measures the funds temporarily risked by creditors (current liabilities) with the funds invested in the company by the owners (equity). The smaller the net worth and the larger the liabilities, the less security exists for creditors. In general, firms with current liabilities in excess of two-thirds of net worth are considered poor credit risks. For the optoelectronics database as a whole, current liabilities exceeded net worth by 136 percent. Thirty-five of 76 respondents (47 percent) exceeded the 66 percent threshold. Every product category averages above the 66 percent level, with the defense and components group better off than most. The display group, again, appears to be a greater risk to creditors, with current liabilities averaging 250 percent of net worth. Care should be taken in interpreting the averages for the consumer products and surveillance groups since the number of respondents is low.

Production

Because optoelectronics is a technology that pervades multiple and diverse products, there are little data on overall U.S. optoelectronics shipments for useful comparison purposes. However, Japan's Optoelectronics Industry and Technology Development Association (OITDA) has conducted annual assessments of the Japanese optoelectronics industry since 1980. The product codes used in the BXA Optoelectronics survey were loosely modelled on OITDA's data format in order to make useful comparisons. Unfortunately, this was not

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[8] Ibid.

[9] Ibid.

possible in many cases due to a shortage of data. It should be noted that many survey respondents, especially large companies with multiple divisions, were unable to report shipment information for just optoelectronic categories.

-- Shipments

One hundred and two establishments provided information on the value of shipments of optoelectronics-related products for the 1989-1995 period, with 66 establishments providing shipment data for all seven years. Fourteen companies qualified for the small business exemption and provided 1991 data only. The remaining companies provided shipment information for only a part of the time period for a variety of reasons, most often due to incomplete records.

BXA's survey captured nearly $6 billion in domestic optoelectronics shipments in 1991. The control group of companies providing shipment information for all years shows that total optoelectronics shipments fell by about eight percent in 1990 from 1989 levels. The drop in 1990 is also evident in the data figures for all companies responding. Since that time, however, shipments have rebounded and companies expect the upward trend to continue through 1995 (See Figure IV-5).

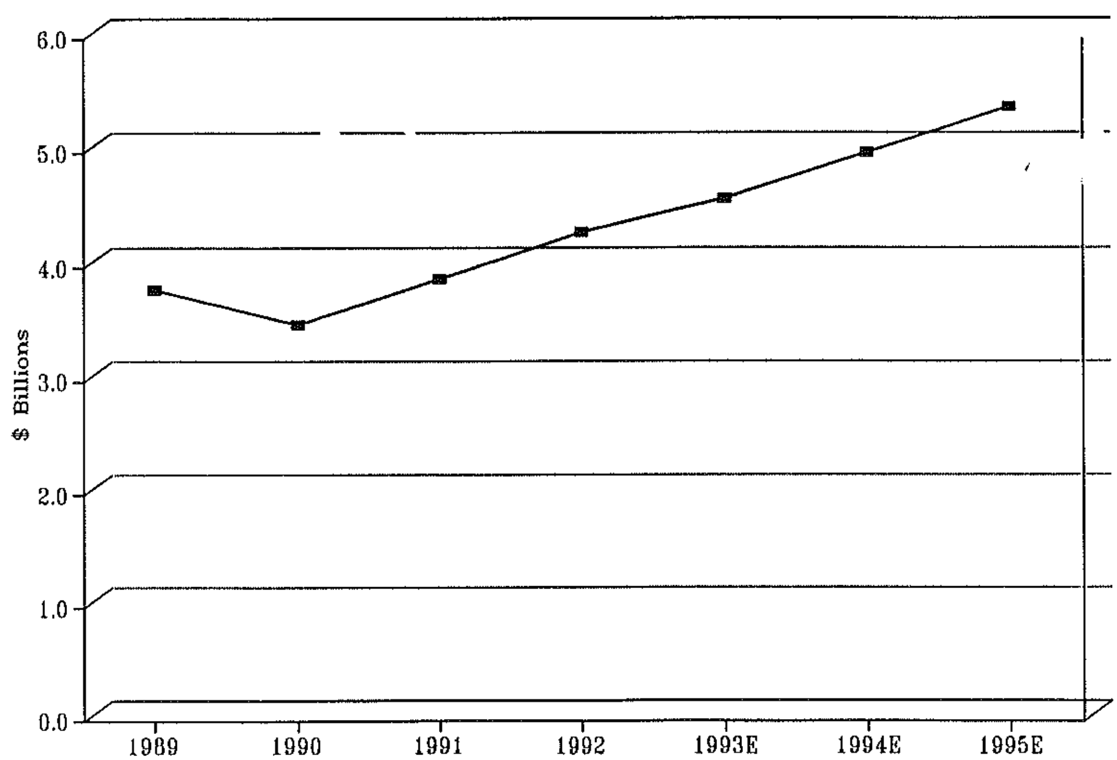
Shipments by broad product group are presented in Table IV-10. As in other report sections, for this analysis the companies in the BXA survey were broadly classified into these categories in order to discern trends in individual product categories. It should be noted that some companies are included in more than one category if they were a major participant in more than one optoelectronic product category; for this reason, the sum of shipments in Table IV-9 does not match that of Table IV-8.

TABLE IV-8
OPTOELECTRONIC PRODUCT SHIPMENTS
1989-1995 (projected)
(In $ Millions)

	1989	1990	1991*	1992	1993E	1994E	1995E
All Reported Shipments (102 Estabs.)	$5259	$4993	$5917	$4944	$5246	$5503	$5944
Shipments by Those Reporting all Years (66 estabs.)	$3772	$3467	$3941	$4262	$4556	$5015	$5378
% Change over Previous Year (66 Estabs.)	--	-8.1%	+13.7%	+8.1%	+6.9%	+10.1%	+6.4%

Source: BXA Optoelectronics Survey

Figure IV-5
Optoelectronics Shipments
(66 Establishments Reporting)



Source: BXA Optoelectronics Survey

TABLE IV-9
SHIPMENTS BY PRODUCT GROUP
1989-1993 (projected)
(In $ Millions, with 66 Establishments Reporting)

PRODUCT GROUP (# of Estabs)	1989	1990	1991	1992	1993E	1994E	1995E
Communications (16)	$1158	$1325	$1352	$1480	$1662	1906	$2168
Optical Information (8)	$1714	$1383	$1629	$1798	$1926	$2133	$2178
Displays (7)	$88	$87	$89	$82	$99	$116	$149
Industrial Equipment (20)	$739	$681	$777	$835	$959	$1049	$1098
Lasers (15)	$283	$284	$321	$334	$363	$388	$469
Surveillance (2)	INSUFFICIENT DATA						
Defense (17)	$478	$401	$478	$456	$478	$506	$517
Consumer (1)	INSUFFICIENT DATA						
Components (20)	$270	$281	$292	$310	$369	$408	$510

Source: BXA Optoelectronics Survey

Communications and optical information shipments make up the largest segment of the BXA sample, in terms of value. The communications sector also showed the greatest growth over the period, with shipments rising nearly 28 percent between 1989 and 1992. These companies expect shipments to continue to increase strongly over the 1992-1995 period. Their estimates for 1995 shipments are 46 percent greater than 1992 shipments. Other sectors showing consistent growth and forecasted growth are lasers and optoelectronic components. The remaining categories, including displays, industrial equipment, optical information equipment, and the defense group, show declines in 1990 over 1989 levels. The display and defense segments also show declines in 1992 from 1991, likely in response to

