U.S. GLOBAL COMPETITIVENESS: OPTICAL FIBERS, TECHNOLOGY AND EQUIPMENT

Report to the Committee on Finance, U.S. Senate, Investigation No. 332-233, Under Section 332(g) of the Tariff Act of 1930

USITC PUBLICATION 2054

JANUARY 1988

United States International Trade Commission / Washington, DC 20436

UNITED STATES INTERNATIONAL TRADE COMMISSION

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Preface

On September 10, 1986, at the request of the Committee on Finance of the U.S. Senate 1/ and in accordance with section 332(g) of the Tariff Act of 1930 (19 U.S.C. 1332 (g)), the United States International Trade Commission instituted investigation No. 332-233, U.S. Global Competitiveness: Optical Fibers, Technology and Equipment. The Commission was asked to examine the U.S. optical fiber industry, and its major foreign competitors, to determine the impact of global competition on the industry, and to assess how the industry is responding to these dynamic forces. In its investigation, the Commission was asked by the Committee to analyze and address: (1) measures of the current competitiveness of the U.S. industry in domestic and foreign markets; (2) comparative strengths of U.S. and major foreign competitors in these markets; (3) the nature of the major competitive problems facing the U.S. industry; (4) the sources of these problems, including the extent to which they arise from special transitory or reversible situations or are the result of more fundamental or structural problems; and (5) the importance of U.S. and foreign markets to the future competitiveness of U.S. and foreign producers in terms of economies of scales, growth rates, and pre-empting of market advantages.

Notice of the investigation was given by posting copies of the notice of investigation at the Office of the Secretary, U.S. International Trade Commission, Washington, DC, and by publishing the notice in the Federal Register (51 F.R. 27264), July 30, 1986). 2/

A public hearing on this investigation was held on February 24, 1987, at the U.S. International Trade Commission Building, 701 E Street, NW, Washington, DC, and all persons who requested the opportunity were permitted to appear in person or be represented by counsel. 3/

In the course of this investigation, the Commission collected data and information from questionnaires sent to producers, importers, and purchasers of optical fiber, optical cable, and optical fibers put up in other forms.

In addition, information was gathered from various public and private sources; overseas posts of the U.S. Department of State; overseas field work in Japan, South Korea, Hong Kong, Australia, the United Kingdom, France, West Germany, Belgium, Sweden, Denmark, Italy, and the Netherlands; interviews with U.S. industry executives representing producers, importers, and purchasers of optical fiber, optical cable, other optical fiber forms, and related optoelectronics apparatus and equipment; and from interviews with industry and government officials in related industries, organizations, and agencies, as well as from public data gathered in other Commission studies and other sources. 4/

1/ The request from the Committee on Finance is reproduced in Appendix A.
2/ A copy of the Commission's Notice of Investigation is reproduced in Appendix B.
3/ A copy of the official transcript of this hearing appears in Appendix C.
4/ A discussion of the survey design and research methodology appears in Appendix E.

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Executive Summary 1/

Although applications using optical fibers have been in commercial use for over 20 years, only in this decade has fiber optics 2/ emerged as an efficient, practicable, and cost-efficient telecommunications technology. Optical fibers offer substantial information-carrying capacity, low signal loss, low weight, immunity from electromagnetic interference, compatibility with digital technology, and many other advantages. Long distance telecommunications networks have been one area where optical fiber transmission has proven to be particularly successful. Recent improvements in nondata-purpose glass and plastic optical fibers, bundles, and other optical fiber forms have increased the number of potential applications of fiber optics in advanced medical, industrial, and military applications as well.

The fiber optics industry has progressed rapidly over the past several years and has become a leading edge technology that supplies critical materials and systems for other important industries. Some experts believe that fiber optics technology may be a major determinant of the future competitiveness of other important U.S. industries. For example, its importance to the United States in the next generation of major computer developments, in manufacturing technology (including computer-integrated manufacturing techniques and robotics), and national defense may well be pivotal. For these reasons, the competitive status of the optical fiber industry is of particular importance to the future prospects of U.S. industrial competitiveness in general and is the reason for the selection of this industry for study.

The principal findings of this investigation are as follows:

- <u>The United States currently appears to be the global leader in the production technology for optical fiber. By virtue of important patent rights, the U.S. industry has thus far been able to dominate much of the world market.</u>

The largest U.S. producers, as the holders of a number of basic patents for the production of optical fiber, are able to influence much of the production and distribution of fiber in the United States and throughout the world through legal patent means and extensive licensing agreements.

1/ "Chairman Liebeler and Vice Chairman Brunsdale approved the report with reservations. For a copy of their views, contact the Office of the Secretary and request memorandum CO65-L-02.

2/ In this study, we are defining the fiber optics industry as that industry which produces optical fiber, cable, bundles, ribbon, or other optical fiber forms for transmission of voice, data or video communications, associated optoelectronic devices and equipment, (including but not limited to lasers, detectors, repeaters, connectors, and multiplexers), and optical fiber forms used for non-data purposes in various military, medical and industrial applications, such as sensors, gyros, faceplates, fiberscopes, endoscopes, and other fiber optic instrumentation. When referring to only those sectors involved in the production of optical fiber, cable, or other optical fiber forms, we shall use the term <u>optical fiber industry</u>. For this study, the term optoelectronics shall refer to those sectors of the U.S. optoelectronics industry producing optoelectronic devices involved in fiber optic transmission.

However, according to a number of industry analysts, as certain basic patents covering the manufacturing process for optical fiber expire -- some as early as 1988 -- the competitiveness of the U.S. industry is likely to be challenged by foreign producers possessing similar technology in Japan, the United Kingdom, West Germany, France, Italy, Sweden, the Netherlands, Australia, and Canada. Furthermore, certain newly industralized countries, particularly South Korea, are also expected to become competitive within the next few years (pp. 3-10 through 3-20).

- <u>Short-run, transitional factors affecting the competitiveness of U.S. fiber optics firms during 1983-86 included declining U.S. costs, exchange rate fluctuations, the lack of international standards, and a major slump in demand</u>.

Learning curve effects resulted in major cost reductions in fiber optic devices and systems during 1983-86, and caused declining producer prices in the United States. More recently, the decline in the value of the dollar has made U.S. products more attractive to consumers in U.S. and Western European markets relative to those of Japanese and European competitors.

Other factors having adverse effects on the U.S. industry include the current lack of other domestic or international standards in the industry, which has negatively affected both the supply side and demand side, and a major slump in demand caused by the completion of major long distance optical fiber networks in the United States (pp. 9-24 through 9-32).

- <u>The U.S. market for optical fiber is the largest and most open in the world, and has attracted the competitive efforts of major foreign fiber optic producers</u>.

The U.S. market now accounts for approximately one-half of current world consumption of optical fiber and cable, as well as for related optoelectronic equipment and systems used for fiber optic transmission. Following the 1984 breakup of AT&T, with its previous captive supplier relationship with Western Electric, the U.S. market has become the most open in the world with respect to telecommunications services and equipment and has attracted competition from firms based in such leading producing countries as Japan, Canada, the United Kingdom, West Germany, France, and Italy.

The telecommunications markets of the major producer countries of Japan, Western Europe, and Canada have not been nearly as open as the U.S. market, as markets in these countries have been controlled by government monopsonies (PTTs) which have shown strong preferences for national suppliers of equipment. Nevertheless, the largest U.S. producer, Corning Glass Works, has (by virtue of important patent rights) been able to retain and expand its share in foreign markets as well as in the United States. The company has gained market share in various overseas markets by developing joint ventures and licensing arrangements.

The U.S. market for nondata fiber applications in the military, industrial, and medical sectors is also growing, but is not nearly as large as in telecommunications and accounts for less than 5 percent of total fiber and cable sales. West Germany, the United Kingdom, Japan, and other industrialized and newly industrialized countries also have significant and growing markets for nondata fibers (pp. 4-1 through 4-13 and 5-19 through 5-32).

- <u>During 1983-85, U.S. demand for optical fiber and cable in long distance telecommunications applications expanded rapidly before stabilizing in 1986</u>.

The substantial increase in demand was due in part to the emergence of new competitors to AT&T in the long distance telecommunications market after the breakup of that company in 1984, and to improvements in optical fiber technology that permitted these providers to establish significant long distance service capacity very rapidly. However, in 1986 there was an unexpected slowdown in U.S. demand for optical fiber and cable as improvements in optoelectronic technology resulted in increased transmission speeds and information carrying capacity over the same optical fiber line. This situation led to at least several mergers and consolidations among major telecommunications carriers.

Though the slowdown in demand has continued into 1987, most industry observers believe it is only temporary and that demand will pick up again as more intensive use of optical fiber and cable is made in local area networks, military and industrial applications, and finally in subscriber links to the home. Before this can occur, however, standards will need to be developed and costs will have to be brought down in these more component-intensive networks and systems (pp. 5-1 through 5-20).

- <u>Demand for optical fiber and cable in important Western European long distance and data communications markets also expanded rapidly but did not peak until 1985 and 1986, before it subsided in 1987</u>.

During 1986, when market demand for optical fiber and cable became sluggish in the United States, demand in West Germany, the United Kingdom, France, and Canada continued to expand as major backbone networks in those countries were still being installed. However, by the middle of 1987, demand growth in those important foreign markets also began to slow down as long distance networks approached completion (pp. 4-1 through 4-13 and 10-6).

- <u>Demand for optical fiber and cable in East Asia, Japan, and Australia expanded rapidly and is expected to increase over the next few years in the telecommunications and data communications markets</u>.

Between 1986 and 1991, Japanese consumption of optical fiber is expected to increase by over eight times to 2.9 million fiber kilometers per year. Australian consumption is also projected to increase by 50 percent between 1987/88 and 1990/91. After that, however, Australian demand is expected to decline slightly and then level off. Demand in various East Asian markets is also likely to be strong over the next decade, as these countries develop new longhaul systems and replace existing networks with optical fiber cable (pp. 10-60 through 10-109).

- <u>The lack of industry standards has impeded growth in demand for certain types of fiber optic systems</u>.

The lack of industry standards has especially hindered the development of demand for optical fiber and cable in component-intensive local area and subscriber networks as well as in industrial environments. Firms are reluctant to allocate sizeable portions of their capital budgets for systems which may be outdated or incompatible with associated systems as soon as they are installed.

The demand for optical fiber systems over the next ten years is contingent, in part, on the development of international standards. The development of Integrated System Digital Networks (ISDN) should provide the necessary impetus for the development and adoption of international standards; however, the process is slow. Although it is difficult to measure the progress being made in other countries, various industry representatives believe that the Western Europeans, the Japanese, and the Australians are further along than the U.S. industry in the development of national standards for optoelectronic components used in fiber optic systems. If these countries continue to maintain their lead in this area, the U.S. industry will be at a distinct disadvantage (pp. 9-29 through 9-31).

- The U.S. optical fiber industry is very concentrated with two firms accounting for over 80 percent of total production.

The production of telecommunications and data transmission fibers is limited to those companies to whom Corning has granted licenses to manufacture fiber. At present, the only companies licensed to manufacture telecommunications grade optical fiber in the United States are AT&T, Alcatel-Celwave, and Spectran. Corning and AT&T are the dominant producers. Another smaller U.S. producer, Lightwave Technologies, Inc., is currently contesting Corning's claim that it has violated Corning's patents by producing optical fiber.

Although there may be as many as 20 U.S. producers of optical fiber used for nondata purposes, all but several of these are small firms (pp. 6-1 through 6-3).

- The U.S. optical cable industry is concentrated, but to a lesser extent than the optical fiber industry.

For the most part, U.S. optical cable producers began as telecommunications cable manufacturers, using copper wire rather than optical fiber. As the demand for optical cable developed, these manufacturers expanded their production facilities to include optical cable. In addition, since the 1984 AT&T divestiture, the U.S. market has seen the entry of several additional cable manufacturing subsidiaries of foreign-based telecommunications equipment manufacturers (pp. 6-3 through 6-5).

- The growth of the optical fiber industry has been very rapid. Between 1982 and 1985, U.S. sales of optical fiber and cable increased almost seven-fold from $88.6 million to $594 million, an average annual growth rate of 89 percent. Though the growth in shipments subsided in 1986, sales still reached $657.5 million in that year, an increase of 11 percent over 1985.

The largest portion of this growth came from increased sales of optical fiber and cable used in long distance telecommunications networks. Applications for data purposes (voice, video, and data) accounted for over

90 percent of all U.S. sales of fiber and cable. Prior to 1982, sales of optical fiber for such purposes were limited mostly to batches for test purposes (pp. 6-10 through 6-12).

o U.S. domestic shipments of nondata-purpose optical fibers, cables, and bundles also increased during 1983-86.

U.S. shipments of optical fiber used for nondata purposes also rose during the period but not nearly at the pace of optical fiber used for voice, video, and data communications. Such shipments accounted for less than 10 percent of total U.S. sales in 1986. Although shipments of mature products such as coherent and noncoherent bundles used principally for medical and industrial illumination and image-projection purposes remained fairly level over the period, substantial increases in domestic shipments of fiber optic sensors and faceplates were responsible for much of the growth in nondata fibers (pp. 6-1 through 6-12).

o U.S. practical capacity for optical fiber increased more than six-fold from 1983 to 1986, more than doubling between 1985 and 1986 alone.

Industry sources report that the substantial increase in production capacity for optical fiber was due to the strong growth in market demand during the rapid and extensive installation of long distance telecommunications networks by AT&T, the Regional Bell Operating Companies, MCI, U.S. Sprint, and other operating common carriers that entered the market after the AT&T divestiture.

Single mode fiber capacity increased from 78 percent of total telecommunications-grade fiber capacity in 1983 to 91 percent in 1986, as improved laser transmission devices and coupling techniques over the period increasingly made this the preferred medium over multimode fiber in long distance networks.

Much of the increase in production capacity for nondata fibers occurred in 1986, and was accounted for principally by increased capacity for manufacturing fiber optic faceplates and sensors. Requirements for these products increased as new uses for these products were developed; applications have included vision devices, submarine detection systems, and industrial sensing instrumentation (pp. 6-5 through 6-9).

o The U.S. balance of trade in optical fiber and cable improved in 1986 after falling in 1984 and 1985. Most of the changes in the trade balance were due to changing conditions in the U.S. market and exchange rate changes.