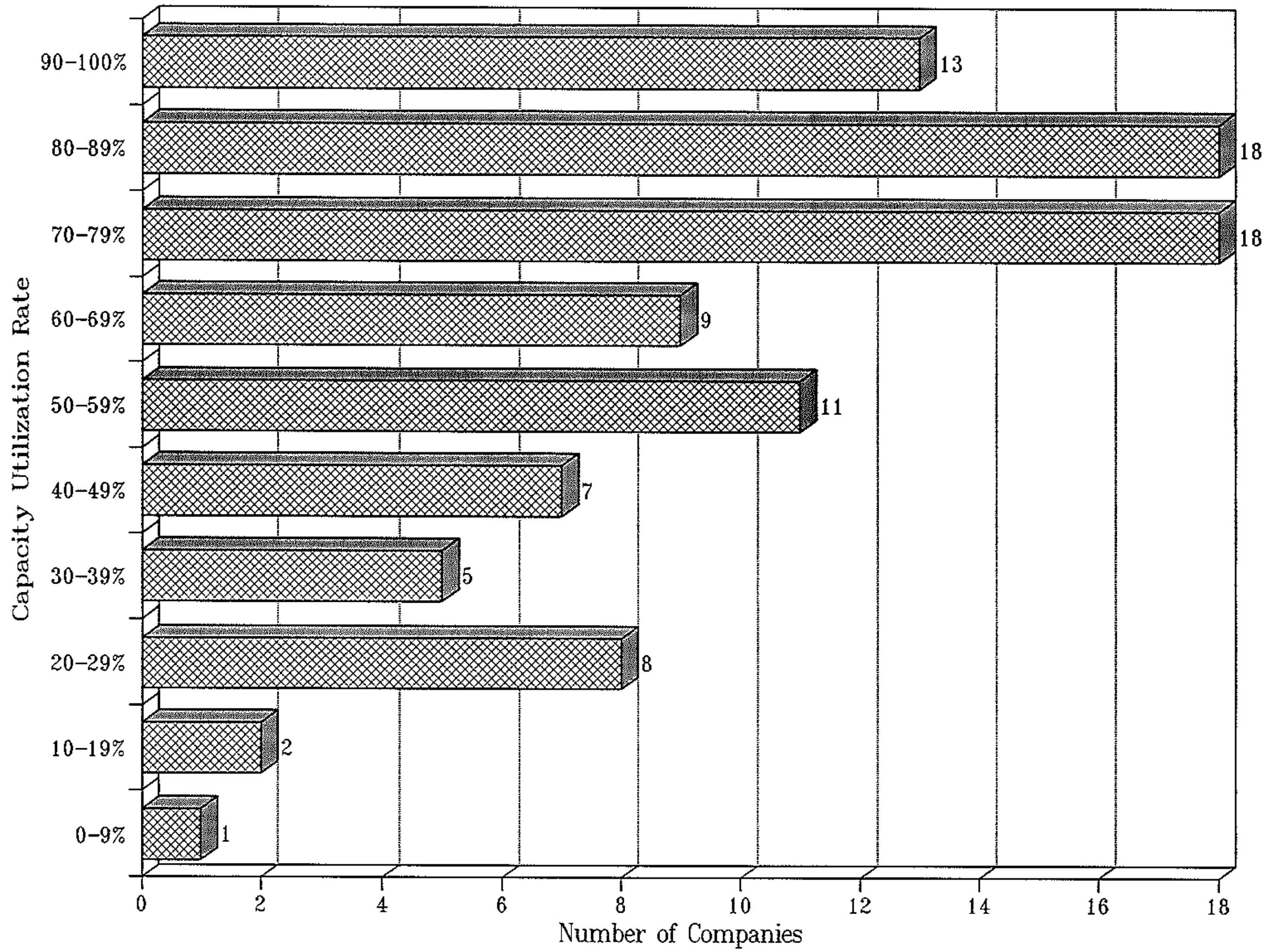
declining military budgets (the U.S. display industry is heavily dependent on defense contracts). However, even these producers are surprisingly optimistic about their shipments prospects.

-- Capacity Utilization

Survey respondents provided information on their capacity utilization rate for 1991; that is, the percentage of their practical capacity that they were using on average during 1991. Practical production capacity was defined as the greatest level of output that an optoelectronics manufacturing establishment could achieve within the framework of a realistic work pattern. Machinery and equipment in place and ready to operate and the present product mix were considered in estimating this rate. Survey responses are summarized in Table IV-10 and Figure IV-6.

The average capacity utilization rate was slightly over 63 percent in 1991, with a range of just 3 percent to 100 percent. About one quarter of the firms in the survey were operating at less than 50 percent of capacity that year. In contrast, the average capacity utilization rate for industrial production as a whole was about 79 percent in 1991, according to Business Week figures (which are based on Federal Reserve/BLS data). Capacity utilization rates varied by optoelectronic product group, with the display and defense groups showing lower than average utilization rates (54.7 percent and 57.5 percent, respectively). Nearly one-half of the display companies and over one-third of the defense group were operating at less than half of their capacity production levels. In contrast, the laser group posted a higher than average capacity utilization rate of over 73 percent, and only one out of 17 laser companies responding was operating at less than 50 percent of capacity. The remaining optoelectronic product group sectors had capacity utilization rates of close to the 63 percent average for all survey participants. Nonetheless, the capacity utilization rates for all the optoelectronics groups, including lasers, were still considerably less than average for all manufacturing sectors (about 79 percent).

Figure IV-6
Capacity Utilization Rate (1991)



Source: BXA Optoelectronics Survey

TABLE IV-10
CAPACITY UTILIZATION RATES & TIME TO REACH CAPACITY: 1991
92 ESTABLISHMENTS REPORTING

Optoelectronics Product Group	# of Responses	Average Capacity Utilization Rate (%)	Range	% of Respondents < 50% Capacity	Time to Reach Capacity (Weeks)	Range (weeks)
Communications	21	63.7%	27-100%	24%	17.8	3-52
Information	10	68.6%	25-100%	20%	16.0	5-39
Displays	15	54.7%	3-95%	47%	14.7	4-52
Industrial Equip.	18	65.7%	3-95%	22%	10.4	1-26
Lasers	17	73.2%	40-100%	6%	11.2	4-20
Surveillance	3	63.0	20-89%	33%	14.7	6-26
Defense	26	57.5%	10-100%	35%	23.5	1-63
Consumer	1	90.0%	--	0%	4.0	--
Components	15	62.5%	3-100%	20%	13.3	6-20
ALL GROUPS	**92**	**63.2%**	**3-100%**	**25%**	**16.9**	**1-63**

Source: BXA Optoelectronics Survey

-- Sourcing

Survey respondents were asked whether they were the sole or single source for any optoelectronic product or technology. While 49 respondents indicated that they were <u>not</u> sole or single source suppliers, 33 respondents said that they were (some for multiple optoelectronic products). Many of these producers manufacture optoelectronic components for use in military systems for which they were the only qualified source. The specific products mentioned are not listed here so as not to disclose the identity of the firms in our survey; however, weapons systems supported include cruise missiles, fighter aircraft, TADS, LANTIRN, Mark 404, Wide Area Mine, and IR Maverick missile. (The next section provides more detail on military systems supported by survey respondents). In addition, some companies considered themselves to be sole source suppliers for commercial optoelectronics products. They participated in particular product/technology niches in which

there were no other competitors, or they held a patent for a particular product, or they produced optoelectronic components to a specific customer's requirements.

Survey respondents were also asked if they relied on any sole or single source suppliers for parts, subcomponents or raw materials for their optoelectronic products. Twenty-nine respondents listed specific examples of essential components for which they are dependent on sole/single sources of supply. One material -- glass -- was by far the most frequently mentioned item. Various types of optical glass were mentioned (e.g., anode glass, glass rod, core glass, cladding glass), but all came from three basic sources: Corning/Dow Corning (U.S.), Schott Glass (Germany and U.S.), and Heraeus Amersil (Germany). It appears that for some types/grades of glass, only one of these companies is a qualified supplier at present. Other components mentioned include diode lasers, photomultipliers, optical fiber, electronic circuits, high reliability LEDs, photodiodes, and optical switches. In most cases, firms indicated that the loss of supplies of these items would halt production until another source could be qualified, often at greatly increased costs.

The companies in the survey relied on a wide range of imported machinery and equipment, parts, subcomponents and raw materials to produce their optoelectronic products. Table IV-11 lists selected foreign-sourced items. In the machinery and equipment category, test and measurement equipment was the most frequently mentioned imported item, the primary source of supply for which was Japan. The reason given for importing was that no U.S. source was available; price was also mentioned.

In the parts, components, and raw materials category, various types of optical glass were again frequently mentioned, with Japan and Germany being the leading suppliers. Also frequently mentioned were various types of ceramic materials (e.g., ferrules, substrates, subassemblies), with Japan again identified as the source of supply with no adequate domestic source. Basic optoelectronic components such as LEDs, photodiodes, photomultipliers, and connectors also received numerous mentions; these items were most often imported because of their lower costs/better quality rather than the lack of a domestic source. In particular, many companies (including U.S. facilities of several Japanese companies) reported that they were dependent on Japanese lasers. In addition to Japan,

Taiwan, China, and Singapore were listed as suppliers for various optoelectronic parts and components.

TABLE IV-11
SELECTED IMPORTED ITEMS USED BY
SURVEYED OPTOELECTRONICS COMPANIES

ITEM DESCRIPTION	IMPORTED FROM:	REASON FOR IMPORTING:
A. Machinery & Equipment		
Test & Measurement Equipment	Japan, United Kingdom	No U.S. Source
Vacuum Pumps, Diffusion Pumps, Evaporation Equipment	Lichtenstein, France	Lower Cost
Wafer Saws	Japan, Switzerland	Lower Cost
Grinding, Milling, Turning Machines, Lathes	Japan	Domestic Source Inadequate
Aligners	Japan	Domestic Source Inadequate
B. Parts, Components & Materials		
Glass (various types)	Germany, Japan	No U.S. Source
Optical Components & Subassemblies (e.g., laser diodes, LEDs, LCDs, photomultipliers)	Japan, Pacific Rim, U.K.	Domestic Source Inadequate; Lower Cost
Integrated Circuits	Japan	No U.S. Source