The nine-fold increase in U.S. imports from $11 million to $97 million during the 1983-85 period occurred during a period of very rapid expansion of telecommunications network capacity in the United States, much of which was based on fiber optic systems. While the U.S. industry began to develop additional production capacity during this period, much of the development was not operational until 1985-86. During 1985, U.S. imports accounted for nearly 15 percent of U.S. domestic consumption in the United States. However, when major long distance networks were completed in the U.S. market during 1986, and overall U.S. consumption leveled off, imports tapered off faster and fell to $71 million, or about 11 percent of U.S. consumption in the year, while exports nearly doubled to $68 million.. The weakening U.S. dollar relative to the currencies of its major foreign competitors also contributed to the improvement in the trade balance.

Because basic U.S. patents on optical fiber remained in effect during this period, most of the growth in imports was accounted for by optical cable and nondata purpose optical fiber. Canada was by far the largest supplier, accounting for $42 million or 59 percent of total imports. The bulk of the remaining imports were supplied by the United Kingdom (21 percent), Japan (10 percent), and West Germany (3 percent), (pp. 7-1 through 7-15).

- o <u>U.S. capacity utilization for optical fiber and cable for data purposes operated at or near 100 percent in 1983-85 but dropped precipitously in 1986</u>.

Because of the leveling off of consumption in the U.S. market in 1986, right after the establishment of substantial new manufacturing capacity, U.S. capacity utilization dropped to 64 percent for optical fiber. Meanwhile capacity utilization rates for optical fiber for nondata purposes increased moderately over the period, from 76 percent in 1983 to 80 percent in 1986 (pp. 6-9 through 6-10).

- o <u>During the 1980s, optical fiber and cable progressed from the research and early commercial stages to become relatively mature products</u>.

Between 1983 and 1986, annual average purchaser prices for glass telecommunications-grade (single mode) optical cable decreased by 25 percent from $517 to $318 per fiber kilometer. However, the downward trend in annual prices was not continuous. Industry officials attributed large 1984 drops in single mode optical fiber and cable prices to production learning curve effects and increases in supply. Strong demand growth for optical fiber and cable in 1984 and 1985 helped prices stabilize in those years. However, simultaneous declines in demand growth and increases in supply caused prices to drop significantly in 1986 and in the first two quarters of 1987. The shifts in demand were attributed to the completion of U.S. long distance networks and the opening of new U.S. plants, respectively, with a resultant increase in production capacity (pp. 9-1 through 9-12).

- o <u>The optoelectronics side of the fiber optics industry is currently in a greater state of flux than the fiber and cable portion of the industry</u>.

During the past two years, suppliers of longwave laser devices for use in fiber optic telecommunication systems have increased from about a half-dozen to 20. The rapid expansion of supply and simultaneous contraction in consumption has resulted in a downward pressure in prices which are from one-half to one-third what they were in 1985. Although many of the newer entrants to the laser portion of the fiber optics industry are U.S. manufacturers, these small, new companies are more vulnerable to plummeting prices than are the larger and more established Japanese electronic producers responsible for most of that country's laser production.

Industry observers attribute the rapid success of the U.S. laser and detector segment of the fiber optic industry, in both U.S. and overseas (particularly European) markets, largely to superior product technology resulting from an above-average rate of investment in research and development. Company officials of the relatively small but innovative firms that have been especially successful in this sector are worried that the challenge from larger, more fully integrated foreign producers will make it difficult for their firms to carry on the level of research and development needed to remain viable in this rapidly changing industry (pp. 8-1 through 8-17). 1/

o <u>During 1983-86, total research and development expenditures reported by U.S. producers in response to the Commission questionnaire more than tripled to $66 million</u>.

Most of the reported increase occurred during the second half of the period, with a 63-percent increase in spending reported between 1984 and 1985 and a 78-percent increase between 1985 and 1986. In interviews with the Commission, various industry analysts indicated that research and development activity was expected to continue at the same pace as it had during the 1983-86 period.

These industry representatives noted that 95 percent of the research and development work on fiber optics in U.S. companies is internally generated and that the long-run nature of much research in this area conflicts with their firms' emphasis on realizing short-run profits. These individuals pointed out that foreign manufacturers, especially in Western Europe and Japan, are at an advantage since much of their research is funded through joint efforts of the government and industry and consequently has a longer-term duration and focus (pp. 11-6 through 11-7).

o <u>Most of the competition faced by U.S. producers in U.S. and global markets for optical fiber and cable comes from manufacturers in Western Europe, Canada, and Japan</u>.

The principal European competition has come from firms in the four major industrial countries of the United Kingdom, West Germany, France, and Italy. However, strong competitors in optical fiber and cable are found in the Netherlands and Sweden as well.

Northern Telecom, a major Canadian manufacturer of telecommunications equipment, has benefited from its proximity to the United States and its established presence in the U.S. market, and has become the largest single foreign supplier of optical cable to the United States.

1/ It should be noted that, in addition to these smaller U.S. component firms in the optoelectronics sector of the industry, major integrated producers in the U.S. telecommunicating and electonics industries such as AT&T and the Rockwell Corporation have indicated that they intend to increase production of their own components for optoelectronic systems which they will use to supply their own fiber optic networks. Previously, these larger companies depended to a large extent on outside component manufacturers, including Japanese producers for a large number of the components (especially lasers) used in their total optoelectronic systems.

The Japanese industry and government have reportedly targeted the fiber optics industry for special support and attention to give it a competitive advantage in the international market. Although Japan has thus far been inhibited by U.S. patents from effectively competing in the U.S. market for optical fiber, there is little doubt among industry officials that Japan is a major supplier of optical fiber, as well as other related technology and equipment in the global marketplace (pp. 4-1 through 4-24, 7-1 through 7-15, and 10-1 through 10-109).

o <u>Major competitors in Japan and Western Europe are working to compete effectively with leading U.S. suppliers in the global fiber optics market.</u>

Japanese producers are reportedly working with major plant equipment manufacturers in that country to develop continuous fiber drawing technology and machinery, both to increase their efficiency in optical fiber production and to overcome present patent restraints.

Japan is generally regarded as the leader in applied research and product development of certain optoelectronic components and systems that drive optical fiber lightwave systems. This is particularly true with regard to its advanced work in gallium arsenide and certain laser technologies. Japanese producers have also gained more experience than U.S. or Western European firms in the mass production and commercialization of certain optoelectronic devices. Included in these are compact disk systems that many industry experts believe will be transferable in the near future to optical fiber transmission systems, especially those used in local area networks and subscriber links to the home.

European producers have also developed new products and production methods. With the assistance of their government-controlled telecommunications monopolies (PTTs), producers in European countries have been engaged in research efforts that may result in European producers gaining an edge in the development and production of certain fiber optic systems, particularly those used in advanced data communications, local area networks, and eventually subscriber links to the home. In the near future, local subscriber links are expected to have a greater effect on the demand for fiber optic products than have long distance telecommunication systems.

Because European producers face a relatively fragmented domestic market, controlled by each country's PTT, the European Community has initiated several long-range programs that would permit joint research and development efforts by firms in different countries, and the consolidation of individual European telecommunication markets into one common market so that European companies can compete on a more equal footing with the United States and Japan (pp. 10-1 through 10-109).

o <u>Some industry analysts believe that those who develop new optoelectronic technologies needed for using optical fiber more widely and effectively in its many potential applications stand, on the basis of present evidence, to gain a dominant and possibly controlling influence on the sale of optical fiber and cables</u>.

How effectively U.S. optical fiber producers develop these capabilities, or develop relationships with those who have them, could be crucial to their future success. Although there is evidence that at least one or two of the major U.S. fiber/cable producers have been attempting to establish relationships with optoelectronic component firms, officials of some of the more important U.S. optoelectronic manufacturers have concluded that such ventures are not being pursued aggressively enough to counter efforts by the more fully integrated Japanese and European firms (pp. 8-1 through 8-17).

o <u>Though the U.S. market for optical fiber and cable, and related optoelectronic components and systems, is the largest and most open in the world, U.S. industry officials generally indicated that foreign competition in the U.S. market is not a real problem. They maintain that the real problem for U.S. firms is that many of the foreign markets are closed to U.S. companies</u>.

Company officials responding to the Commission questionnaire indicated that U.S. government efforts to encourage the opening of foreign markets, including U.S.-Japanese bilateral talks to open up Japan's telecommunications equipment market, have been useful to them and therefore should be continued.

However, the officials warned that protectionist trade policies in response to foreign competitor behavior might prove to be counterproductive as a result of the increasing internationalization of U.S. corporations in the fiber optics industry. Many of the U.S. companies have facilities in other countries or have entered into joint ventures with firms in overseas markets. An increase in U.S. tariff and nontariff barriers might actually make it more difficult for the U.S. industry to compete in the international market because the barriers would potentially increase the price of intermediate goods and component parts, many of which must be imported (pp. 11-7 through 11-9).

o <u>U.S. firms responding to the Commission questionnaire consider the U.S. industry to be competitive in the U.S. market; however, 60 percent of U.S. producers indicated that foreign producers have an advantage in the international market</u>.

The strong patent position and technology lead of U.S. industry has clearly helped it retain and expand its market share in the U.S. and world market. However, various industry analysts wonder what will happen when important basic patents of the leading U.S. producers run out during the next several years.

Because domestic demand for optical fiber and cable has declined somewhat during the past year and a half, the U.S. producers' less competitive position in the international market is of some concern to the industry as a whole. U.S. producers have indicated that they are focusing on reducing costs, and working to increase the efficacy of their marketing, as well as their research and development (pp. 11-1 through 11-3).

- <u>The problems with U.S. produced fiber optics products most frequently cited by both U.S. and foreign industry officials are related to the lack of system standards, insufficient marketing and technical assistance support, lack of favorable financing, and delays, uncertainties and other problems generated by U.S. export control policy</u>.

Other factors affecting U.S. competitiveness cited by U.S. and foreign industry officials included the lack of funding provided by the U.S. government for research and development in this technology, lack of market and industry data, and marketing practices that inhibit U.S. success in overseas markets (pp. 11-1 through 11-20).

- <u>It is clear that the U.S. optical fiber and cable industry currently is competitive in the U.S. and global market. It is not clear, however, whether the U.S. industry will remain competitive</u>.

The most important factors affecting the future competitiveness of the U.S. industry include access to foreign markets, U.S. export controls, the ability of the U.S. industry to develop new technology, and to gain the lead in establishing international standards. Without additional action on the part of the U.S. industry and the U.S. government, some critical foreign markets will remain closed, or access will be quite limited. In addition, if U.S. export control procedures are not streamlined and if export control lists are not revised more frequently to reflect current foreign availability of new technology, U.S. industry efforts to compete internationally will continue to be hampered. Faced with limited access to foreign markets and increased competition in the U.S. market as certain key U.S. patents expire, the U.S. industry may find itself losing its competitive edge.

A continued emphasis by U.S. government on military-related research and development and by U.S. industry on research and development projects that emphasize short-term profit objectives, most observers believe, is likely to result in further deterioration of the U.S. industry's relative position in the international market. Such deterioration will be exacerbated if European and Japanese governments make progress in their efforts to develop comprehensive, commercially oriented R&D programs.

Finally, a continued ad hoc approach by U.S. industry to the development of standards may cause it to lose ground to more aggressive Japanese and European efforts in this area. In short, while the U.S. industry presently enjoys a strong competitive position in the domestic market, a number of forces have the potential to erode that position unless the industry makes sufficient headway in meeting the challenges in both optical fiber and cable, and in optoelectronics. The U.S. government can either ease or complicate industry efforts through its policies in export controls, export finance, and the allocation of government-funded R&D priorities (pp. 11-12 through 11-20).

CHAPTER 1. INTRODUCTION AND CONCEPTS OF COMPETITIVENESS 1/

To provide measures of competitiveness for the fiber optics industry, it is necessary to understand what is meant by the term, competitiveness. The following sections provide a brief overview of (1) selected literature dealing with industrial and international competitiveness, (2) general measurements of competitiveness, and (3) determinants of competitiveness in the fiber optics industry.

Definitions of Competitiveness

In a general sense, everyone understands what it means to be competitive. However, despite much research which has focused on industrial and international competitiveness, there is no single, commonly accepted definition of the concept. The term is often applied interchangeably to international and industrial competitiveness. 2/ Therefore, the first task of any competitiveness study is to identify appropriate economic indicators of competitiveness for a particular level of analysis.

Developing quantitative measures of competitiveness is not an easy matter. As one economist noted in discussing U.S. price competitiveness, it is not possible to develop absolute measures of price competitiveness. Therefore, appropriate measures can only be in relative terms.3/

Some theorists define competitiveness simply as the ability of a nation's industry to operate successfully in international markets, as measured by export shares. Definitions of international competitiveness most often are based on some measure of comparative advantage for the production and international distribution of certain goods and services. Nations enjoying the lowest average unit costs for particular goods and services are likely to become major exporters. 4/ Consequently, determinants of comparative advantage include: factor endowments, technological differences, scale economies, market barriers and imperfections, and demand factors. 5/

1/ See app. D for a review of selected literature on competitiveness.
2/ Gary L. Guenther, "Industrial Competitiveness: Definitions, Measures, and Key Determinants," CRS Report No. 86-535 E. The Library of Congress, February 3, 1986, p. 4. Another study notes that: "National and corporate competitiveness are analytically distinct but practically intertwined," Stephen Cohen, David Teece, Laura D'Andrea Tyson, and John Zysman, Competitiveness, November 1984, p. 2.
3/ Suomela, who is currently Director of the Office of Economics of the U.S. International Trade Commission, stated, "...we cannot say that a firm is twice as price competitive if it cuts all of its prices by 50 percent, only that the firm has become more price competitive." John W. Suomela, "The Meaning and Measurement of International Price Competitiveness," Business and Economics Section, Proceedings of the American Statistical Association, 1978.
4/ Op. cit., Gary L. Guenther.
5/ R.M. Stern, "Testing Trade Theories," International Trade and Finance: Frontiers of Research, (1976) P.B. Kenner, editor, New York: Cambridge University Press.