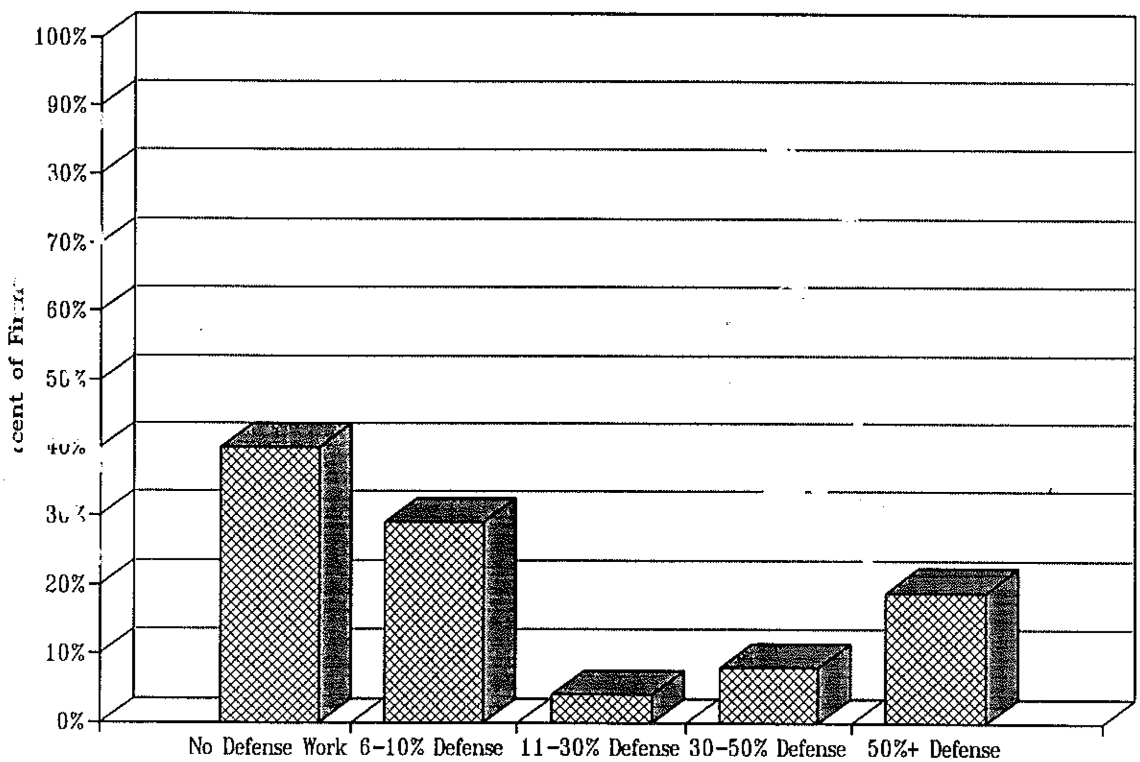
Source: BXA Optoelectronics Survey

Defense Production

About 20 percent of total optoelectronics shipments were reportedly for defense applications. Of the 102 establishments responding to the shipments question for 1991, 61 reported some level of defense shipments, ranging from just one percent of their total shipments to 100

percent. Most establishments (70 percent) have either no defense shipments or very little (less than 10 percent of shipments). Many of the companies that did not report defense shipments may nevertheless supply the military market; the "dual-use" nature of many optoelectronic products and the fact that they tend to be subsystems make it difficult for the firms to track defense shipments. However, a substantial minority of firms (about 20 percent) are heavily dependent on defense shipments (more than 50 percent of business). Over 10 percent of the establishments were almost exclusively defense producers (See Figure IV-7).

Figure IV-7
Percent of Shipments for Defense
by Percent of Firms



Source: BXA Optoelectronics Survey

There were significant differences among the various product groups with regard to their dependence on defense markets. While the average for the database as a whole was about 20 percent, the industrial equipment, laser, and components producers tended to rely on defense for a much smaller percentage of shipments (6-8 percent). In contrast, the "defense group" had an average of 73 percent of shipments going to defense, and the display group had over a quarter of sales to defense. The communications and optical information systems groups were also near the overall average (20 percent and 14 percent, respectively).

-- Military Systems Supported

The firms in the BXA survey group reported supplying optoelectronics products to a wide range of weapons systems and other military equipment. The items supplied ranged from optoelectronics components such as photodetectors and laser diodes, to subsystems such as optical gyroscopes, to military systems such as the LANTIRN -- a two-pod navigation/targeting system for night and under-the-weather ground attack.[10] Table IV-12 displays the number of companies reporting, the optoelectronics items supplied, and the military systems supported. Keeping in mind that companies often supplied more than one type of optoelectronics item to support a variety of military systems, the most frequently identified items were displays, followed by photodetectors, semiconductor devices such as light emitting and laser diodes, fiber optic cable and subsystems, and optical sensors & equipment. Lasers, optical receivers, and optical communications components were reported five times each; video equipment, hybrid components (photocouplers and encoders), and military systems were identified by four companies each; and optical munitions, and other components such as memory devices and boresights each were identified by two firms.

When companies were asked whether they believed cuts in defense spending would impact their defense research or manufacturing operations, forty-three believed there would be some type of negative impact, ranging from severe to marginal. Twenty-one companies reported that cuts in defense spending would not affect them, however, and eight companies were as yet unsure how cutbacks would affect them.

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[10] Air Force Association, "A Checklist of Major Aeronautical Systems," Air Force Magazine, January 1991, p. 48.

TABLE IV-12
MILITARY SYSTEMS SUPPORTED BY OPTOELECTRONICS ESTABLISHMENTS

#	Item Supplied	Military Systems
9	DISPLAYS (e.g., *Plasma (3), *Electroluminescent (2), *Active Matrix and *Passive Liquid Crystal (2), LED, *Head-Up)	Aircraft: *F-15 Lorops, *F-16 A/B & D/H, *F-22, *UH-60, *KC-135, *A-12, *RAH-66, *Combat Talon MC-130E, *Pave Low MH-53J Helicopter, B1B Aviation Systems: *AN/PSG-5, *GSC-59, *TXC-124 Other: M1A2 Abrams, M1 Tank test equipment, Motorola Jstars, ManPack Magnavox, *Mobile Subscribers Equipment, JTIDS Class IIL terminal, Army Scout Program, Seawolf Submarine A/C plant; *MLRS, *Tomahawk Launch System, *P3C Anti Submarine Warfare System, BCS - Battery Computer System Milstar, Space Shuttle (Orbital Display Unit).
7	PHOTO DETECTORS (e.g., UV/IR, *CCDs/Focal Plane Arrays, etc.)	Aircraft: *A-6, *B-52, *F/A-18, Avenger, Rembass, TRSS, MIDS Missiles: AIM-9L, 9M, 9P, 9-P4, *Maverick, Hellfire, Tow Sights Other: M1 tank, BFVS, *SADARM, Javelin, Eris, Leap, AGCW, INEWs
6	SEMICONDUCTOR LIGHT SOURCES: LEDs (3) & Laser Diodes (3)	Avionics Systems: AN-BSY-2, *Dogfight-MHI, Bradley Vehicle Avionics Systems Missiles: Sidewinder, Tomahawk, *HARM AGM88, *Trident II-MK-6, *RBS 7 Bofors, *Mistrial-Matra Other: Satellite Communications, Brilliant Pebbles Communications Linkage, OASYS helicopter Wire Avoidance Lidar, *Sinegars, M1A1 - Gunners, F-15 Lorops, Army Fiber Optic Transmission System
6	*FIBER OPTIC CABLE & SUBSYSTEMS (e.g., *Tethered Optical Fiber, *Cable TV Distribution Systems, *Fiber Optic Video Transmission)	Aviation Systems: AN/GRC-206, TYQ-23 TAOC, AUV Testbed Tethered Applications: Air Force Sky Ray, Navy-Torpedoes, Skipjack Fiber Optic Systems: NAWAS System for underwater hydrophone network for submarine detection, *Undersea Electro-Optical Network - AT&T, *Video Fibe System, *CCTV Security System, *Space Launch Transmission System, *RDA - AT&T, *RMES, *ATV-NOSC, *S1Q-25-FEL
6	SENSORS & EQUIPMENT (e.g., *Inertial Reference System, Infrared Telescopes, Night Vision Devices, FLIR, Image Intensifiers)	Aircraft: AFTI, *F-22, *AH-64, *RAH-66, Falcon Knight Aviation Systems: AN/PVS 2,4,5,6, VVS-2, TVS-5 Missiles: Tomahawk, *Minuteman III, *MSLS Other: Underwater Detection, *Infrared and Millimeter Wave, Sensor Fuzed Weapons, Safer, Thermal Weapon Sight
5	*LASERS (e.g., *Solid State -- Nd:YAG, Dye, Multibeam Custom Welding System)	Aircraft: *Apache, *Darkstar, MSS OH58D Helicopter (KIOWA), *Commanch *F/A-18 FLIR POD, *LANTIRN Targeting Pod Other: Magic Lantern, *Stingray Bradley Fighting Vehicle, Acquilla, Coronet Prince, *M-1 Tank, Army RADC, Army Micom R&D, Recuperator Plate Welding
5	*OPTICAL LASER/RECEIVERS & TRANSCEIVERS	Guidance and Control: *Target Designators/Rangefinders for Night Hawk and C 130 Gunship, *Multiple Independent Target Systems (MITS), TACSLAN - Tactical Air Control System Local Area Network, Coronet Prince, JSTARS Block I Grand Station Module.

#	Item Supplied	Military Systems
5	OPTICAL COMPONENTS: Optical Switches (3), Splitters (1), WDM (1)	Aircraft: C-17 Cockpit, Darkstar, F-18 FLIR POD, Advanced Tactical Fighter Helicopter Other: Nevada Test Site (EGG), NASA Kennedy Space Center
4	CAMERAS/PRINTERS: KB35A & *Hoss Cameras, *Airborne Video Recorders, Printers	*SOA, *F18-FMS, *Maverick Missile, *SH-60S, *AH-1W Cobra, *Magic Lantern, *Navy AEGIS Destroyer & WISS Program, CALS
4	*HYBRID OPTICAL DEVICES: Photocouplers (3), Optical Encoders (1)	Aircraft: *B-2, *F-16 Fire Control, C-17. Phalanx/ Vertical Launch System Controls, B1B SRS-3 & 8 Radar Missiles: *FOG-M, *Patriot, *Hawk, IR Maverick, Standard, SLAM Other: *Gyroscopes, Sensors, *TOAC-85, *GPS and Milstar Satellites, *Space Shuttle (computer solid rocket boosters), *M1 Tank
2	OPTICAL MUNITIONS: * Laser Target Designators/ Range Finders	Aircraft: *LANTIRN Targeting Pod, *KIOWA Mast-Mounted Sight, *Apache TADS/PNVS, *F/A-18 FLIR Pod Missiles: *Hellfire, *DSP Other: *AGM-130, *GBU-15
2	OTHER: *Boresights, Data Storage & Retrieval Unit, Digital Memory Unit	Aircraft: AV-88 Harrier, F/8-18D Night Attack, V-22 Osprey, B-2 Tanks: *M1A1 Abrams, *M113 Other: *SMAW

* Indicates items most effected by defense cutbacks
Source: BXA Optoelectronics Survey

Table IV-12 identifies those items and defense systems that survey respondents indicate would be most effected by defense cuts with an asterisk. Additionally, companies included areas of basic research, such as lasers, laser receivers, and optical receivers that would also be cut back due to reductions in defense spending.

-- Defense Conversion

Because of the nature of optoelectronics, many companies do not perceive that there will be major problems in converting their manufacturing operations to commercial production. Nineteen survey respondents did describe difficulties with conversion; not surprisingly, these tended to be the companies most dependent on the defense market. Many of these firms said there is limited or no commercial market for their product lines. Others said that while there is a commercial market, their current production process is geared toward low volumes of high cost (and high quality) goods. Major and costly retooling would be necessary to convert these operations to serve commercial markets, which are commodity and price driven

rather than technology driven. Two firms said they would need fewer employees to serve commercial markets because of less stringent testing requirements and paperwork. Several firms cited organizational obstacles to conversion: their firms' organizational structures are presently geared toward serving primarily one customer -- the Federal Government. Major cultural changes, and changes in accounting, marketing, and other business functions would be necessary before successful participation in commercial markets would be possible. A number of firms believed that Federal (financial) assistance will be necessary for them to make the transition or "bridge the gap."

Some specific recommendations for federal assistance were provided: government investment in developing a U.S.-based display manufacturing base (initiatives already underway through ARPA and NIST/ATP); procurement from other U.S. non-defense government agencies; ARPA contracts for dual-use technologies; increased government commercial R&D funding; funding for field-testing to help with competition against big players in market; and an increased Small Business Innovative Research program. In addition to direct funding, other suggestions included offering tax concessions on R&D for transition to commercial production, decreasing procurement restrictions, increasing military use of commercial/dual-use products, creating markets to stimulate commercial development, setting up government programs to enable defense manufacturers to retool, establishing a commercial ARPA, and instituting a "freer" export control policy. Solutions not involving the government included use of strategic alliances and joint ventures to team resources.

At the time of the BXA survey, most survey recipients were unaware of Federal, state, or local programs designed specifically to facilitate the defense conversion process. Only eight companies participated in programs sponsored by the Departments of Defense or Commerce, Small Business Administration, National Aeronautics and Space Administration, Massachusetts, and New York that are helping them in the transition.

Companies will seek to remain competitive in this still huge national and international market, regardless of the extent of defense cutbacks. They will continue to improve their operating efficiencies through layoffs, diversifications, reorganizations, acquisitions of smaller and weaker competitors, and increasingly, strategic alliances. Some evidence of the

ongoing defense transition is already evident in the optoelectronics sector. For example, Hughes Aircraft Co. acquired Flight Dynamics Inc. for $14.5 million for in order to establish a commanding position in the commercial heads-up display market.[11] McDonnell Douglas and France's Thomson-CSF, among the world's largest defense contractors, signed a memorandum of understanding in 1992 to produce high-power laser diodes, microlasers, laser components, and equipment for commercial, defense and space applications.[12] Diversification efforts include shifting into new non-defense government markets and leveraging existing defense-oriented technology to break into commercial markets. Joint ventures will help companies to share the risks of marketing and servicing the commercial market.

In 1982, Galileo Electro-Optics Corporation of Sturbridge, Mass., received 85 percent of its total revenues from defense sales of night-vision goggles in particular. This year, however, Galileo hopes to be completely out of this market, even though there are still opportunities for night-vision equipment sales. "Fiscal year sales for 1991 were 13 percent below 1990, a decline entirely attributable to a 54 percent drop in military sales... but the company is now in the black."[13]

Employment

Companies in the BXA survey group provided actual and projected employment information for their optoelectronics operations for the 1989-1995 period. Employment was broken down into several broad job categories: sales and technical service; scientists and engineers; production workers; and administrative and other. Eighty-five of the surveyed establishments provided employment information for 1991, accounting for about 55,600 employees. The breakdown of employment by job category is presented in the Figure IV-8.

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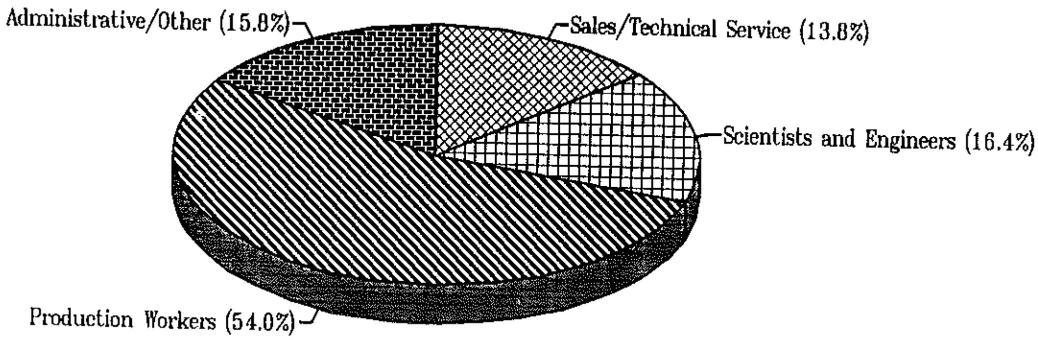
[11] Holton, Conrad W., "The Writing on the Wall: Military-Based Photonics Firms Get the Message," Photonics Spectra, June 1992, pp. 62-70.

[12] Ibid.

[13] Ibid., p. 69.

Figure IV-8
Employment by Employee Type



Source: BAA Optoelectronics Survey

Sixty establishments provided employment information for all years between 1989 and 1992. Table IV-13 presents these data, which can be used to identify trends in employment in the optoelectronics industry as a whole. Employment increased about three percent per year in 1990 and 1991, and was virtually stagnant between 1991 and 1992. Those companies making estimates for future years expect their employment to remain essentially unchanged through 1994, with a modest increase anticipated for 1995. The average size of an optoelectronics establishment is about 750 employees.

TABLE IV-13
EMPLOYMENT IN OPTOELECTRONICS
(60 ESTABLISHMENTS REPORTING)

JOB CATEGORY	1989	1990	1991	1992
Marketing, Sales & Service	5,292	5,641	5,692	5,485
Scientists & Engineers	7,549	7,779	8,032	8,043
Production Workers	24,684	25,322	26,238	26,076
Administrative/Other	6,295	6,475	6,685	6,843
TOTAL	43,820	45,237	46,647	46,447
Annual % Change:	--	+ 3.2	+3.1	0.0

Source: BXA Optoelectronics Survey

Employment was also analyzed by optoelectronic product group, and is presented in Table IV-14 (for those companies providing complete responses). The telecommunications sector accounts for the most employment in the BXA survey sample; telecommunications firms are larger than average, but have a lower percentage of scientists and engineers than many other optoelectronics product groups. The optical information group has on average even more employees, and about the average percentage of scientists and engineers. Both fields have consistently increased employment over the period.

The flat panel display companies in the survey sample are very small, with an average of just 96 employees; total employment in this group has also consistently risen. The establishments in the defense group are also relatively small (often divisions within larger companies), but an extremely high percentage of employees are scientists or engineers (38 percent). In some cases, the establishments in the defense group do research and prototyping only, and perform no real manufacturing. This product group experienced declines in employment in 1991 and 1992 from 1990 levels, likely as a result of the beginning of military cutbacks.

TABLE IV-14
EMPLOYMENT BY OPTOELECTRONICS PRODUCT GROUPS
(Number of Employees)

PRODUCT GROUP	# of Estab.	1989	1990	1991	1992	% Engineers	Avg. Size
Telecommunications	16	21,726	22,898	24,294	24,563	11.2%	1518
Optical Information	6	16,091	16,752	17,413	17,602	16.9%	2934
Displays	9	703	825	864	912	19.9%	96
Industrial Equipment	9	4293	4406	4137	4116	8.4%	460
Lasers	7	2394	2322	2344	2169	14.8%	335
Surveillance	3	1600	1370	1216	1081	12.9%	405
Defense	20	4918	5028	4857	4608	38.4%	243
Consumer	INSUFFICIENT DATA						
Components	11	5916	6118	6275	6484	9.5%	570

Source: BXA Optoelectronics Survey

The industrial equipment and components product groups have a lower percentage of scientists and engineers than average. This is probably because they are more mature industry segments. While employment appears to be on the increase in the components sector, it has declined from 1990 levels in industrial equipment.