Although the concept of comparative advantage provides a greater understanding of competitiveness in the international economic environment, it does not explain all of the factors that affect competitiveness. Much research has been conducted at the industry level also.

One area of research has focused on the process of technological change. For instance, Vernon addressed this issue to a certain extent in his "product life cycle" theory. The theory suggests that manufacturers generally pass through four stages: introduction, growth, maturity, and decline. Maturity signifies the point at which product standardization occurs; typically in a mature industry, manufacturers will switch to offshore production to lower their average unit costs and maximize their competitive advantage. 1/

Although the product life cycle theory does not completely explain industrial growth and development, it has provided a basis for further research concerning firms' decisions regarding research and development and the technological advantages gained by such R&D activity. The technological innovation which results from research and development extends the growth stage of the product life cycle and is a major determinant of competitiveness. Moreover, Vernon recognized that competitiveness is not a static concept. Because competitive conditions between industries and between nations change over time, an analysis of U.S. competitiveness is more usefully discussed within a comparative, time series framework. 2/

Measurements of Competitiveness in the International Market

Analyzing competitiveness quantitatively involves constructing two measures. The first measure indicates an industry's competitive performance (e.g., share of world trade); the second quantifies the major determinants of competitiveness.

Although difficult to interpret, a number of performance measures have been used to indicate international competitiveness. 3/ One often-used indicator of U.S. international competitiveness is the trade balance. However, this measure is limited because "(1) It does not speak directly to the level or growth in U.S. exports; (2) U.S. trade deficits partially reflect the relative growth rates of the U.S. and its trading partners". 4/

1/ Raymond Vernon, "International Investment and International Trade in the Product Cycle," Quarterly Journal of Economics, 80 (1966), pp. 190-207.
2/ A different approach has been taken by the U.S. Department of Commerce. The Office of Competitive Assessment, U.S. Department of Commerce, has produced a series of studies covering various U.S. industries, including the fiber optics industry. These reports provide a descriptive account of recent trends in the industry and develop an analytical framework within which to compare the particular U.S. industry to its counterparts in major producer countries. For example, see A Competitive Assessment of the U.S. Fiber Optics Industry, Office of Telecommunications, International Trade Administration, U.S. Department of Commerce, September 1984 (update in progress).
3/ As discussed earlier, measures of competitiveness are relative, for the most part; thus, these measures may simply indicate trends.
4/ "U.S. International Competitiveness: Perception and Reality" New York Stock Exchange Office of Economic Research, August 1984, p. 9.

A second performance indicator is the share of U.S. exports in global markets, which attempts to measure how well an industry does in world markets. This measure also suffers from a number of shortcomings. What is the appropriate base year? What are the influences of exchange rates? Is a large share in the world market a desirable goal from the standpoint of the country as a whole?

A third performance indicator is the profitability of a domestic industry. When an industry, such as fiber optics, is composed of multinational companies with production facilities throughout the world, it can be difficult to equate industry profitability with geographic competitiveness. 1/ Furthermore, when a company produces a number of products in a vertically integrated environment, it is often difficult to relate the profitability of the company to one production facility.

Since prices, ultimately based on cost considerations, are important determinants of overall international competitiveness (i.e., over all industries), a number of aggregate price indexes have been developed to measure determinants of competitiveness. Morgan Guaranty Trust Company has published ratios of wholesale price indexes for manufacturing. The Department of Commerce has used the ratio of the U.S. wholesale price index for manufactured goods to the import unit value index for manufactured goods. The United Kingdom Treasury has used a variety of ratios including ratios of export unit values, wholesale price indexes, and wholesale prices to import unit values and unit labor costs. The OECD has also produced similar ratios that they call competitiveness indicators.

Determinants of Competitiveness for the Fiber Optics Industry

This investigation focuses on the fiber optics industry. The international competitiveness of the U.S. economy is examined only to the extent that it affects the competitiveness of the industry. To assess the prospects for the U.S. industry to maintain market position with respect to its foreign counterparts, this study evaluates the industry's performance over the past four years. 2/

A number of factors affect competitiveness: some are within the control of the firms in the industry, while some are exogenous factors which can only be affected by national governments through policy initiatives. Important determinants of industrial competitiveness that have been identified by a number of researchers are (1) the cost structure of the industry, (2) the quality of the industry's output and its inputs, (3) exchange rates, and (4) government policies that affect industry structure and performance. 3/ All of

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1/ Robert E. Lipsey and Irving B. Kravis, "The Competitive Position of U.S. Manufacturing Firms," Banca Nazionale del Lavoro Quarterly Review, No. 153, June 1985.

2/ The study focused on the 1983-86 period primarily because prior to 1983, production levels were fairly insignificant and data were not readily available.

3/ Guenther, p. 11. See also, President's Commission of Industrial Competitiveness, Global Competition: The New Reality, January 1985, Volume 2, Office of Technology Assessment, p. 20 and, "U.S. International Competitiveness: Perception and Reality," New York Stock Exchange Office of Economic Research, August 1984, p. 8.

these factors have had a direct bearing on the competitiveness of the fiber optics industry. Of particular importance in the fiber optics industry are (1) determinants which affect the quality of the industry's inputs and its output, (2) government policies that have an impact on the structure of the industry--particularly in countries where the telecommunications industry is a national monopoly, and (3) the impact that market structure has on performance as well as the effect it has on behavior of the industry.

In particular, the fiber optics industry has been characterized by rapid change, market segmentation, and, within certain segments, a high degree of concentration. Because much of the fiber optics production and technology is geared for the telecommunications market, it is important to examine the results of that market's deregulation on producers within the industry. In addition, a significant amount of optical fiber and cable production is targeted for the military market, and consequently is affected by the military procurement process. All of this has had an impact not only on what is produced, but also on the focus of basic research and product development.

The degree of concentration of market power and patents, rapid technological developments, and relatively high capital intensiveness of the industry combine to make barriers to entry into the market a particular concern. The importance of learning curves to industries such as fiber optics has also been examined by a number of researchers. One conclusion concerning the effect of learning curves on industrial competitiveness is that mastering the learning curve and capitalizing on the experience is one way in which a company may gain an advantage over its competition. That is, while the product itself may not be easily appropriated, the actual production processes are appropriable. 1/

Recent analysis has also focused on diversification or vertical integration as additional determinants of competitiveness. Certain firms have developed competitive advantage beyond what their costs, learning curve, and manufacturing proficiency would provide, by positioning themselves strategically. Through diversification or vertical integration, firms have sought ways to minimize the risks associated with product development and market expansion. 2/ In addition, firms have gained access to foreign markets by

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1/ Richard Baldwin and Paul Krugman, "Market Access and International Competition: A Simulation Study of 16k Random Access Memories," NBER Working Paper #1936, June 1986, pp. 7-8.

Some observers note that Japanese firms, among others, have demonstrated how concentrated and persistent efforts to improve production efficiency and product quality can permit new entrants to gain competitive advantage over original product innovators.

2/ Diversification allows firms to minimize risk by being able to undertake research and development projects in different product areas. According to some analysts, this strategy may allow diversified firms to gain competitive advantage over firms that are not diversified. See, for example, William L. Baldwin and John T. Scott, Market Structure and Technological Change, New York: Harwood Academic Publishers, 1987, p. 18.

entering into joint ventures, establishing subsidiaries, as well as entering into technology transfer agreements. 1/

Finally, government intervention is a critical factor in the competitiveness of this industry. It has been suggested that one of the factors contributing to the Japanese industry's ability to compete is the Japanese government's role in targeting this industry and subsequently supporting it through various research, financing, and development efforts. In various countries, the governments have protected the domestic industry through the institution of various tariff measures. Government support also occurs indirectly, through tax credits for research and development and other measures which facilitate the development and growth of the industry.

Scope of the Report

This report analyzes the characteristics of the international market for fiber optics products and presents a profile of the U.S. industry. For the purpose of this study, the U.S. industry is defined as including those firms operating domestic facilities for the production of optical fiber and optical cable used for data and non-data purposes. Firms which produce optoelectronic components used in fiber optic systems are also included to the extent that developments in the various sectors of the optoelectronics industry have an impact on the continued development of the optical fiber and optical cable industry. In addition, industry profiles for selected producer countries are presented in Chapter 10.

Market information was collected through the use of staff interviews and questionnaires, as well as secondary sources. Questionnaires were sent to optical fiber and cable producers and importers as well as to selected users of these products. 2/

The report uses this information in conjunction with information collected through interviews with selected foreign producers and industry analysts to formulate comparisons of various foreign producers. These comparisons are used to assess the state of the U.S. industry in the international market.

1/ These strategies have been pursued by U.S. and foreign fiber optics producers. The demand for optical fiber and cable is largely a function of the demand for optical fiber systems. Thus, leadership in optoelectronics or in fiber optic systems may become a determinant of competitiveness in fiber optics which is equal to or even more important than competitiveness in optical fiber production *per se*. The initial producers of optical fiber and cable have emphasized patent advantage and dominance of major markets; latecomers are seeking to gain market shares through leadership in the development of new (e.g. optoelectronic) technologies and the capability to provide and service optical systems.
2/ See app. E for a review of the study's survey design and methodology.

CHAPTER 2. PRODUCT DESCRIPTION AND USES 1/

Optical fibers are used in a variety of data and non-data light transmission systems. These include such non-data elements and apparatus as illumination devices and image transmission systems in industrial and medical applications, laser delivery systems in advanced microsurgical techniques, fiber optic sensors, gyros, and face plates in industrial and military systems. The most recent developments in fiber optic systems, however, have been in long distance telecommunications, and other data transmission applications. These include the communication of voice, data, and video information in local area and subscriber networks, computer networks, industrial process and control systems, and in cable TV. Data transmission systems, especially long distance telecommunications, currently represent the dominant application of optical fibers. However, many of the non-data elements and systems were commercially viable in the 1960s and 1970s before research and development on telecommunications-quality fibers reduced attenuation, 2/ or signal loss, of these fibers to the extent necessary to make them viable in commercial telecommunication systems by the late 1970s.

Telecommunication and other data transmission systems are based on systems consisting of optical fibers and associated lightwave optoelectronic transmission, connecting, and detecting or receiving components (figure 2-1). The transmitted information is converted from electrical impulses into light waves by a laser or light emitting diode. 3/ At the point of reception, the light waves are converted back into electrical impulses by fiber-optic detectors. 4/

Optical Fibers for Voice, Video, and Data Communications

Optical fibers used for voice, video, and data communications are hair-thin strands of glass or plastic which are usually combined in cables for transmitting information in the form of light pulses from one point to another. Optical fibers are made up of two concentric layers, an optical core, or inner layer, which has a refractive index 5/ higher than the outer layer, or optical cladding. Light injected into the core strikes the core-to-cladding interface at greater than the critical angle and is reflected back into the core by the principle of total internal reflection. Since the

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1/ The descriptions of optical fibers, cables, and optoelectronic components and systems in this section were developed primarily from notes taken in staff interviews with engineers and technology experts of leading fiber optics manufacturers and from definitions and overviews of fiber optic technology contained in U.S. Long Distance Fiber Optic Networks: Technology Evolution and Advanced Concepts, IGI Consulting, Inc., prepared for NASA, October, 1986, International Fiber Optics and Communications, Annual Handbook and Buyers Guide, IGI Consulting, 1986, and Fiber Optics and Lightwave Communication Standard Dictionary, Martin Wein, Van Nostrand Reinhold Company, 1981.
2/ See app. F for the glossary of techical terms.
3/ See app. F for the glossary of technical terms.
4/ Ibid.
5/ Ibid.

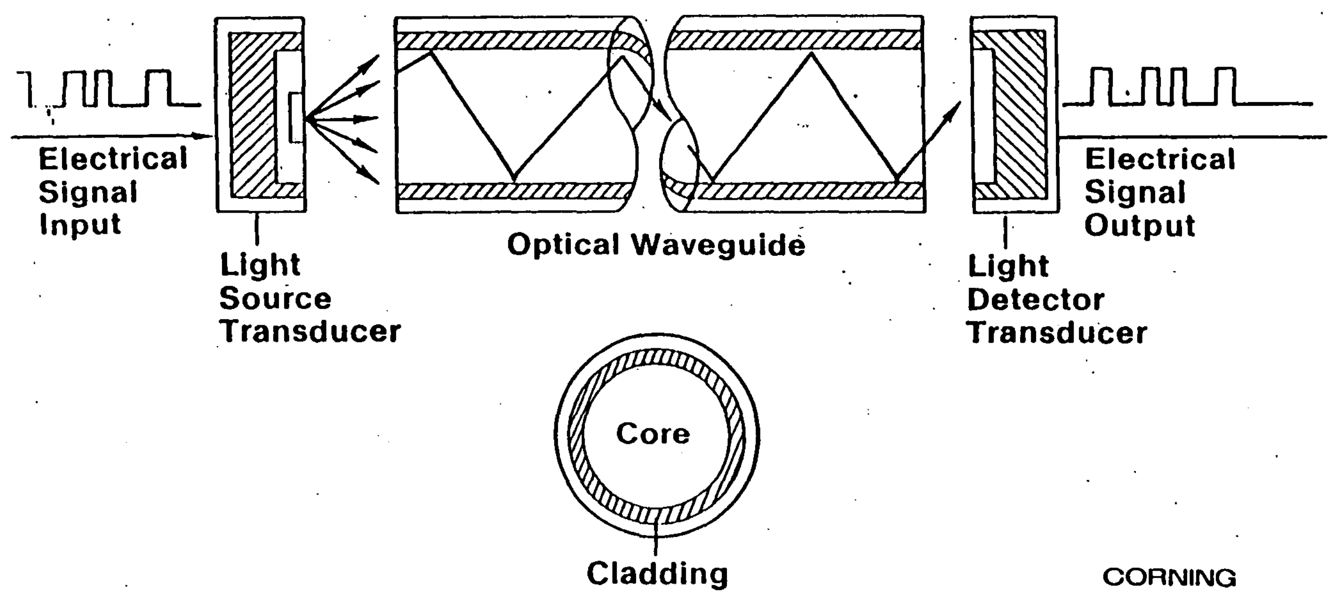


Figure 2-1
Optical fiber transmission system

angles of incidence and reflection are equal, light striking the interface at more than the critical angle is refracted out of the cladding and is absorbed, or is transmitted out of the fiber. The remaining light is transmitted through the fiber, where it is channeled into various modes, which represent allowed solutions to electro-magnetic field equations. Each mode is consequently a possible path for a light ray traveling down a fiber.

All Glass Multimode Step-index Fibers 1/

Glass multimode optical fibers (fig. 2-2) are optical fibers containing glass cores and claddings that support the propagation of more than one mode of a given wavelength and typically have cores of greater than 10 microns. 2/ Because the modes in multimode step-indexed fibers are transmitted over different waves or path lengths at different velocities, reflecting at different angles from the interface of the core and cladding, they arrive at the receiver, or detector, at different times. The resulting pulse spreads ("modal dispersion") limit the bandwidth, or information carrying capacity, of the system.

All Glass Multimode Graded Index Fibers

These are a type of multimode fiber designed to overcome modal dispersion. Their cores consist of a series of concentric rings, each with a gradually lower refractive index as they extend outwards from the axis. Because light travels more rapidly in a lower-index medium, light at a greater distance from the fiber axis travels faster. The changes of path length and velocity caused by the varying refractive indexes reduces the differences in propagation time between the various modes reaching the detector. This reduces the dispersion of the signal and allows for greater bandwidth, or information carrying capacity of such fibers.

All Glass Monomode Optical Fibers

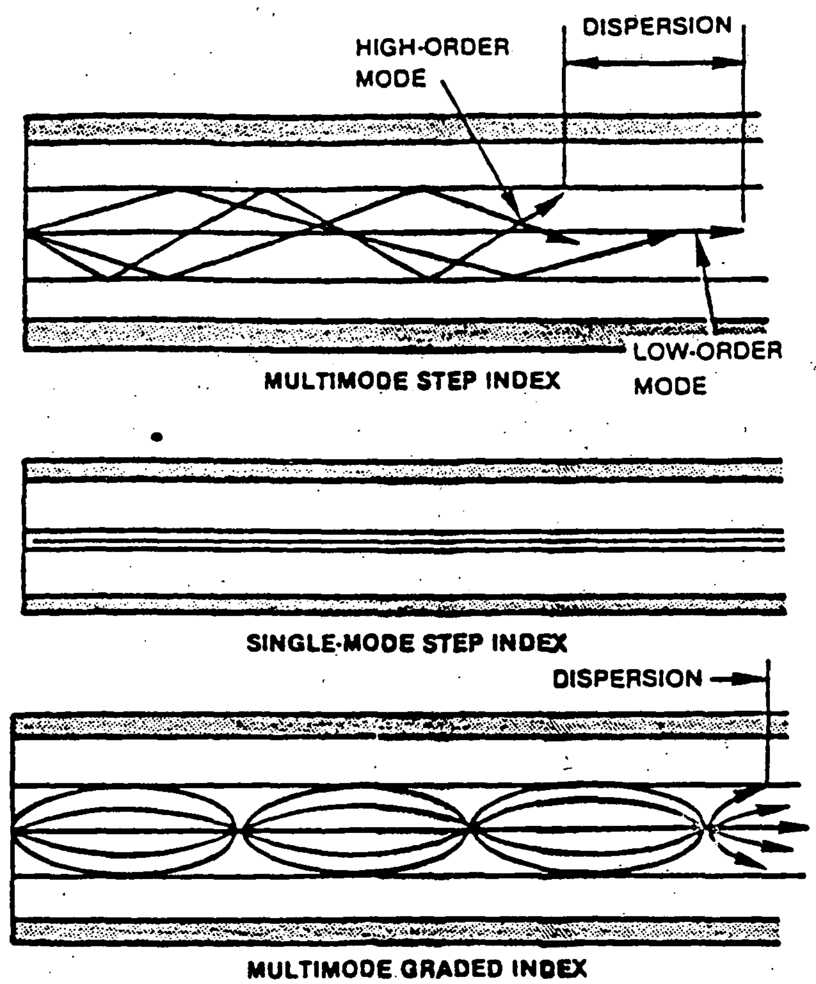
These are glass core and cladding single mode, step-index fibers that, because of their relatively small core diameters (2 to 10 microns), allow the propagation of only one mode of a given wavelength of light. This mode travels essentially parallel to the axis of the core, and thus minimizes dispersion and increases bandwidth. Because light is transmitted at longer wave lengths than multimode fiber types (above 1,300 nanometers (nm)), its use reduces attenuation 3/ losses and permits transmission over longer distances.

1/ A micron, or micrometer, is a unit of length equal to one millionth of a meter. Both multimode and monomode optical fibers used for lightwave transmission systems typically have total diameters of 125 microns, about the diameter of an average human hair.

2/ A micron, or micrometer, is a unit of length equal to one millionth of a meter. Both multimode and monomode optical fibers used for lightwave transmission systems typically have total diameters of 125 microns, about the diameter of an average human hair.

3/ See app. F for the glossary of technical terms.

Figure 2-2
Multimode and singlemode optical fibers



Amp, Inc.

At the present time, most long distance telephone and telecommunications data are transmitted over monomode fibers in the United States.

Dispersion-Shifted Fibers

These are recently developed glass fibers which reduce dispersion and offer higher data rates and transmission over longer distances than traditional glass fibers.

Plastic Clad Glass and All Plastic Optical Fibers

These consist of either an optical fiber with a glass optical core and a plastic optical cladding, or a plastic optical core and a plastic optical cladding. Plastic fibers offer the advantages of low weight, large diameter core, easy connection, low cost, and operation in the visible range of the spectrum. However, due to their relatively high loss (attenuation) and low bandwidth, these fibers are used primarily in short-distance applications.

Optical Cable for Voice, Video, and Data Communications

Optical cables (fig. 2-3) for voice, video, and data communications are optical fibers incorporated into an assembly of materials that provides tensile strength, external protection, and handling properties comparable to those of equivalent copper or coaxial cables. Presently, cables typically used in long distance telecommunications systems in the United States consist of a varying number of all glass monomode (single mode) optical fibers. However, some cables, especially those installed prior to 1983, use multimode optical fibers. Most local area network, computer-interconnect, and other premises-type cables are composed of multimode glass optical fibers; this reliance on multimode fiber may decrease in the future since, some industry officials believe, monomode glass fibers may eventually replace multimode fibers in such installations. Cables comprising plastic clad glass fibers are typically used in installations requiring shorter lengths and minimum bandwidths.

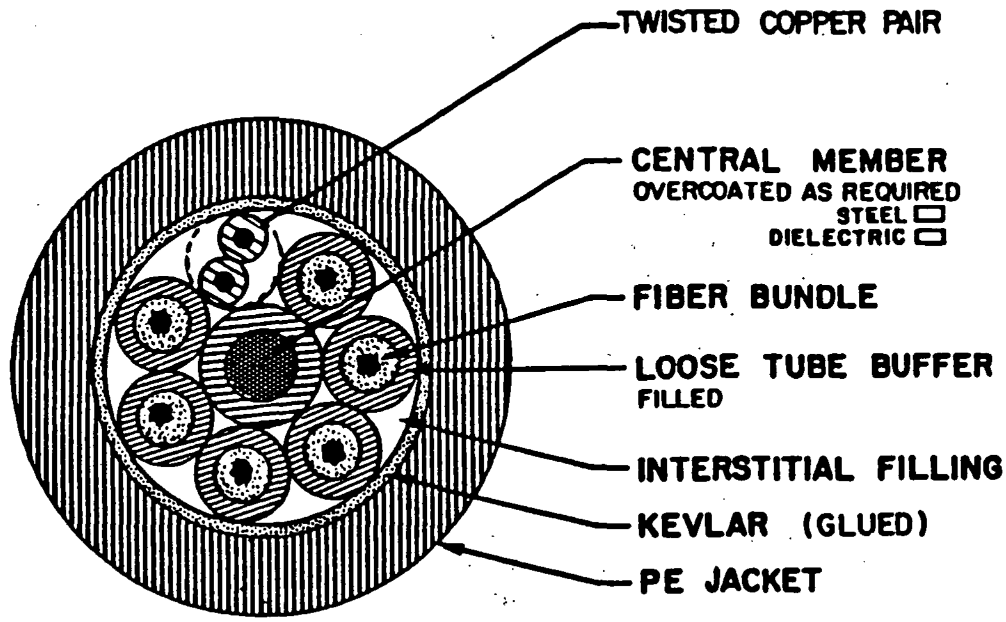
Tight Buffered Optical Cables

Tight buffered optical cable is one of the two most common construction methods for incorporating an optical fiber or fibers in a cable. In a tight jacket, a material such as PVC or polyurethane is bound tightly around the fiber and provides good crush resistance and bend radii, which makes these cables ideal for short-distance, less protected applications.

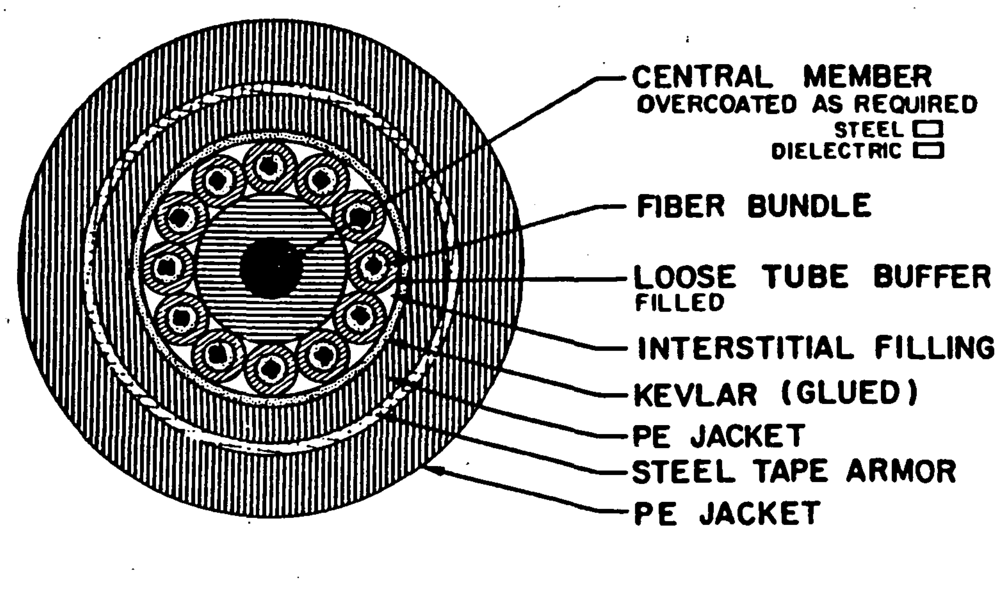
Loose Tube Optical Cables

In loose tube cables, the optical fiber is encapsulated in a plastic tube that has an inside diameter several times larger than the fiber's diameter. Such a construction loosens the fiber from the rest of the cable, allowing the cable to be twisted, pulled and stressed with little effect on the optical fibers. Long distance networks in the United States typically contain loose tube fiber cables since the decoupling of the fiber from the tube allows the

Figure 2-3
Basic cable designs



(LOOSE TUBE)CABLE
31-36 FIBERS-SINGLE JACKET- 1 TWISTED COPPER PAIR
25-30 FIBERS - SINGLE JACKET - 2 TWISTED COPPER PAIR
(AN ADDITIONAL COPPER PAIR REPLACES ANY BUFFER TUBE)



(LOOSE TUBE) CABLE
67-72 FIBERS—DOUBLE JACKET—STEEL TAPE ARMOR

cables to be pulled and stretched as they are being installed, without harming the fiber. Cable to be buried underground is often constructed with steel sheathing for protection against rodents and other elements.

Cable strength members in both tight buffered and loose tube optical cables are typically made of a Dupont manufactured Aramid yarn (Kevlar), or steel, either in the center or in the periphery of the cable. The tubes in loose cable are also often filled with jelly, powder, or pressurized air to protect against moisture.

Specialized Optical Cables

Optical cables can be constructed in a variety of ways to meet specialized environmental conditions. Undersea cables are constructed to withstand the great amount of pressure exerted by several kilometers of ocean water above them and are given protection from problems of hydrogenation that may result from the undersea environment. Military tactical and nontactical system cables are designed to meet various extreme or rugged conditions encountered in strategic or battlefield environments.

Various local area network or premise wiring systems require a variety of types of cables depending on the particular application within the network. For example, duplex cables, consisting of two optical fibers in a single cable structure, are typically used within building or premises locations; typically one fiber is used to transmit signals in one direction and the other to transmit in the opposite direction. Breakout cables are used to breakout or separate particular fibers or groups of fibers in an incoming cable for transmission to different points or terminals in a network. Plenum cables are polyvinyl chloride (PVC) jacketed optical cables designed for use in building risers and in horizontal and vertical distribution; the cables contain no metallic elements, and are often classified by Underwriters Laboratories as to their flame propagation characteristics. Interconnect cables are constructed in a variety of ways to permit viable interfaces with a variety of network terminals, mainframe and microcomputers, word processors, and other system components.

Non-data Optical Fiber Forms

There are a number of non-data types of optical fiber, cable and other multiple fiber forms being used in industrial, military, and medical applications.

Coherent Bundles

These are aligned bundles of optical fibers arranged so that coordinates of each fiber are the same at the two ends of the bundles. The bundles permit the transmission of images and are used in various applications; for example, medical instruments such as endoscopes or bronchoscopes permit doctors to visualize interior cavities of the body.

Noncoherent Bundles

These are a collection of optical fibers arranged randomly for the purpose of transmitting light but not images. One important application of noncoherent bundles is in medical instrumentation to provide illumination in remote areas of the body. They are also used in various other application such as automobiles, where they are used in dashboard illumination.

Faceplates

These consist of fused coherent bundles used for the transmission of images over a short distance. Faceplates are used in various applications, notably in military night vision devices.

Fiber Optic Sensors

These are optical fibers used in apparatus designed to detect or sense environmental effects such as pressure, temperature, magnetic and electric fields, rotation, and other effects. Intrinsic fiber optic sensors are made up of optical fibers engaged in the various sensing actions themselves. In extrinsic fiber optic sensors, the optical fibers are used merely to transmit data information from traditional sensing devices such as electronic sensors.