-- Labor Concerns

While the vast majority of firms in the BXA survey group did not experience or foresee any labor problems, fifteen establishments provided comments on this issue. A few companies indicated that they had a surplus of labor due to layoffs from defense spending cutbacks and generally poor economic conditions. Ten companies expressed concern over a scarcity of

particular engineering skills, and one company complained of having to do substantial in-house job training. Seven companies suggested there may be a lack of specific job skills in the future due to reductions in defense spending. One company described excessive turnover as a problem.

CHAPTER V
COMPETITIVENESS FACTORS

Self Assessment

Survey recipients were asked to evaluate the relative standing of their firm or establishment as compared to their competitors in Japan, Europe, and the Pacific Rim (other than Japan) on a variety of competitive factors. The firms were asked to rank their responses from 1 to 5, where 1 means they are far ahead of their competitors, 2 means they are slightly ahead, three is even, 4 slightly behind, and 5, far behind. Their aggregated and averaged responses are presented in Table V-1 below.

From the table, it can be seen that U.S. firms believe that they have the technological advantage (including R&D capability, R&D application, engineering capability, overall technology), particularly over their competitors in the Pacific Rim. U.S. firms also believe they have the technological edge over European firms, but this lead is not as great. On the other hand, U.S. firms ranked their Japanese competitors at or near parity for most of the technology-oriented competitive factors. Japanese firms are rated as slightly less competitive in design capability than U.S. firms.

With regard to product and service performance competitive factors (e.g., price, quality, delivery and customer satisfaction), again, U.S. firms believe they have a substantial lead over their Pacific Rim competitors. They also believe they have a slight lead over their Japanese and European rivals. Interestingly, price does not appear to be a significant advantage or disadvantage for any particular region, although U.S. firms rate themselves slightly ahead of the Pacific Rim and Europe on this factor.

The final category of competitive factors, the overall business environment, reveals the greatest area of disadvantage according to the survey respondents. This category includes such factors as access to and cost of capital, the legal and regulatory environment, the cost and quality of labor, and the support of government. With the exception of labor, U.S. firms uniformly rate themselves at a competitive disadvantage vis-a-vis competitors,

TABLE V-1
COMPETITIVENESS SELF ASSESSMENT

(Scale: 1= U.S. Advantage; 3 = Parity; 5 = U.S. Disadvantage)

COMPETITIVE FACTOR	VERSUS PACIFIC RIM	VERSUS JAPAN	VERSUS EUROPE
DESIGN CAPABILITY	1.8	2.6	2.3
ENGINEERING CAPABILITY	1.8	2.9	2.4
R&D CAPABILITY	1.9	3.1	2.6
R&D APPLICATION	1.9	3.0	2.5
OVERALL TECHNOLOGY	1.8	2.9	2.4
PRICE	2.7	3.0	2.7
DELIVERY	2.0	2.4	2.3
CUSTOMER SATISFACTION	1.7	2.3	2.1
QUALITY	1.8	2.6	2.4
ACCESS TO CAPITAL	3.3	3.8	3.2
ACCESS TO R&D FUNDS	2.9	3.5	3.1
COST OF CAPITAL	3.1	3.6	3.0
LABOR	3.0	3.0	2.8
LEGAL/ REGULATORY ENVIRONMENT	4.1	4.0	3.6
GOVERNMENT SUPPORT	3.9	4.3	3.9

Source: BXA Optoelectronics Survey

particularly in Japan, on factors affecting the general business atmosphere. According to the survey respondents, labor is not a significant competitive factor as all regions are rated approximately evenly. There are two competing elements of labor, however: cost of labor (in which the Pacific Rim would likely have a competitive advantage) and quality of labor force (in which Japan or Europe may have an advantage). Unfortunately, the survey did not break these elements out separately.

U.S. firms believe their greatest area of competitive disadvantage are in the legal and regulatory environment and government support. For these factors, U.S. firms rate themselves significantly worse off than their competitors in the Pacific Rim, Japan and Europe.

The competitiveness self assessments were also broken down by similar product groups in an attempt to discern any differences in the experiences of each group. In general, the responses of each product group were similar to those of the entire survey presented above. However, there were several differences, particularly in the technology area. These results, in abbreviated form, are presented in Table V-2.

As can be seen from the table, the survey respondents rated Japanese firms the most competitive in the area of displays (3.7 on a scale of 5); this is no surprise, given that Japanese firms reportedly control about 95 percent of the flat panel display industry at present. Japanese firms were also rated above average competitiveness in the area of communications and optical information systems, and lower than average in industrial equipment, lasers, and particularly in the defense category.

Firms in the Pacific Rim were universally rated technologically weaker by the U.S. firms across all product groups. However, they were rated the strongest competitors in the optical information category, which includes such well commercialized items as fax machines, copiers, and printers.

TABLE V-2
RELATIVE STATUS OF SURVEY RESPONDENTS ON
TECHNOLOGY FACTORS
(Scale: 1= U.S. Advantage; 3=Parity; 5 = U.S. Disadvantage)

OPTOELECTRONICS PRODUCT GROUP	VERSUS PACIFIC RIM	VERSUS JAPAN	VERSUS EUROPE
COMMUNICATIONS	2.0	3.2	2.6
OPTICAL INFORMATION SYSTEMS	2.4	3.2	2.1
DISPLAYS	2.1	3.7	2.4
INDUSTRIAL EQUIPMENT	1.8	2.7	2.4
LASERS	1.6	2.7	2.9
DEFENSE OPTOELECTRONICS	2.0	2.4	2.4
OPTOELECTRONICS COMPONENTS	1.7	2.8	2.3
OVERALL AVERAGE	1.8	2.9	2.4

SOURCE: BXA Optoelectronics Survey

European firms were also consistently rated less technologically competitive by the U.S. survey respondents. They are, however, rated as near equals to U.S. firms in the laser category and are also fairly strong in communications.

Technology Leadership

Seventy three of the surveyed companies considered themselves "world leaders" in some area of optoelectronics-related components, fiber optic communications, information, industrial/medical, and military equipment/know-how. Not surprisingly, no companies identified themselves as world leaders in any optoelectronics-related transportation or consumer equipment fields. The most frequently cited world leadership class products were lasers (solid state and gas), displays (plasma and passive matrix liquid crystal), laser diodes,

night vision equipment and fiber optic telecommunications equipment. Companies were most optimistic about their technology leadership continuing to improve over the next five years in the areas of lasers and displays. No companies thought their technology lead would decline in those areas over the next five years.

Generally, companies were favorable in their predictions for their technology lead over the next five years. For the products identified, a little less than half, or about 45 percent, believed their technology lead would not change; slightly less than that, or 40 percent, believed their lead would improve; and about 15 percent believed their lead would decline. Predictably, Japanese firms were identified more often than European and U.S. firms in particular as nearest competitors.

TABLE V-3
TECHNOLOGY LEADS LOST BY U.S. FIRMS

Type of Product/Technology	Companies Responding	Foreign Competitors
Telecommunications (e.g., SONET, couplers, telecomm lasers, manufacturing know-how, optical fiber, high speed ICs, optical switches)	6	Japan (6), Europe (2), Australia (1)
Test & Measurement (e.g., velocimeters, micro positioning)	2	Japan (2), Europe (1)
Displays (e.g., LCDs, CRTs)	7	Japan (7), Europe (1), Korea
Components (detectors, avalanche photodiodes, laser diodes)	4	Japan (2), Canada (1) Europe (2)
Consumer (cameras, VCRs)	1	Japan (1)
Lasers	4	Japan (3), Europe (2)

Source: BXA Optoelectronics Survey

Additionally, companies were asked to indicate whether or not they had lost their technology lead to a foreign firm in a particular product area during the past five years. Twenty-four companies responded affirmatively, identifying the product/technology and the foreign

competitor(s). As presented in Table V-3, product areas suffering the greatest loss were displays (liquid crystal displays in particular), telecommunications equipment, and lasers. Japanese firms were identified most frequently (21 times), European firms (8 times) and one time each to Canadian, Korean, and Australian firms.

Obstacles to Competitiveness

Survey recipients were asked to discuss obstacles to their competitiveness -- financial, technological, or legal/regulatory. Their responses can be broken into three general categories: U.S. business environment, internal (company) factors, and the international environment.

Broadly, the business environment in the United States was by far the biggest obstacle to competitiveness cited by survey respondents. Lack of access to low cost capital was perhaps the single most frequently cited obstacle. Similarly, government policies that discourage investment and R&D were also frequently mentioned, as was the lack of a coherent U.S. government "industrial policy." In the latter category, some firms wanted additional government funding of R&D, while others cited uncertainty of funding, or government policies that were anti-business in general. Specific anti-business policies mentioned include U.S. export controls, environmental and health regulations, antitrust, the litigious environment, U.S. government auditing policies/procedures, and the lack of permanent investment/R&D tax credits. Cutbacks in the U.S. defense budget was another commonly mentioned obstacle to competitiveness. Some additional complaints relating to the general business environment in the United States include the poor quality of the U.S. workforce/poor educational system, the general state of the economy, U.S. protectionism, and the high cost of labor.

In the category of internal firm constraints to competitiveness, several survey respondents cited technological impediments, such as delays in product development, production scheduling, lack of automation/robotics, reliance on foreign sources for parts and components, and inability to bring production costs down. Other survey respondents blamed their firms' business strategies for their lack of competitiveness (e.g., short-term thinking, focusing on shareholder profits over long-term R&D benefits).