Infrared (IR) Optical Fibers

These low-loss fibers are now being developed and have the potential for a variety of data and non-data applications such as laser power delivery, remote sensing, and long-distance communications. The optical losses in these fibers remain well below the lowest for conventional silica fibers, but their mechanical properties are inherently poorer.

Optoelectronic components and systems

Light Sources

These are used with the necessary transmission electronics to convert electrical signals to optical signals and to send the signals down the fiber. There are two semiconductor devices that are typically used in lightwave systems: the semiconductor laser and the light-emitting diode (LED). Each is typically made of gallium arsenide or related III-V (from the Periodic Table) compounds. 1/

Lasers and LEDs can both operate as light sources in fiber optic systems. However, LEDs are less powerful and operate at slower speeds, making them more suitable for applications requiring shorter transmission distances and less bandwidth, or information carrying, requirements. Up to the present time, LEDs have been used successfully in local area networks (LANs) connecting buildings and campuses, and in computer interconnects. LEDs are also typically used in industrial systems. The advantage of the LED compared

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1/ See app. F. for the glossary of technical terms.

to lasers, has been its reliability, lower price, ease of use, and generally longer lifetime. These are important characteristics given the relatively larger number of connections, splices, and repeaters needed in complex local area and building premises networks.

Laser diodes, on the other hand, have been the source more suited and more regularly used for long-distance and high bandwidth fiber optic networks, including long distance telecommunications systems. This is due to the laser's faster rise time (resulting in greater bandwidth or information carrying capacity), longer operating wavelengths (which permit it to operate at wavelengths where attenuation or loss in signal is lowest), more narrow spectral width (permitting more efficient coupling into the fiber), and greater launching power. At the present time, lightwave lasers in long distance telecommunication networks are able to transmit voice, data, and video over a distance of more than 30 miles before requiring a repeater (compared to 1 to 2 kilometers in a standard copper, coaxial system).

Detectors

These perform complementary functions to the lasers and LEDs used in lightwave systems. They are used to convert optical energy (watts) to electrical energy (amps). Requirements for detectors in fiber optic transmissions include a high response to the incident optical energy, high sensitivity to less powerful signals, adequate bandwidth to respond to the information carrying capacity of the rest of the system, low sensitivity to changes in environmental conditions (temperature), and a low cost. Detectors most commonly used in fiber optics links are silicon-based solid state semiconductor PIN and avalanche (APD) photodiodes. 1/ PIN diodes provide the simplest detectors, but their sensitivity is limited by thermal no[illegible] in subsequent stages of optical fiber transmission. Avalanche photod[illegible]es (APDs) provide internal current gain within the detector. This results in a larger output current and thereby reduces the effect of subsequent amplified noise. However, the avalanche process introduces noise and there is an optimum gain to achieve maximum receiver sensitivity. 2/ In long distance telecommunications, Gallium Indium Arsenide (GaInAs) PIN and Germanium avalanche photodiodes GeAPD detectors, operating between 1,000 nm and 1,600 nm, have been used successfully up to the present time.

Multiplexers

Multiplexers permit more than one signal to be transmitted on a single fiber (fig. 2-4). Up until recently, almost all multiplexers have operated electronically. There are two basic types of multiplexing: time division multiplexing, in which signals from several sources share the circuit by using the circuit in successive time slots, and frequency division multiplexing, in which the available transmission frequency range is divided into narrower bands, each of which is used as a separate channel. In optical transmission, combined signals from the multiplexers are converted to an optical signal and transmitted over the fiber. At the other end, a complementary process

1/ See app. F. for the glossary of technical terms.
2/ Ira Jacobs and Stewart E. Miller, "Optical transmission of voice and data," IEEE Spectrum, February 1977, p. 39.

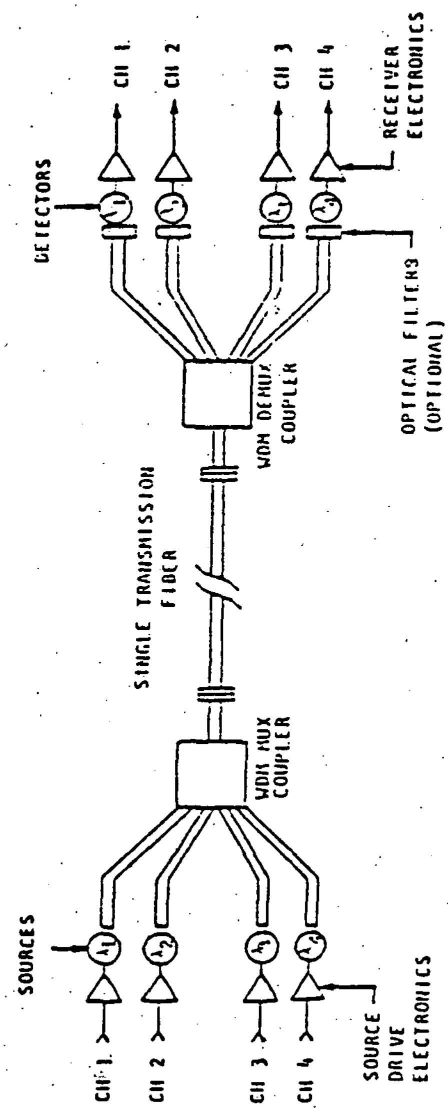
(demultiplexing) breaks down the multiplexed transmissions into their constituent signals. However, even when carried by lightwave systems, such multiplexing requires electronic devices.

A more recent development in optical communications is wavelength division multiplexing (WDM), which allows the combination of signals at high speeds through the multiplexing of optical beams of different wavelengths. Because light of different wavelengths propagate without interfering with one another, several channels of information can be transmitted over a single optical fiber, increasing its information carrying capacity, or bandwidth.

Connectors

Fiber optic connectors represent the physical interfaces for a fiber optic system and are used to connect and interconnect the various components of long distance, local area network, data, industrial, medical, and military fiber optic systems. Connectors may be designed in a variety of ways to fit particular situations but all are used to complete connections by mating two fiber terminations in some form of housing. Connectors are a critical component of a fiber optic system since any attenuation or losses occurring at connection points in the system lessen the effectiveness of the total system.

Figure 2-4
Wavelength division multiplexing



Source: Information Gatekeepers, Inc. 1985

CHAPTER 3. THE EFFECT OF TECHNOLOGY, PATENTS, AND LICENSING ISSUES ON THE FIBER OPTICS INDUSTRY

Fiber optic systems have been in use for over 20 years. The first practical uses of optical fibers were for transmitting light through nonaligned fused bundles (noncoherent bundles) in much the same manner that water is carried in a pipe. Such bundles were used in such diverse applications as automobile dashboard illumination, decorative elements, and medical illumination. Subsequently, by aligning fibers coherently, fiber bundles were devised that could transmit and project images, which permitted improved medical endoscopy and industrial diagnostic techniques.

Optical communication was anticipated in the early 1960s when the laser was developed and reduced to practical use. Bell Laboratories and Corning Glassworks in the United States, a consortium of researchers in the United Kingdom, and Nippon Sheet Glass-Nippon Electric in Japan then mounted broadly based research efforts on materials, optical devices, and optical transmission devices on materials, and optical transmission media. Behind their efforts was a long-range view that bandwidths available in the visible or near-infrared ranges were needed for telecommunications. 1/

All of the groups made strong efforts to try to bring fiber losses down from values typical of fibers used in medical instruments or 1 decible per meter (dB/m). 2/ Of the four, Corning was the first to be able to achieve significant results. In 1970, Corning officials announced that they had achieved a "high-silica fiber" hundreds of meters long having losses under 20 decibels per kilometer (dB/km). Since then, other researchers have achieved significant technological advances to where current losses in long distance telecommunications fiber are under 1 dB/Km. These developments have permitted a new revolution in telcommunications, with glass silica optical fibers increasingly replacing copper-based cable in networks throughout the world.

The following two sections describe the production processes and technology involved in manufacturing telecommunications-grade optical fiber by major world producers, and examine how important patents and licensing practices have affected the international fiber optics market. Finally, the last section in this chapter discusses some other important technological issues and developments in various components of fiber optic systems that may have important implications for the future success of the U.S. industry as well as of its major foreign competitors.

Optical Fiber Production and Technology

There are at least four different processes commonly used to manufacture telecommunications quality optical fiber; however, all are variations of a single process patented by Corning Glassworks in 1972, known as the outside vapor deposition process (OVD).

1/ Ira Jacobs and Stewart E. Miller, "Optical Transmission of Voice and Data," IEEE Spectrum, February 1977, p. 33.
2/ See app. F for the glossary of technical terms.

The manufacture of optical fiber takes place in two discrete steps. The first step is to produce a preform and the second to draw the fiber. The processes of all major producers currently include these two separate steps; however, research is currently being done by Japanese and Dutch firms to merge these two steps into a continuous process that could facilitate more economical production on very large scales. 1/

The optical fiber preform is a large scale version of the resultant fibers that will be drawn from it. In the manufacture of the preform, the optical and geometrical properties of the fiber are determined - the fiber preform contains all of the critical optical information (in particular the core to cladding refractive index profile) that will give the fiber its characteristics. 2/

The preform is commonly made of fused silica, and includes small amounts of such dopants as germanium, phosphorous, or boron to lower or raise the refractive index slightly. In the OVD process developed by Corning, a doped (germanium-added) fused silica soot is built up layer by layer on the outside of a small mandrel or rod by passing the rotating rod back and forth over a flame in a chemical vapor deposition process (fig. 3-1). In a similar basic process developed by Bell Laboratories and used by AT&T and its licensees to manufacture optical fiber, the layers of soot are built up on the inside of a hollow tube by means of an input gas stream. In the Bell modified chemical-vapor deposition (MCVD) process, the layers are built up on the inside of a hollow silica tube by means of an input gas stream (fig. 3-2).

After the preform is completed, fiber drawing starts. The preform is mounted on a moveable platform just below the top of a vertical draw tower (fig. 3-3). The preform descends into a furnace heated from 1,800-2,200°C. The softened glass is drawn by gravity to produce a "gob" that is captured on spinning capstans and wheels. The viscous fluid's surface tension assures that the core and cladding materials are pulled at the same time, in proportional rates, to keep the core-cladding refractive indices of the resultant optical fiber the same as that of the initial preform.

The draw tower itself consists of rectangular steel modules, including (1) the base, (2) the center sections, and (3) the preform feeding unit. Computerized control consoles are located both in the upper part of the tower and below in a control cabinet. Underneath the preform feeding unit is the furnace with its electrical systems, a fiber diameter gauge, primary coating equipment, concentricity monitor, curing equipment, capstan, and fiber take-up equipment. 3/

As soon as the fiber leaves the furnace, a few of its characteristics are measured to ascertain that the fiber meets certain specifications. This

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1/ Commission interviews with industry officials in Western Europe during August and September 1987, and comments by industry analysts in "Japanese Fiber-Making System Draws 600 Meters Per Minute," Lightwave, December 1986, pages 42 and 43.
2/ Jouko Kurkki and Gregory Perry, "The Precise Art of Fiber Manufacture," Lightwave, August 1986, p. 29.
3/ Jouko Kurkki and Gregory Perry, "The Precise Art of Fiber Manufacture," Lightwave, August 1986, p. 29.

Figure 3-1
Optical fiber preform manufacture (OVD method)

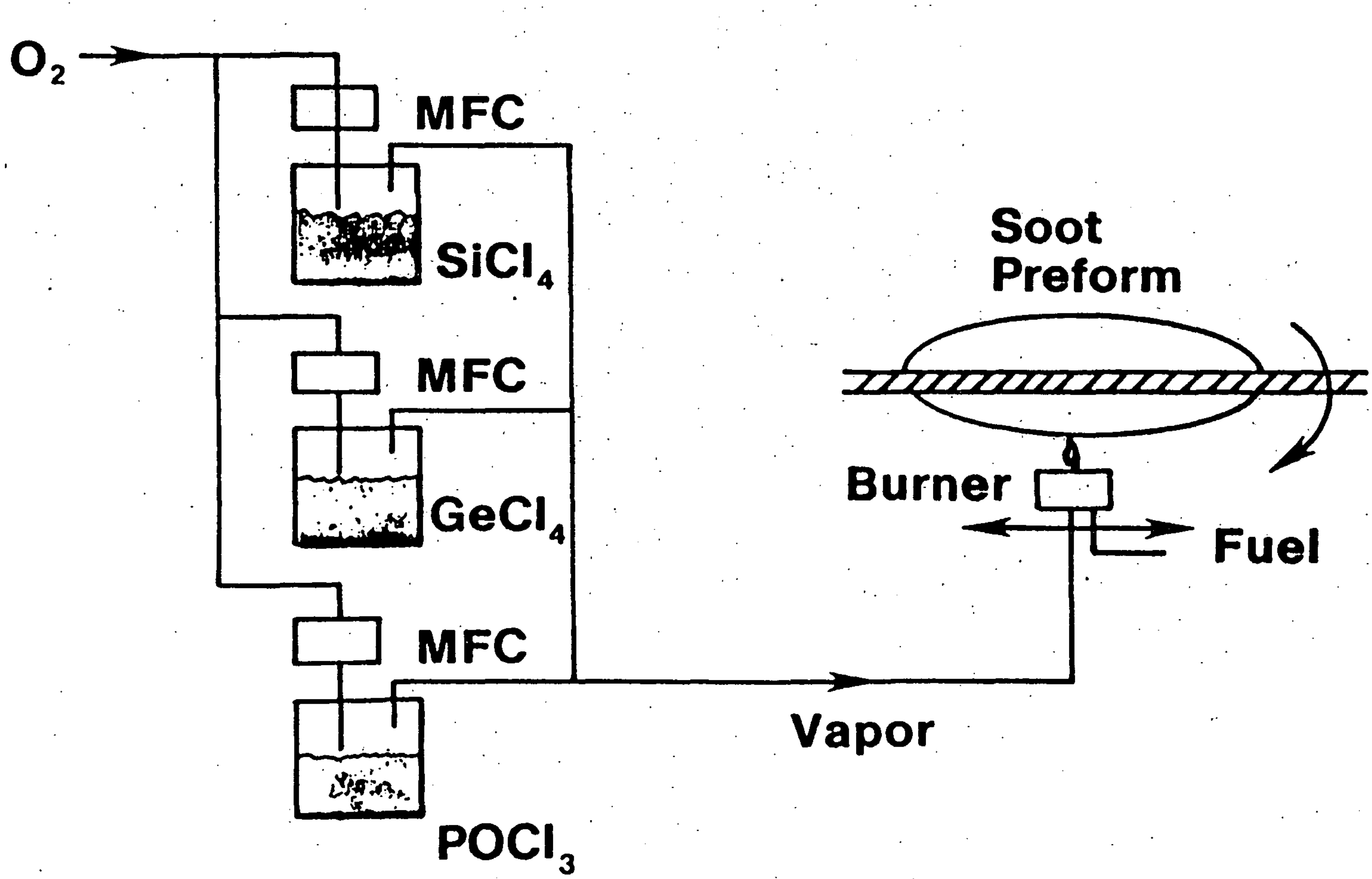


Figure 3-2
Otpical fiber preform manufacture (MCVD method)

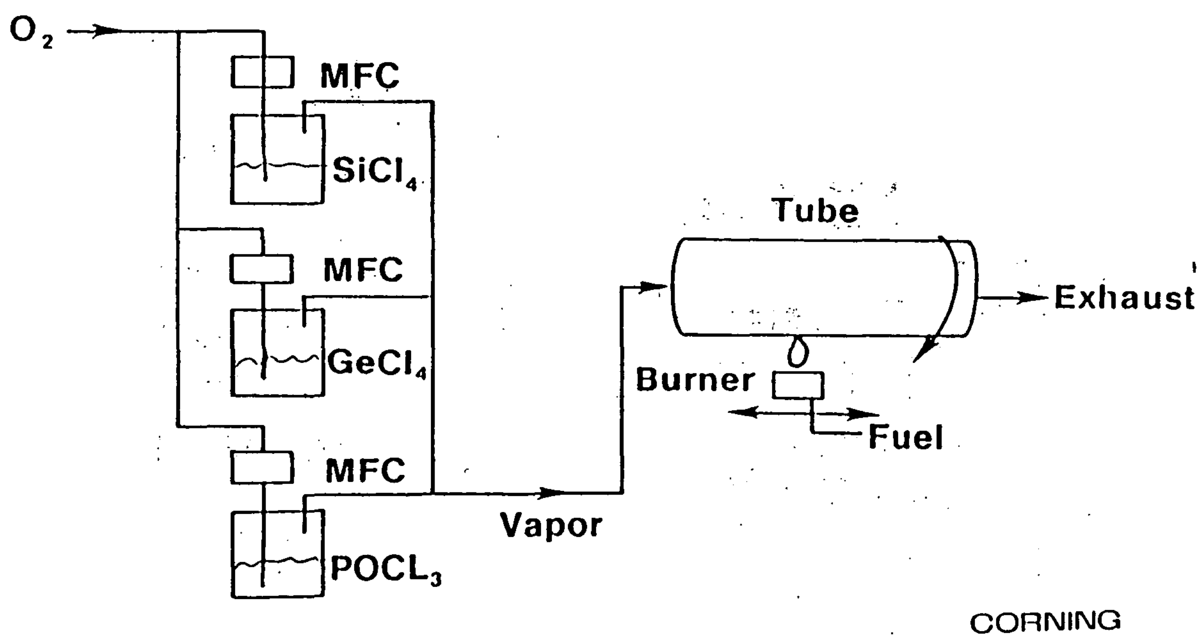
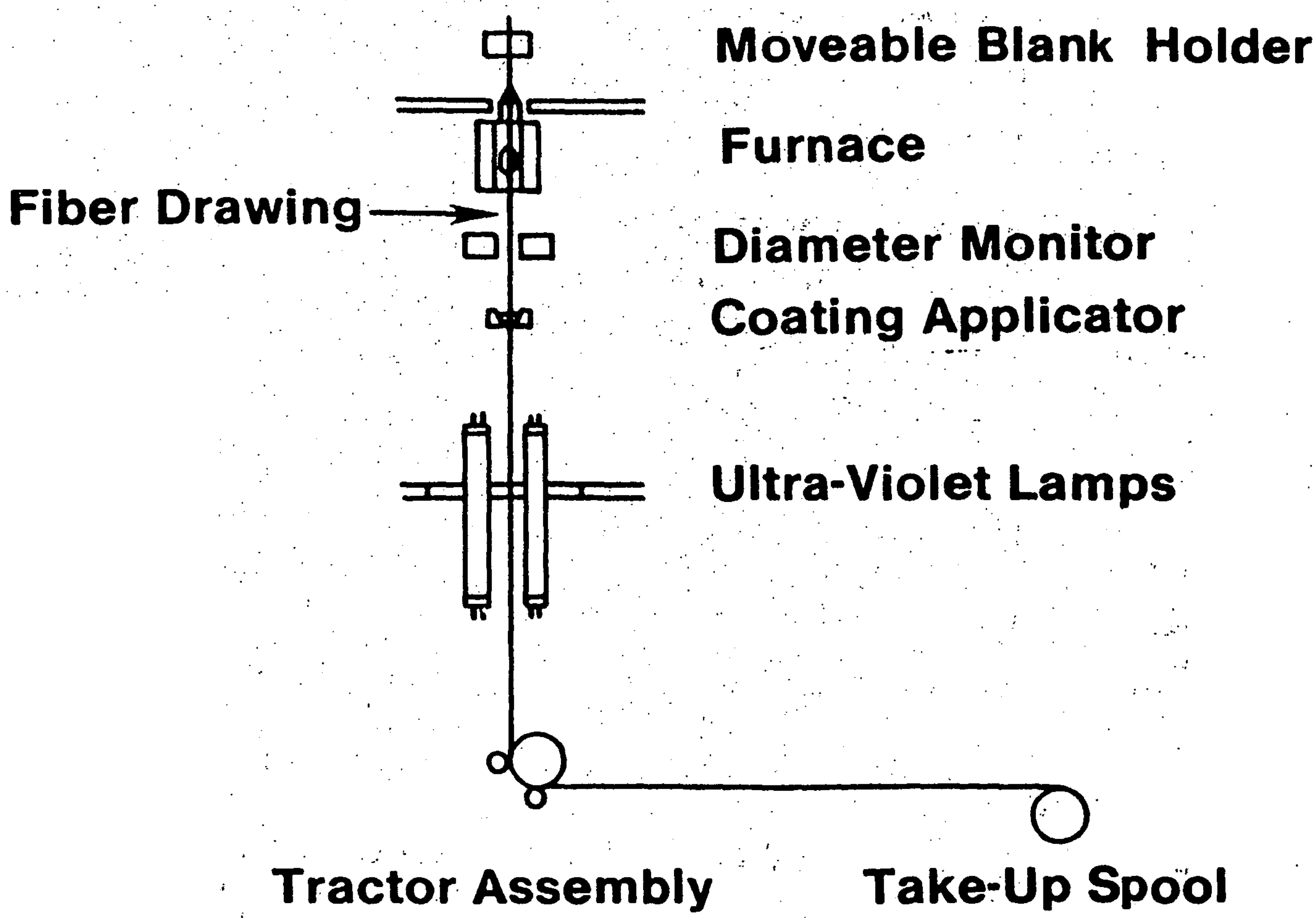


Figure 3-3
Optical fiber drawing process



function is performed by a laser interferometer that measures the fiber's position and diameter. The monitor has two outputs:

> One is the preform X-Y position, which is fed back directly to the preform centering system. This feedback loop dynamically maintains the preform's position, keeping it within one millimeter of the true center of the furnace. The feedback's control also assumes an even temperature distribution in the preform, improves the fibers concentricity and allows the fiber maker to draw useable fiber for imperfectly shaped preforms. The second output signal from the monitor is an analog signal that represents the fiber deviation from its ideal diameter. The information is fed to the tower console, and if changes are needed, they occur at the fiber pickup capstan. 1/

Next the optical fiber passes through a pressurized coating system consisting of two sections - the first is a reservoir where the coating material is kept during preform changes and where new coating materials are added; the second is the coating disk through which the fiber passes. The two major types of primary coating are silicone rubbers, which cure at high temperatures, and acrylates which need ultraviolet light for curing. The performance of the coating stage is monitored immediately, using a laser interference system which determines the concentricity of the fiber within the primary coating and displays patterns continuously on video monitors.

The fiber is drawn from the tower by a precision wheel capstan. The rotation speed of the capstan determines the pulling tension and speed. This speed, which can be as slow as 15 meters per minute or as fast as 600 meters per second in some specialized equipment, is monitored with a digital readout at the control console. Because it is the capstan that determines the draw speed, it is here that the signal from the fiber diameter measuring system comes and affects the draw speed. 2/ Throughout manual operation, and during the start up sequence, this feedback loop is left open. Once fiber of acceptable quality starts coming off of the preform, winding is switched to a takeup reel.

The Commission witnessed the general manufacturing process above in a number of plants in the United States and Western Europe. It is a highly automated, capital-intensive process involving complex computer-controlled interactive systems, skilled technicians, and clean environments. The primary differences in the manufacturing technology consist in the preform manufacture. The outside vapor deposition (OVD) and modified chemical vapor deposition methods (MCVD) have already been described. Another variation on these methods is the vapor phase axial deposition (VAD) technique developed in Japan, in which silicon tetrachloride and other raw materials are sent to the oxygen hydrogen burner. As a result of their chemical reaction, formed glass

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1/ Ibid., p. 30.
2/ Jouko Kurkki and Gregory Perry, "The Precise Art of Fiber Manufacture," Lightwave, August 1986, p. 31.

particles adhere to the top of the gathering bar, forming the sooty preform. The preform is then sintered (heated) to make it uniform and transparent. The plasma chemical vapor deposition process (PCVD) developed by the Dutch multinational company Philips is a variation on the modified chemical vapor deposition method which improves the speed of glass preform storage. The Commission staff noted while viewing the Philips preform manufacture that the heat for chemical vapor deposition was provided by microwave rather than by a flame as in the other variations of the process. 1/

Japanese and Dutch industry officials and technologists are convinced that their respective VAD and PCVD processes are distinct methods of optical fiber preform manufacture that lend themselves well to future continuous process manufacturing systems that will combine the separate steps of preform-manufacture and fiber drawing and will result in drastically reduced costs. U.S. officials interviewed by the Commission however, discounted the viability or importance of continuous process manufacture and indicated to the staff that they do not believe developments in that area will have an impact one way or the other on future global competitiveness in optical fiber. 2/ European officials were more cautious in discounting Japanese claims, however, noting that "the Japanese are not ones to boast about something that they do not believe deeply in." 3/ In 1986, the Japanese Nippon Telegraph and Telephone company announced it had successfully completed a four-year development effort with Kobe Steel Company to develop continuous drawing technology and equipment using the VAD technique. As indicated later in this chapter, the U.S. manufacturer, Corning Glassworks, has vigorously contended that all major processes for manufacturing telecommunications quality optical fiber are variations on its own OVD method for preform development.

How Optical Fiber Patents and Licensing Issues Affect the Fiber Optics Industry

Product and manufacturing process patents held by the world's two largest producers of optical fiber, Corning Glass Works and AT&T, have a widespread effect on the U.S. industry's success at home and in the international market. Although researchers at the United Kingdom's Standard Communications Laboratories (SCL), then an ITT subsdiary, were the first to discover and announce the possibility of communications over glass optical fibers, it was the development work of Corning and AT&T (in its Bell Laboratories) that made optical communications a reality. 4/ In 1970, Corning reported the production of a fiber that transmitted data with less that 20 dB/Km attenuation or loss, a barrier that the SCL researchers, K.C. Kao and G.A. Hockman had established as the maximum loss acceptable for efficient transmission of voice and data over glass fibers.

1/ Commission interview with officials of Philips, in Eindhoven, Netherlands, on Sept. 9, 1987.
2/ Commission interviews with officials of various U.S. optical fiber and cable producers, during domestic field work in July and August 1986.
3/ Commission interview with officials of the European Commission of the European Communities in Brussels, Belgium, on Dec. 9, 1986.
4/ Harvey Blustain, Richard Guenther, John Lawler, and Paul Polishuk, U.S. Long Distance Fiber Optic Networks: Technology Evolution and Advanced of Concepts, Prepared for NASA, Volume II, IGI Consultions, Inc., Boston, MA, October 1986, p. 11.

Corning and AT&T continued their work on perfecting the purity and reducing the attention 1/ in glass fibers throughout the 1970s and decided to enter into a cross-licensing agreement with respect to optical fiber. By 1972, losses were below 4 dB/Km in laboratory samples and work continued on improving the efficiency of the manufacturing processes to bring costs down to an acceptable level, i.e., a level that would permit commercial application of optical fibers in long distance telecommunication networks. In 1975, Corning announced the development of the chemical vapor deposition technique for making silica graded-index multimode fibers. This technique is the basis for all manufacturing of telecommunications-grade fiber, whether multimode or single mode. Although Corning currently holds over 150 patents related to optical fiber in the United States alone, and over 270 outside of the United States, it is two basic patents (U.S. Letters Patent 3,659,915, known as the '"915" patent) for the fiber and another (U.S. Letters Patent 3,933,454, referred to as the '"454" patent) covering a specific improvement in the manufacturing process of the fiber, that are the most important and relevant to the current development of the international market. Corning has defended its patents and has filed suit against firms that it believes are infringing its patents. This is because "Corning feels that its development provided the ultrapure glass combination that had been sought for years by others and opened the door to lightwave communication." 2/

Corning obtained its patents in the United States in the early 1970s. Corning has granted licenses to a number of firms. AT&T with its cross-licensing agreement was free to develop and market fibers under its modified chemical vapor deposition (MCVD) process and even licensed some firms on its own. U.S. firms currently licensed by Corning include Alcatel-Celwave (formerly ITT Electro-Optics) and Spectran, the third and fourth largest U.S. producers of optical fiber after Corning and AT&T.