The final obstacles to competitiveness were external: such factors as inability to penetrate foreign markets due to trade barriers, and alleged dumping by foreign firms in the U.S. market. Some obstacles in this category are the flip side of those in the U.S. business environment, such as the close relationship between foreign governments and their industry, the ability of foreign competitors to finance high levels of R&D, lower labor and other production costs abroad, and better educated workforces overseas.

Below are discussions of some specific factors affecting the competitiveness of U.S. firms in the optoelectronics areas:

-- U.S. Trade Practices

Optoelectronics manufacturers listed a variety of U.S. trade practices that affect their business, both positively and negatively. On the positive side, one firm mentioned that the pending North American Free Trade Agreement with Canada and Mexico would improve their competitiveness in Canada. Another praised the Office of the United States Trade Representative for its successful effort to open the Japanese telecommunications market to U.S. firms, while yet another was complimentary of the Department of Commerce's sponsorship of international trade shows and missions.

On the other hand, many firms again mentioned export controls on dual-use and military technologies as hindering their competitiveness. They believed that the U.S. Government applies these controls more restrictively than other nations, and that even when they were ultimately allowed to export, the red tape and delays in the approval process were detrimental.[1] One firm accused the U.S. Government of applying export controls based on "buzz words" while ignoring the important issue of availability of competing foreign products. Several firms mentioned that export controls had been liberalized in recent years, and that the process had also improved, however. Several other trade practices relating to purely military trade were mentioned as hindrances, including Department of Defense policy

[1] Since the time of the survey, U.S. export controls have been liberalized for certain optoelectronics products, including telecommunications.

to seek recoupment of non-recurring costs from foreign purchases of U.S. defense equipment, and the lack of financing by the Export-Import Bank for defense exports.

Many survey respondents believe that the U.S. market is more open to foreign competition than foreign markets are to U.S. firms, and the U.S. government does not take appropriate action. They believe that the U.S. should take action, such as imposing duties, to "level the playing field," as well as being more aggressive in enforcing U.S antidumping laws. Several firms specifically criticized the antidumping decision imposed by the U.S. government on Japanese Active Matrix Liquid Crystal Displays -- they believed that applying this duty only to the displays themselves and not to the finished products incorporating the displays was counterproductive. {Note: since the BXA survey, the duties on imported flat panels were rescinded by the U.S. Government.}

Other firms called for a "Buy America" policy on optoelectronics to protect and develop this critical industry in the United States. On the other hand, one firm wanted the U.S. government to remove duties on imported optoelectronic components that they use in the manufacturing process of larger systems. Lastly, two firms mentioned antitrust decisions by the FTC and Justice that hindered their ability to compete in international markets.

-- Foreign Trade Practices

While many were unable to provide specifics, survey respondents listed wide range of foreign government trade practices that put U.S. firms at a competitive disadvantage. Among the most commonly cited practices related to financial support for foreign firms, including R&D grants/credits, investment credits, favorable tax treatment, and low interest loans to finance start up companies, exports, R&D and investment. Numerous countries were mentioned as providing these types of programs to their optoelectronics industries, including (roughly in order of prevalence) Japan, Europe (as a whole), France, Korea, Taiwan, Germany, United Kingdom, Singapore, China, and Malaysia.

European Community programs including ESPRIT, RACE, and EUREKA were mentioned by several firms as examples of the direct funding by European Governments in areas related to optoelectronics (at nearly $2 billion per year). Similarly, many companies mentioned

MITI of Japan, but few gave specific examples of how MITI programs benefitted the Japanese optoelectronics industry. One company cited the monthly tax levied by the Japanese Government on all TV owners, the proceeds of which are distributed to Japanese display manufacturers for research and development. Another company explained that some foreign governments, such as Singapore and Malaysia, had extensive government programs to lure foreign investment in optoelectronics facilities and other high technology investment.

Emerging Competitors

Survey respondents were asked which countries/regions have emerging optoelectronics capabilities that have the potential to become major competitors in the future. South Korea was the most frequently referred to in this regard, with 16 mentions, especially in the area of displays and communications. The second most frequently mentioned country was China, with 13 cites. The communications, industrial equipment, and component categories were specifically mentioned for China. Other areas in the Pacific Rim were also often cited, including Taiwan and Singapore (six mentions each) and Malaysia (three mentions).

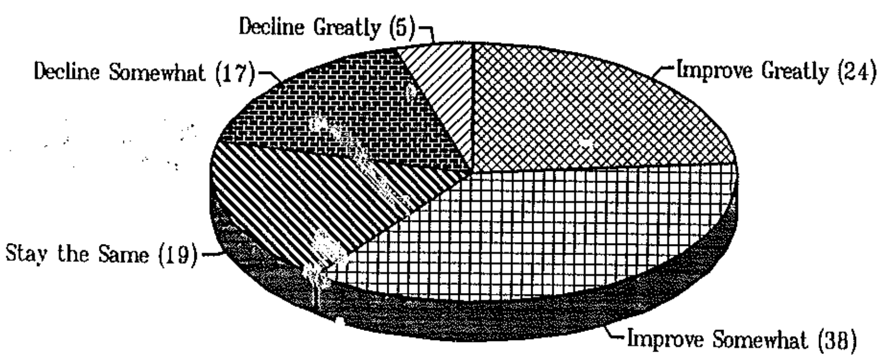
Russia/former Soviet Union received eight mentions as an up and coming competitor, while Eastern European countries (especially the former East Germany) received six mentions. Most survey respondents believed Russia to be at least 5-10 years behind overall in the optoelectronics industry, albeit with certain "pockets of excellence" (such as lasers, materials). Many firms pointed out that Russia has excellent research, design and basic technology capabilities, as well as an outstanding skill and knowledge base and superior educational system in math and physics. However, they were unanimous in their belief that Russian firms were very weak in manufacturing, quality control, and marketing as well as having poor infrastructure and inferior or "antiquated" equipment and facilities. Nonetheless, some firms consider Russia to have enormous "untapped potential" that "should not be taken lightly."

In addition to these regions, Israel received several mentions as an emerging competitor, as did France (particularly in the military/defense sector). Other countries receiving multiple mentions were Mexico, Italy, the U.K., and Australia. Countries mentioned by at least one survey respondent include Canada, Spain, the Netherlands, India, Brazil, and Austria.

Competitive Outlook

Survey participants were asked to project their firm's competitive prospects for the near future (next five years). Respondents were mostly optimistic about their competitive prospects. Out of 103 establishments responding, over 60 percent expected the competitiveness of their optoelectronic products to improve somewhat or greatly over the next five years. About one fifth of the respondents anticipated no change in the competitiveness status. On the other hand, 23 firms expected their competitiveness to decline greatly or somewhat in the near term (See Figure V-1).

Figure V-1
Competitive Outlook - Next 5 Years
(103 Firms Reporting)



Source: BXA Optoel... nics Survey

There did not appear to be a particular pattern among those companies anticipating a decline in competitiveness. All product groups were represented, although a slightly higher percentage of the industrial equipment and laser producers had a negative outlook on their future competitiveness. In general, however, it appears that future competitiveness is largely based on individual firm situations and less on the status for an entire sector of the optoelectronics industry.

Firms provided a variety of reasons for changes, positive or negative, in their competitiveness in the future. On the positive side, many firms cited their efforts to increase or expand research and development and investment in new plants/equipment as being the key to their future improved competitiveness. Others mentioned improved process technology, productivity, increases in product quality and reduced production costs as major factors. Many firms also mentioned that they were entering new domestic or international markets that were expected to be profitable, based on commercialization of new technologies or a greater general acceptance of optoelectronics in many applications.

Another category of responses related to the business aspects of the firms, such as marketing experience, organization, determination, strategic partnerships, and sound business plans. Many firms cited the increased involvement/attention of the federal government as a factor in their improved future competitiveness, either directly through funding (NIST, ARPA, SBIR) or indirectly through increased attention to optoelectronics in general. Finally, one firm mentioned outside factors as being the primary determinant of their future improved competitiveness: specifically, that Japanese firms would be less competitive because of the increased cost of capital to them.

Those firms that expected a decline in competitiveness over the next five years also mentioned a variety of reasons. The most common explanation was increasing international competition, especially in Japan. The firms indicated that their global competitors were entering new optoelectronics markets, had economies of scale in production, offered lower prices, and received significant government support. Another very common reason given for future declines in competitiveness was reliance on declining U.S. defense budgets.

In addition to these frequent reasons, firms cited several internal impediments to competitiveness, such as lack of vision and commitment, poor business decisions, and poor customer/supplier relationships. In addition, several respondents highlighted their lack of government R&D support/inability to finance R&D in comparison to their foreign competitors. Another category of responses relates to regulations: the cost of providing health benefits to employees, the cost of labor, U.S. export controls, taxes, and environmental/health regulations were specifically mentioned.

CHAPTER VI
OPTOELECTRONICS RESEARCH OUTSIDE PRIVATE FIRMS

Introduction

In the field of optoelectronics as in many emerging technology areas, much research and development is performed outside of private firms -- at Government laboratories and in academic institutions. It was the primary objective of this report to assess the status of U.S. firms in conducting research, develop, and commercializing optoelectronics technologies. It was beyond the scope of the study to perform a complete review of federal and academic efforts in the area of optoelectronics. However, a specialized questionnaire was developed and sent to several universities and government laboratories known to have major optoelectronics-related programs (see appendix B). The main focus of this survey was to measure the extent and nature of the relationship between these public entities and private sector firms. Unlike the questionnaire mailed to private sector optoelectronics manufacturers, this questionnaire was completed on a voluntary basis; only five universities and two government labs provided responses. Reports in optoelectronics-related publications were used to supplement this information.