Corning also obtained patents in each of the Western European telecommunications markets that it determined were important, including the United Kingdom, West Germany, France, and Italy. 3/ Corning was also able to resolve potential patent-infringement disputes and establish an important European marketing presence by developing joint-ventures and licensing agreements with major telecommunications and cable equipment suppliers in each of the government-controlled telecommunications markets of the major European countries. 4/ In Canada, Corning granted a license to Northern Telecom Ltd., a major Canadian manufacturer of telecommunications equipment, that permitted Northern to produce optical fiber for sale in the Canadian and selected foreign markets, but prohibited it from selling directly in the U.S. market. Many of Corning's European joint-venture and licensing agreements contain similar clauses that permit Corning to control sales of optical fiber in various foreign markets and prevent competition from foreign competitors in the U.S. market. Corning was, however, unable to patent its '"915" and '"454" technology in Japan, which is rapidly becoming a major competitor producer country to the U.S. industry.

1/ See app. F for the glossary of technical terms.
2/ "A fiber-optics patent squabble," Chemical Week, Apr. 18, 1984, p. 17.
3/ Official Journal of the European Communities, August 22, 2986.
4/ Ibid.

In April 1984, after Sumitomo had begun exporting optical fiber to the United States, Corning filed a complaint with the U.S. International Trade Commission under section 337 of the Tariff Act of 1930 (19 U.S.C. 1337) alleging that such imports infringed its patents and were injuring the U.S. fiber-making industry. Corning requested the Commission to issue an order excluding the allegedly infringing optical fiber from entry. The Commission found an unfair trade practice (i.e., that the patents were infringed) but found that unfair practice did not have the effect or tendency to destroy or substantially injure a domestic industry or restrain or monopolize trade and commerce in the United States. Accordingly, the requested relief was not provided. The United States Court of Appeals of the Federal Circuit affirmed the Commission's determination of no violation of section 337 on the basis of no injury, vacating the Commission's patent determination as moot.

As Sumitomo neared completion of a new optical fiber and cable plant in Research Triangle Park, North Carolina, the company filed suit seeking a declaratory judgment that it would not violate Corning's '"915" and '"454" patents by manufacturing optical fiber and also claimed that the patents themselves were invalid and unenforceable. Corning responded by suing Sumitomo for patent infringement alleging that the VAD process by which Sumitomo would make fiber violated three of Corning's patents.

On October 13, 1987, Judge William C. Connor of the U.S. District Court for the Southern District of New York found that Sumitomo Electric Industries of Japan had infringed two product patents, the '"915" patent discussed above covering monomode fiber and a '"550" patent covering multimode fiber, but that the "454" Corning patent protecting a process for removing water during fiber manufacture was not infringed since it was "apparent" that Sumitomo had switched to a modified manufacturing process after the U.S. International Trade Commission ruled in 1985 that both the "915" and "454" patents had been infringed. All of the optical fibers made or sold by Sumitomo in the United States were found to infringe either or both of the "915" and "550" patents. In his ruling, Judge Connor stated that "Corning is entitled to an injunction against continued infringement, and to recover appropriately increased damages." 1/ A Sumitomo spokesman said after the ruling that the company had discontinued optical fiber production at its Research Triangle Park plant, but that Sumitomo would most likely appeal the ruling.

Before the October, 1987 ruling in New York, Corning had sought legislation that would have amended section 337 of the Tariff Act of 1930, to provide for the "ITC action" against a foreign infringer such as Sumitomo without finding economic injury." 2/ To date such legislation has not been passed.

Corning also recently won an action to prevent U.S. production of optical fibers by a joint-venture named SoneTran established by Spectran and the Southern New England Telephone Company (SNET). Corning maintained that the SoneTran fiber infringed Corning's '"915" patent and that SoneTran could not

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1/ "Sumitomo Loses Case on Corning's Patents," New York Times, Oct. 14, 1987, p. D1.
2/ "House is Urged to Link Imports with Patent Rights," Lightwave, April 1986, p. 11.

produce it without a license. Prior to the 1984 breakup of AT&T, SNET had been part of that company and had sublicensing privileges due to AT&T's cross-licensing agreement with Corning. SNET contended that it had the right to pass its sublicensing rights onto its new joint-venture company. Corning charged, however, "that following AT&T's sales of SNET holdings, SNET is no longer affiliated with AT&T," and therefore, "SNET is no longer entitled to the sublicense previously available through the AT&T-Corning agreement, which granted sublicenses to AT&T and its associated companies." 1/ SNET replied to Corning's suit by filing a counter suit, claiming that SNET retained its sublicense because of continued association with AT&T. In addition, SNET sued Corning for damages it claimed had resulted from "the alleged interference in SoneTran's business which the Corning allegations have caused," and also accused Corning of unfair competition. 2/ In August 1987, the Spectran-SNET joint venture was dissolved when the U.S. District Court for the Western District of New York ruled in favor of Corning and held that SNET was not licensed under Corning optical fiber patents and therefore could not sublicense those rights to SoneTran. Although SoneTran was dissolved, SNET and Spectran officials indicated that the ruling would probably be appealed and that, if they prevailed on appeal, the SoneTran operation could be reinstituted.

Another court action still pending involves a much smaller U.S. manufacturer of optical fiber, Lightwave Technologies, Inc. (LTI), and Corning. Early in 1986, LTI, a firm which also produces optical cable, sued Corning for "unofficially claiming that LTI had infringed" Corning's fused silica optical waveguide patent ('"915") and for the interference in its business that this claim caused, allegedly disrupting LTI's relations with investors, suppliers, and customers. 3/ LTI further alleged that Corning had violated the Sherman Anti-Trust Act and claimed that the Corning patents were invalid and unenforceable. 4/

In response to the LTI suit, Corning countersued LTI, formally alleging that LTI infringed its patents. The LTI-Corning suit and countersuit are still in the discovery phase.

Although Corning has never initiated patent infringement cases in European courts, European industry officials interviewed by the Commission in 1986 and 1987 seemed in agreement that Corning's at least partially successful litigation efforts against Sumitomo in both the United States and Canada, and against other U.S. domestic manufacturers, had a significant effect on the willingness of Western European firms to challenge Corning's patents.

Several European manufacturers interviewed by the Commission, including firms with joint-ventures or licensing agreements with Corning, indicated that

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1/ "Corning sues SNET for patent violation at SoneTran venture," Lightwave, June 1986, p. 15.
2/ Ibid.
3/ "Corning sues SNET for patent violation at Sonetran venture," Lightwave, June 1986, p. 15.
4/ Ibid.

they believed they had developed unique optical fiber processes that are beyond the reach of Corning's patents. However, because of Corning's record in defending its patents in the United States, officials of these firms indicated that it seemed to make more sense to take a license from Corning than to devote considerable time and expense to litigation efforts. 1/

Corning's joint ventures and licensing arrangements with major telecommunications equipment suppliers in the four leading European markets, the United Kingdom, West Germany, France, and Italy, have given the U.S. company a considerable amount of influence over optical fiber technology, production, and sales in this market. 2/ According to a European Community (EC) decision released in August 1986, Corning's joint ventures in the EC had a combined production capacity of 385,000 kilometers per year, which represented 48 percent of total estimated EC capacity. 3/

Because of the perceived economic implications of a single foreign firm's participation in several different joint ventures and related patent license agreements with firms in different Member States, EC officials initiated a proceeding on July 6, 1983, to consider whether the Corning joint ventures were in violation of certain regulations that were issued in 1962 pursuant to the Treaty establishing the European Economic Community. 4/ The regulations prohibited business relationships that could forseeably restrain competition in the EC. The EC was particularly concerned about Corning's joint ventures with certain telecommunications cable and equipment suppliers located in three member states. The EC believed that these relationships could have led to a market allocation between the three joint ventures by extensive coordination of output, sales and pricing decisions and by the exchange of sensitive competitive information. 5/ The EC further objected to certain specific provisions contained in the licensing agreements, which EC officials believed gave Corning a controlling influence over the individual joint ventures and over the European optical fiber market as a whole.

> The Commission's objections were made in the light of Corning's strong controlling powers over each joint venture by way of its voting rights in the shareholders' meetings and its representation on the boards of management of the joint ventures. The Commission's assessment was further based on the particular conditions of the optical fiber market in which Corning has a strong patent position, on the fact that Corning's partners are

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1/ Commission interviews with officials of major European producers of optical fiber and cable during December 1986 and September 1987.
2/ Ibid.
3/ "Commission Decision of 14 July 1986 relating to a proceeding under Article 85 of the EEC Treaty (IV/30.320-optical fibres)," Official Journal of the European Communities, Aug. 22, 1986, p. No. 1 236/33.
4/ "Commission Decision of 14 July 1986 relating to a proceeding under Article 85 of the EEC Treaty (IV/30.320-optical fibres)," Official Journal of the European Communities, Aug. 22, 1986, p. L 236/30--L236/44.
5/ Ibid., p. No. L 236/30.

> major cable makers and suppliers to national posts and telecommunications undertakings of authorities (PTTs) in their respective countries and that only a limited number of sources of supply for optical fibres is available in the EEC and world-wide. 1/

EC officials interviewed by the International Trade Commission in December 1986, indicated that they were particularly concerned about the development of an increasingly monopolistic position by a foreign competitor in what was already an oligopolistic market. 2/ EC officials indicated that they had already been attempting to convince individual EC member states of the need to relax the traditionally rigid regulatory environments characteristic of European telecommunications markets so that the European industries would remain competitive with U.S. and Japanese competitors in a rapidly changing technological environment where telecommunications and information technology industries were beginning to merge.

In December 1983, the EC held a hearing at which all the parties concerned were permitted to submit observations and proposed amendments to the original agreements to address the EC's concerns regarding the economic implications of the existing joint venture and licensing relationships. After important changes were made in the Corning agreements, and after consideration was given to issues such as technology transfer and changing market developments, the EC issued a decision on July 14, 1986. The decision stated that the "anticompetitive" regulations of the EC treaty would be inapplicable to the Corning joint venture during the period from November 1985 to January 7, 2001, but that the ruling was subject to revocation if European competitiveness in optical fiber or telcommunications should become threatened. 3/

In interviews in September 1987, EC officials advised the International Trade Commission that they were particularly concerned about market developments whereby Corning "continued to exercise a considerable amount of control over its joint-ventures and thus over the European marketplace for optical fiber as a whole, despite the limitations imposed on Corning by the EC in return for the favorable July 14, 1986, Commission decision." 4/ Due to these developments and to rapidly changing competitive conditions and pressures in Europe, EC officials indicated that consideration was being given to the possibility of reversing or modifying the July 14, 1986, decision. However, they did not indicate that such changes would in fact be made. 5/

1/ "Commission Decision of 14 July 1986 relating to a proceeding under Article 85 of the EEC Treaty (IV/30.320-optical fibres)," Official Journal of the European Communities, Aug. 22, 1986, p. No. L 236/30--L236/31.
2/ Commision interview with officials of the Commission of the European Communities, in Brussels, Belgium, on December 9, 1986. See app. F for the glosssary of technical terms for definitions of monopoly and oligopoly.
3/ "Commission Decision of 14 July 1986 relating to a proceeding under Article 85 of the EEC Treaty (IV/30.320-optical fibres)," Official Journal of the European Communities, Aug. 22, 1986.
4/ International Trade Commission interviews with legal and technical Commission of the European Communities in Brussels, Belgium on Sept. 10 and 11, 1987.
5/ Ibid.

Because of the position Corning and, to a lesser degree, AT&T have in the global marketplace for optical fiber due to their possession of critical technology, one of the key issues emerging concerns the possible impact on U.S. as well as the international market for in optical fiber when the first of these patents expired in 1988. Various U.S. industry officials advised the Commission that by then the issue will be moot since the previous control of the large companies over the technology has permitted them to establish large market shares at the expense of smaller, would-be competitors. Other industry officials believe, however, that the expiration of Corning's patents will have a favorable impact on competition in the U.S. market, particularly in local area and data communications.

European government and industry officials also differed on the effect that the expiration of Corning's basic patents will have on the global market. 1/ Most industry officials agreed, however, that there would be some major impact resulting from the expired patents.

EC officials seemed particularly concerned about Corning's influence on the European optical fiber market and industry even after its patents expire. 2/ These officials were particularly concerned about Corning's recent successes in litigation against the SoneTran joint venture of Spectran and SNET in the United States, and expectations that Corning would be successful against Sumitomo in litigation pending before a U.S. District Court in New York. The major concern of European Commission legal officials was that Corning will introduce important new technology upon expiration of its basic "915," "454," and "550" and related patents that will permit it to maintain its dominant global and thus European market positions.

Other Technology Developments and Trends That Are Likely to Have An Impact on Competitiveness

Advanced Fibers

The attenuation, or loss level of optical fibers, has now reached its theoretical limit, thus making it difficult to squeeze greater distances between repeaters from current fiber technology in long distance telecommunications. The use of a new generation of fiber material, including heavy metal fluorides currently being developed in U.S. and Japanese laboratories, "could probably result in repeaterless distances of up to several thousand kilometers" from an average of 30 to 50 kilometers today. 3/ This would cut down on lightwave optoelectronic component costs, particularly in transoceanic cable systems in which more specialized optoelectronic components comprise a greater proportion of total system costs than do traditional land-based telephone networks.

Fluoride fibers also have potential applications in gas analysis, optical temperature sensors, and power delivery systems for surgical laser instrumentation and thus could potentially influence the development and demand for fiber optic applications in non-telecommunications markets. The

1/ Ibid.
2/ Commission interview with officials of the Commission of the European Communities in Brussels, Belgium on Sept. 10 and 11, 1987.
3/ U.S. Long Distance Fiber Optic Networks, IGI Consulting, Inc., Boston, MA, October 1986, p. 16.

U.S. military is supporting research in long wavelength flouride fibers for undersea sensor systems, partly because of their capabilities for supporting long distance transmission and also because they seem to resist radiation better than do silica fibers.