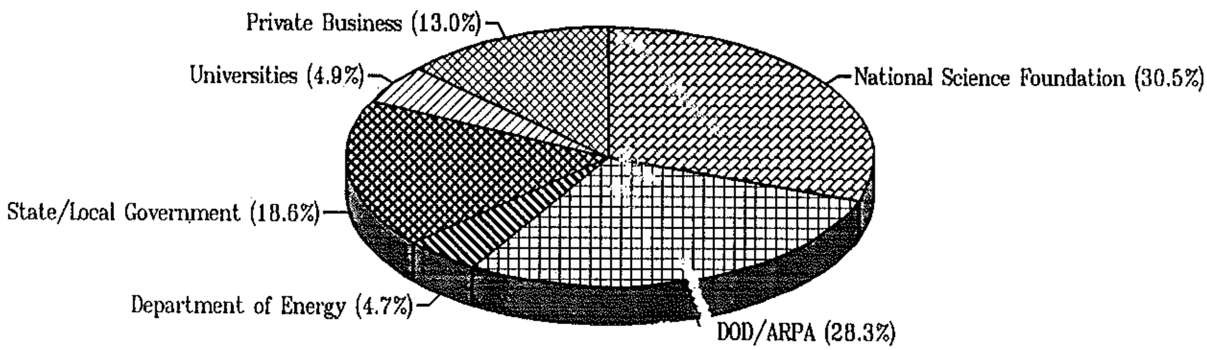
Academic Institutions

The five universities participating in our survey were the Liquid Crystal Institute at Kent State University, Ohio; the Electrical Engineering Program at Cornell University, New York; the Center for High Technology Materials at the University of New Mexico; the Department of Electrical Engineering at the University of Maryland; and the Center for Telecommunications Research at Columbia University, New York. In total, these universities spent $18.7 million on research in optoelectronics-related fields in 1992. In addition, a field visit was made to the Center for Optical Computing at the University of Colorado at Boulder.

The majority of optoelectronics research at the academic institutions responding to the BXA survey was funded by the federal government (63% in 1991); the National Science Foundation (NSF) was the largest single source of funds. All five universities received funding from NSF. In addition, the Department of Defense, especially its Advanced

Research Projects Agency, also supported much R&D at academic institutions; the Department of Energy and its National Labs were smaller players. In addition to federal funding, all five universities received some money from their state or local government to support optoelectronics research. State and Local government accounted for about 18 percent of total research funds in 1992. Private businesses funded about 13% of the optoelectronics research in academic institutions surveyed. Four out of the five universities received some funding from the private sector in this regard.

Figure VI-1
Optoelectronics Research in Academic Institutions by Funding Source



Source: BXA Optoelectronics Survey

According to the survey respondents, the majority of the graduates of these optoelectronics-related academic programs go on to jobs in research organizations (nearly 70%). Only about 15% of graduates are believed to go on to manufacturing jobs; an additional 12 percent continue their research at other academic institutions or obtain teaching positions.

-- Business Community Involvement

All of the universities responding to our survey indicated some degree of cooperation with private sector firms in the area of optoelectronics. Cornell University has direct involvement with the optoelectronics business community; 6 U.S. and 2 foreign firms participate. The firms support specific research projects at the University, with the cost determined by agreement between company and university. The company receives all data produced, as well as fist rights to license any patents. In addition, employees of the firms receive training/advanced degrees through the university. Technology commercialization is a relatively new goal. It is achieved through personnel interchange, joint research, and joint meetings. Cornell cited several successful technology commercializations, including a NaCl color center laser now sold by Burleigh Instruments; Urea and BBO nonlinear crystals sold by Cleveland Crystal; and an optical parametric oscillator now under development at Spectra-Physics.

The Center for High Technology Materials was created in 1985 at the University of New Mexico by the state, with a mandate to enhance interactions between the university, government laboratories and industry. About 20 firms, ranging from large corporations to small, entrepreneurial firms participate. One of the primary goals of the Center is to be responsive to industry needs while retaining the fundamental educational mission of the university. Participating firms provide "mentorship" to university researchers to help focus research on issues of industrial relevance. On occasion, the Center receives contracts/subcontracts for fabrication of specialized materials, structures, and devices. Some examples of successful technology commercialization of research done under this program include: a scanning microscope now commercialized by two small firms, and developments in lithography technology being investigated by a major stepper manufacturer.

The University of Maryland is in the process of establishing an Industry-University Cooperative Research Center funded by NSF on "Optoelectronic Interconnects and Packaging." Each of the six corporate members will pay about $50,000 for membership in the program. Maryland conducts joint research of direct interest to the participating firms, with the goal of transferring packaging technology from the University to its industrial

partners. The firms have a strong voice in the direction of research at the University through twice annual meetings. Since the program is new, there are not many examples of successful technology commercialization. However, discussions are underway with a major aerospace company regarding the transfer of a technology to deposit high quality IR coatings on the facets of semiconductor lasers to make laser amplifiers.

Similarly, Columbia University's Center for Telecommunications Research (established 1983) cooperates with about 15 U.S. and 10 foreign firms. The participating firms pay an annual membership fee, and thereby benefit as active participants in the research with nonexclusive access right to research results.

The University of Colorado at Boulder is home to the Center for Optical Computing, one of the National Science Foundation's Engineering Research Centers. As such, business involvement and technology transfer are a definite missions of the Center. Two local start-up optoelectronics firms are spinoffs from the Center, including Displaytech (flat panel displays) and Boulder Nonlinear Systems (optical correlators).

-- Other University Programs[1]

In addition to the five universities responding to the BXA survey, many other academic institutions have optoelectronics-related research programs. For example, the Department of Defense Advanced Research Projects Agency has established at least three university-based optoelectronics research consortia. The principal center involves the University of Southern California, the University of California at Los Angeles, and the University of New Mexico. Other ARPA consortia are: (1) Cornell, University of California at Santa Barbara, University of California at San Diego, and Rensselaer Polytechnic Institute; and (2) University of New Mexico, Stanford University and California Institute of Technology.

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[1] "Expanding Access to Precompetitive Research in the United States and Japan: Biotechnology and Optoelectronics," Appendix A: Current Research and Development in Optoelectronics in Japan and the United States, National Academy Press, Washington, DC 1990 (Office of Japan Affairs, Office of International Affairs, National Research Council)

The National Science Foundation also sponsors optoelectronics research through its Engineering Research Center (ERCs) and Science and Technology Centers (STCs). For example, the Center for Quantized Structures and Compound Semiconductor Research (an STC) was established at the University of California at Santa Barbara. Corporate members of this center include AT&T, Bell Labs, Bellcore, Hewlett Packard, Hughes, IBM, Motorola, Tektronix, and Rockwell. At the University of Illinois, there is an ERC for Compound Semiconductor Microelectronics with members including IBM, Bellcore, Hughes, Honeywell, Texas Instruments, and Motorola. At the Massachusetts Institute of Technology, optoelectronics materials research is funded; the University of Southern California and University of Rochester have centers devoted to laser systems; and the University of Florida, University of Arizona, Berkeley and the University of Michigan conduct research on optical science in general.

Other universities identified as having major optoelectronics programs include the University of Alabama's Center for Applied Optics, City College of New York's Ultrafast Spectroscopy and Lasers Center (medical photonics), the Institute of Optics at the University of Rochester (New York), and the University of Illinois/Urbana's Beckman Institute.

U.S. Government

As noted above and elsewhere in this report, the federal government is a major source of optoelectronics research and development funds for both private sector firms and universities. In addition, the federal government conducts a significant amount of optoelectronics related R&D at its own research facilities -- more than 600 federal laboratories. As with university research, no attempt was made to comprehensively analyze all federal R&D related to optoelectronics. According to one report, the Department of Defense devoted $92.3 million in 1990 to optoelectronics research through Independent Research and Development funds (IR&D).[2] Another report indicated that the Strategic Defense Initiative Office devotes

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[2] Reilly, Lucy "GAO Calls on Pentagon to Oversee IR&D Funds," Washington Technology, February 20, 1992, p. 22

about $3.5 million per year to optical computing research.[3] One example is funding of survivable optics and integration.

The following few examples are given to provide an overview on the types and variety of research that the U.S. government is involved in the optoelectronics area.
Increasingly, the assets and resources of federal labs -- personnel and equipment -- are being made available to private sector firms. Recent legislation, including the National Competitiveness Technology Transfer Act of 1989, have enabled government labs to apply their technological strengths to enhancing the economic competitiveness of the United States by creating, developing, and cost effectively transferring commercially valuable technology through cooperative arrangements with industry, universities, and non-profit intermediaries.

Not surprisingly, the Department of Defense is a major source of research and development in the area of optoelectronics. While the Advanced Research Projects Agency funds much research at other facilities and is now in the process of assembling consortia to develop optical interconnects and an all optical communications network, other DOD-owned facilities maintain in-house programs. For example, Wright Patterson Air Force Base's Laser Hardened Materials Evaluation Lab (Dayton, OH) is home to the nation's most powerful laser (a 32 foot carbon dioxide laser built by Acurex of Mountain View, California for use in strategic defense applications). The Air Force is trying to attract industry to rent time on the laser, and is seeking to find commercial applications of the laser in welding, heat treatment, cutting materials, air conditioning systems.[4] Other Defense labs with major optoelectronics programs include the Hanscom Air Force Base and Rome (NY) Air Defense Center, the U.S. Army's Huntsville, Alabama facilities and Henry Diamond Lab, the Naval Research Lab, and the Strategic Defense Initiatives Office.

Other Department of Defense initiatives in optoelectronics include a Center for Optics Manufacturing in Rochester, NY to develop new manufacturing capabilities for optical glass,

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[3] Katauskas, Ted, "Optical Computing Reaches a Crossroads," Research and Development, January, 1991, p.32.

[4] Reilly, Lucy, "Laser Looks for Use," Washington Technology, June 10 1993.

and a manufacturing technology program (MANTECH) funded by the U.S. Army's Strategic Defense Command on Monolithic Multiband Infrared focal plane arrays.

Another major source of government optoelectronics R&D is the Department of Energy. All four major DOE national labs are active in the field. For example, Los Alamos National Lab has major program on Free Electron Lasers as the light source (XUV) for submicron lithography (ultimate large scale integration). Los Alamos also has large excimer (UV) laser programs specializing in imaging applications. Sandia National Lab is also strong in lasers and pulsed power technology, and has some ongoing efforts in optical computing, optical displays, and infrared optics (associated with defense programs). Oak Ridge National Laboratory is active in the areas o f advanced electro-optical materials, optical memories, fiber optics applications, materials for optoelectronic integrated circuits, and advanced photonics-based physical measurements (temperatures, strain, pressure, etc.). Lawrence Livermore National Lab has large Nd:glass (solid state) laser programs and recent emphasis on diode laser arrays. They are also active in advanced electro-optic materials.

The National Aeronautics and Space Administration is yet another source of optoelectronics R&D within the federal government. NASA funds R&D programs in optical communications, optoelectronics integrated circuits (at Jet Propulsion Laboratory) optical correlation for automatic object recognition, and solid state lasers.

CHAPTER VII
FOREIGN INDUSTRY ANALYSIS

The following is the complete Executive Summary from a report prepared by the Bureau of Export Administration's Office of Foreign Availability entitled "Foreign Industry Analysis: Optoelectronics."[1]

Executive Summary

The field of optoelectronics is a broad market which is presently dominated by Japan, the U.S., and certain countries in Western Europe. The array of products developed from this technology have served to meet the growing demands of a wide range of industries, the most prominent of which are telecommunications and information processing.

As a technology, optoelectronics can be broken down into the following three sectors:

Components: These are defined as individual optoelectronic devices that perform a particular function. The six categories of these types of devices are light emitting devices, photodetectors, solar cells, display devices, and optical hybrids.

Equipment: These are defined as optoelectronics devices that are integrated together or with other types of devices to perform a particular function. The six categories of these commodities are optical disk equipment, optical telecommunications equipment, optical I/O equipment, display equipment, laser processing equipment, and optical sensors.

Systems: These are defined as optoelectronic equipment that is integrated together to with other electronic or electromechanical equipment or components to perform a self-contained array of functions.

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[1] The complete report can be obtained through the National Technical Information Service at (703) 487-4650, publication number PB93-18392.

Among these sectors, the best information is available for the **components** market, for which data show Japan consistently as the economic leader in the industry, followed by the U.S. and then Europe. In a 1989 survey of the worldwide components market leaders, when looking at the tom ten, eight of the companies were Japanese, one was American (#5), and one was German (#9). While this may appear as a daunting outlook for U.S. manufacturers, it should not be said that every market has been swept away by Japan. Indeed, in optical fiber sales, the market is almost equally divided among Japan, the U.S. and Europe, and this ratio is predicted to remain fairly constant up through 1997.

As for **equipment**, the Japanese have noted a shifting in their ratios of component/equipment/systems sales. Equipment, as opposed to components, is becoming the more prominent market, a change partially attributable to the booming growth in the area of optical disks. The optoelectronic equipment sector now accounts for 70% of the total Japanese optoelectronic market, a percentage which is not surprising in this modern age. What office can operate today without laser printers, copiers, or the essential facsimile machine? Bar-code readers are now expected items for supermarket checkout or inventory tracking. Add to those commodities the increasing number of consumer items (e.g., camcorders, CD players) and you have a splendid growth market waiting to be tapped.

Systems, while economically a much smaller percentage of the market than either components or equipment, should not be taken lightly. As we enter the growing age of information and the public demand grows larger, those pioneering companies setting the standards for faster and more efficient data processing and telecommunications systems stand to reap great benefits.

A careful evaluation of twenty top market leaders in the optoelectronics industry showed some similar trends. While some practices can be attributed to cultural differences, such as the Japanese combines known as *keiretsu* (privileged company groupings with guaranteed demand for each company's goods by other group members), overall the business techniques employed were strategies intent on assuring the long-term growth of company and its ability to weather fluctuations in the consumer market. These practices were evident on a global basis, and not dependent solely on whether the company involved was Japanese, German,

Swedish, French, or some other nationality. These effective business principles are highlighted in the following conclusions.

Conclusions

The foreign companies reviewed in this study appear to utilize a number of effective business practices in their efforts to both remain competitive and develop the optoelectronic applications of tomorrow. Using the following techniques that they employ could help U.S. industry recoup its losses in this technology.

The foreign competition is seriously committed toward funding for upgraded R&D facilities and equipment. For the companies surveyed, the average percentage of sales revenue devoted to R&D was 10.6%. Additionally, R&D personnel are retained even during lean times, preserving the valuable experience and enabling them to transition faster and more effectively into future projects.

Setting R&D goals for the future and sticking to these goals is an important objective. Long-term strategies need to be stressed, the U.S. pattern of seeking the short-term profit provides no clear direction for a company or the goals to be obtained.

In this world of increasing breakthroughs in science, the need for greater information gathering also plays an important part in fulfilling the research goal. The Japanese efforts to travel the globe in order to keep their research staffs abreast of the latest innovations and insider knowledge have helped them to more much faster in bringing successful products to market.

Enhancing manufacturing is also a high-rated goal of the foreign competition. Using new techniques and better equipment they can produce high quality goods at increasingly cheaper prices. The Japanese tend to devote twice as much R&D to manufacturing processes and tooling in comparison to U.S. companies. Their best engineers are assigned to production rather than design in order to establish the most cost-effective production methods.

Foreign companies focus on the training and continued retraining of their workers. In Germany, apprenticeship programs flourish, providing a steady influx of more productive, well-trained workers to the employment ranks. Many Japanese engineers obtain additional technical degrees that are funded by their company.

Foreign companies are embracing joint ventures with other firms since the cost of commercializing many new optoelectronic technologies is rapidly increasing beyond the means of even large corporations. These efforts bring together different areas of expertise, often resulting in a better product sooner. A joint venture can also help a company gain access to other valuable foreign markets.

To summarize, it's no mystery why the foreign optoelectronic industries are doing well in their competition against the U.S. They are committed to investing in the future, by funding research and training their workers now. Due to cultural and historical differences, it could be difficult for the U.S. to implement some foreign industrial policies that might be effective. However, the salient feature of these foreign policies--this commitment to investing in the future--is an important and realistic goal. The world has become a much smaller place; in order to compete effectively in the global market, U.S. companies must cast aside the old limited focus on short-term profits and goals, and embrace new long-term strategies for developing this technology.

APPENDIX A

Ref. #83

U.S. Department of Commerce
Bureau of Export Administration

OMB Control # 0694-0070
Expires 12-31-92

CRITICAL TECHNOLOGY ASSESSMENT: OPTOELECTRONICS

PURPOSE OF THIS ASSESSMENT

This critical technology assessment was initiated under Section 825 of the Defense Authorization Act of 1991. Section 825 requires the Secretary of Defense, in consultation with the Secretary of Commerce, to submit an annual report to the Armed Services Committees of the Senate and the House of Representatives on the financial and production status of industries supporting the Department of Defense's list of technologies deemed critical to national defense. This report will also be released to the public.

The objective of this assessment is to provide government policymakers and industry planners with needed information and analysis on the optoelectronics industry, a sector which DOD has deemed essential to the development of the next generation of weapon systems needed to ensure our national security. In completing this survey your firm will assist the U.S. Government in understanding the consequences of defense spending cutbacks for your sector as well as the opportunities for defense conversion activities.

THIS REPORT IS REQUIRED BY LAW

This report is required by law (50 U.S.C. App. Sec. 2155). Failure to report can result in a maximum fine of $1,000 or imprisonment up to one year, or both. Information furnished herewith is deemed confidential and will not be published except in accordance with Section 705 of the Defense Production Act of 1950, as amended (50 U.S.C. App. Sec. 2155). Where appropriate, information and material submitted should be designated "BUSINESS CONFIDENTIAL." No business proprietary information will be released under a Freedom of Information Act request.

EXEMPTION

If, since 1989, your firm did not produce or conduct research on optoelectronic-related products, you are not required to complete this form. If this is the case, please provide the information requested below and return this page:

Name of Company	Address (City, State)
Signature of Authorized Official	Date
Name of Official - Please Print	Phone

PLEASE COMPLETE & RETURN THIS QUESTIONNAIRE BY DECEMBER 4, 1992

Critical Technology Assessment:
Optoelectronics
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APPENDIX B

QUESTIONNAIRE FOR ACADEMIC INSTITUTIONS AND GOVERNMENT LABS: OPTOELECTRONICS

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