Traditional silica fiber producers such as Corning Glassworks and AT&T are directing more research and development toward on specialized fibers. 1/ Corning is developing ways to use its chemical vapor deposition process in the manufacture of beryllium flouride (BeF_2) and aluminum flouride fibers (AlF_3). Specialized fibers are perhaps even of greater importance to smaller niche firms which are finding it increasingly difficult to compete with larger firms like Corning, AT&T, and Sumitomo in the mass production of silica fibers. Two firms now offering long wavelength fibers commercially are Spectran in the United States and Le Verre in France. Other firms involved in the development of flouride and other infrared fibers include the Japanese companies Furukawa Electric Company, Kokusai Denshin Denwa (KDD), Matsushita Electric, and Sumitomo Electric, and British Telecom in the United Kingdom. 2/

A more recent emergence from company laboratories is dispersion-shifted and dispersion-flattened fibers. Dispersion 3/ constitutes a significant constraint on the bandwidth, or information carrying capacity, of optical fibers. However, because two major types of dispersion characteristic of silica fibers, material and waveguide dispersion, add algebraically and often have different signs, fibers can be structured so that they cancel each other out. Dispersion-shifted and dispersion-flattened fibers take advantage of this phenomena to permit higher data rate and transmission over longer distances. However, the lack of availability of lasers and detectors that operate in the wavelengths required by these specialized fibers acts as a constraint to their acceptance at the present time. Nevertheless, considerable attention is currently being paid to the development of dispersion-shifted and dispersion-flattened fibers, especially in U.S., British, and Swedish firms. In fact, one regional fiber optic network in the Midwest has already incorporated a hybrid cable design developed by the Swedish firm, Ericsson, which incorporates 12 single mode and 12 dispersion-shifted fibers in a cable linking Kansas City and Joplin, Missouri. 4/

Lightwave Optoelectronic Components and Systems

Notwithstanding the advances in specialized fibers discussed above, most industry experts believe that the area of optoelectronics will probably have the greatest influence on the fiber optics market in the future. The existing glass silica optical fiber technology is already a highly efficient medium capable of transmitting tremendous quantities of voice, video, and data information over long distances. Further developments must be made to increase the reliability and lower the cost of such components as lasers, light-emitting diodes, detectors and receivers, multiplexers, and connectors before full advantage can be taken of the current generation of silica fiber.

1/ At this point, silica fiber has become a relatively low-priced commodity.
2/ Op cit., Harvey Blustain, et al, pp. 30-32.
3/ See app. F for the glossary of technical terms.
4/ Harvey Blustain, Richard Guenther, John Lawlor, and Paul Polishuk, U.S. Long Distance Fiber Optic Networks: Technology, Evolution and Advanced Concepts, prepared for NASA by IGI Consulting, Inc., Boston, MA, October 1986, p. 33.

Industry analysts say that the most significant developments in increasing the efficiency of long-distance fiber optic telecommunications systems over the past two years have been in laser transmission power and speed, and electronic multiplexing. However, more work needs to be done in lowering the cost and increasing the reliability of detectors, receivers, connectors, lasers, and light-emitting diodes to be used in more specialized applications in local area networks (including data transmission and computer-interconnect systems), industrial process and control systems, military systems, and commercial avionics. According to many industry officials interviewed by the Commission, successful applications in these areas have the potential to generate another wave of demand for glass silica fiber that would be considerably larger than the total demand generated in long-distance telecommunications markets over the past several years. However, due to the complexity, and intensiveness of these shorter distance networks and links, much work still needs to be done to lower the costs and increase the reliability of such componentry before such applications can become technically and economically viable.

Improvements in power and long distance lightwave lasers over the past several years substantially increased the bit rates and wavelengths over which voice, video, and data information could be transmitted, improving the efficiency of optical fiber networks. However, researchers are continuing their efforts to improve lightwave transmission equipment. For example, efforts are being made to improve both laser and light emitting diode (LED) performance and reliability, including the development of new types of lasers with greater output power, reduced drive currents, and improved production processes.

One of the major fiber optic developments over the past several years was to move lightwave transmission from operational wavelengths of 1300 nanometers (nm) to transmission over longer wavelengths of 1550 nm. Operation at the higher wavelength results in lower attenuation, or loss, over a given distance. However, a major problem which occurs in conventional lasers at the higher wavelengths is oscillation at multiple wavelengths; the lasers produce signals with wavelengths slightly higher or lower than 1550 nm, resulting in modal dispersion as signals traveling at different speeds down the fiber arrive at the end at different times. 1/ Distributed feedback lasers, developed by Bell Labs, solve this problem by emitting light at a single wavelength when modulated at high speeds.

Recently Japanese firms have focused on this technology. Most of the Japanese work has concentrated on improving reliability and fabrication techniques. The Japanese have recently shown that distributed feedback lasers also benefit from relatively simple fabrication, which uses photolithographic processes. Research by the Japanese has also shown that increased yields may be obtained in the manufacture of such lasers.

New production processes are also being developed to increase manufacturing yields and thus reduce production costs of lasers. Liquid-phase epitaxy (LPE) is the more mature and less-expensive process for producing lasers. However, some firms are now investing in the initially more expensive modified organic chemical vapor deposition (MOCVD) process as a new method of

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1/ See app. F for the glossary of technical terms.

production. "Although more expensive than LPE, MOCVD holds out the promise of producing lower-cost devices through an increase in manufacturing yields." 1/

Researchers interested in increasing the reliability of lasers are seeking to lower the amount of drive current required for lasering. This is because higher temperatures associated with higher drive currents result in laser degradation and wavelength instability. Within ten years it is expected that drive current requirements may be reduced by a factor of ten to the 10-20 milliampere (ma) range.

More work is also being done on light-emitting diodes (LEDs). LEDs have always offered the advantages of increased reliability, simpler circuitry, greater temperature stability, longer lifetimes, and lower costs than lasers. However, they have always been considered an impractical source for single mode fiber, since their coupling efficiency with the much smaller core diameter singlemode fiber is less than with larger core diameter multimode fiber. Nonetheless, edge emitting LEDs, which concentrate their radiation more than the more traditional surface devices, have improved coupling efficiency and now edge-emitting components are being considered a functional light source for single mode fiber. Because LEDs are both less expensive and generally more reliable than laser sources, results in this area would bring down overall system costs in the more component-intensive local area and subscriber networks and thus result in greater acceptance in such applications. 2/

Although detectors are further along in the product life cycle than other fiber optic components, new materials are stimulating efforts to improve the performance of such devices. Work is proceeding on materials like germanium and ternary and quaternary compounds. 3/ Presently, indium gallium phosphide is preferred because of its superior performance in absorption and quantum efficiency, as well as its declining cost. One Japanese company claims that it is working on a detector that has the potential of operating over a repeaterless distance of 125 to 200 miles. 4/ This is especially significant since the increased detecting ability of devices made of these new materials, obviates the need to increase the transmission power of the laser. Because more reliability problems exist in connection with heat generation in lasers, improved detectors are taking on a greater importance in lightwave research.

Another development in the area of detectors is the application of coherent communications technology to increase receiver sensitivity. Conventional detectors operate through direct detection. Over long distances,

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1/ Harvey Blustain, Richard Guenther, John Lawlor, and Paul Polishuk, U.S. Long Distance Networks, IGI Consulting, October 1986, p.

2/ Recently, there has been fierce competition resulting in declining prices in lightwave lasers in the United States and Europe. In addition, further price decreases are expected for smaller lasers as Japanese manufacturers gain experience and economies of scale in the manufacture of similar lasers and packaged systems for compact disk players. These developments have generated a debate among industry officals as to whether lasers might replace LEDs as the logical light source in future local area networks and subscriber links.

3/ See app. F for the glossary of technical terms.

4/ Harvey Blustain, Richard Guenther, John Lawton, and Paul Polishuk, U.S. Long Distance Fiber Optic Networks, prepared for NASA, October 1986, p. 56.

this can result in greatly limited sensitivity. Repeaters are required periodically in an optical fiber system to boost the light signal strength. If detectors were more sensitive to the light signal, the distances between repeaters could be increased.

> Coherent communications addresses this problem. Analogous to frequency modulation in radio, heterodyne coherent communications involves mixing the light emerging from the fiber with a beam from a laser of similar wavelength that functions as a local oscillator in the receiver (fig. 3-4). A stabilization scheme separates the two laser frequencies by a fixed amount. Under the proper operating conditions, the output of the mixer will be an exact replica of the input lightwave signal at an intermediate frequency. The frequency is equal to the difference between the lightwave signal frequency and that of the local oscillator. When this difference is small -- a few gigahertz or less -- it is a simple matter to amplify and demodulate the mixed output using conventional radio-frequency electronic techniques. 1/

One of the main benefits of coherent technology is a potential of 15 to 20 dB improvement in receiver sensitivity, which could increase repeater spacing to 300 kilometers. This would be a particularly important development for transoceanic undersea cable links. In addition to improved sensitivity, coherent detection allows greater frequency selectivity, allowing for hundreds of closely spaced wavelengths on one fiber. Of much interest to industry officials, is the possible use of coherent systems in tunable receivers. In contrast to a wavelength-division-multiplexed system, in which receivers are fixed at their respective optical frequencies, a coherent receiver is tunable, like a radio receiver.

> A telephone company could in principal offer a variety of broad-band integrated services on a single fiber. Fiber-based networks, for example, could transmit many high-speed channels to large groups of subscribers, and a receiver at each customer's premises could be tuned to pick out one channel at a time, perhaps a video program. 2/

Together with improvements in lasers, work on coherent communications is proceeding at laboratories in the United States, the United Kingdom, and Japan. Many industry analysts believe that coherent detection will be introduced in the long-haul networks within several years.

Research and development continues to be done on wavelength division multiplexing (WDM). 3/ A significant development in WDM was reported in the

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1/ Op. cit., Harvey Blustein et al. 56.
2/ "Coherent Technology Advances Faster Than Expected," Lightwave, September 1987, p. 27.
3/ See app. F for the glossary of technical terms.

HETERODYNE COHERENT COMMUNICATIONS

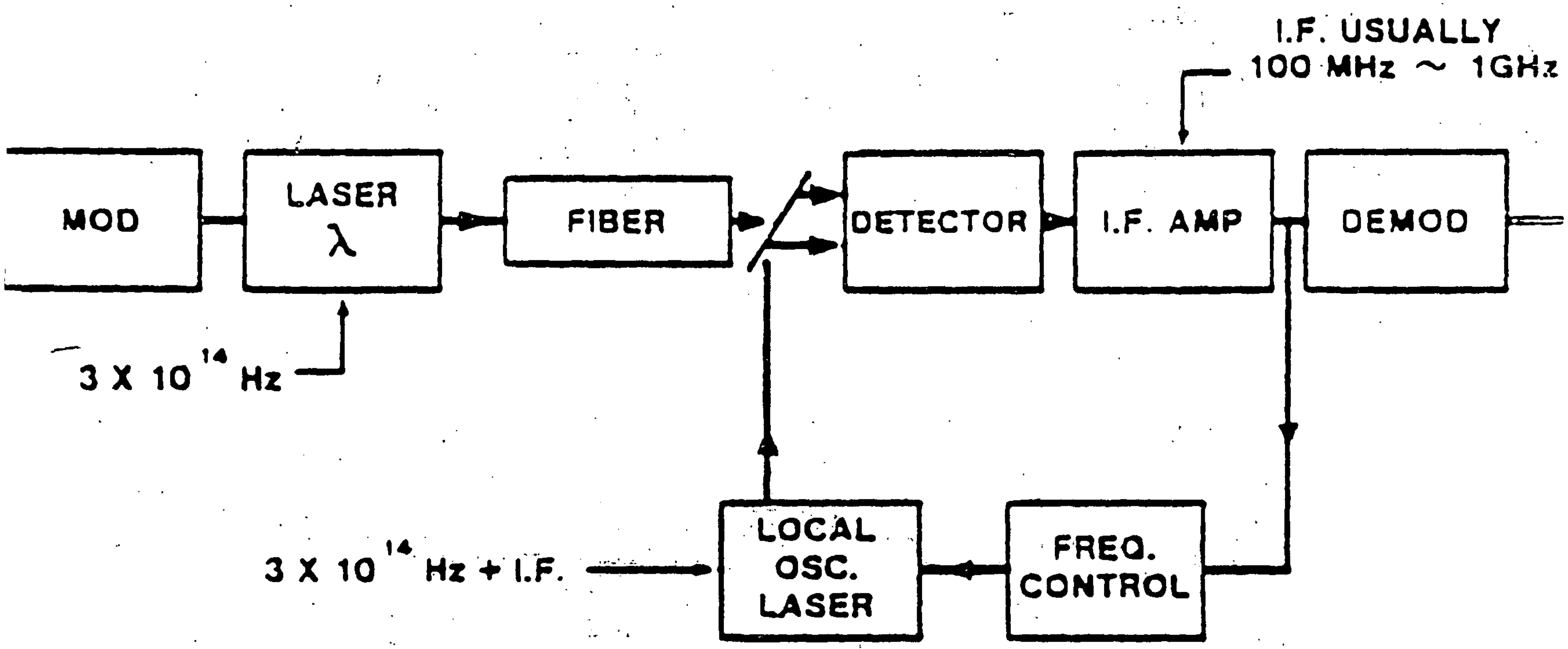

Figure 3-4
Heterodyne coherent communications

spring of 1986 by a major Japanese electronics firm whose laboratory had succeeded in multiplexing and demultiplexing five closely spaced optical signals on one fiber. This multiplexing technique utilized five distributed feedback lasers manufactured from gallium indium arsenide-phosphide/indium phosphide by conventional manufacturing techniques. By permitting the transmission of very narrow-width wavelengths, potential transmission of thousands of closely-packed signals may become a reality. This ultimately will increase the information carrying-capability of a single optical fiber dramatically.

> The most important question affecting WDM; however, is its economics. Given the rapid increase in transmission speed, is there a need for a technique that can increase bitrates even further? And even if the answer is yes, can it be justified?

Splicing and connecting joints of optical fiber transmission system are currently being given a good deal of attention by researchers since it is in the connections that much of the present loss or attenuation occurs in fiber optic systems. This is particularly true in the relatively more component-intensive local area networks and subscriber links--applications which optical fiber and cable manufacturers would like to see develop more rapidly.

Fusion splicing methods involve the actual bonding of fiber ends to one another to complete a connection. Fusion splicing has been used extensively in making splices in long distance telecommunications optical cable. It has been considered to be the most precise type of fiber connection technique, but requires more time and skill to complete properly than do mechanical splicing techniques.

Mechanical splices, unlike fusion splicing methods, do not actually fuse fiber ends to one another, but merely involve end-to-end fiber alignment within a clamp or other type of mechanical device. These devices typically are more easily and less expensively used by less skilled workers to make splices in the field. Leading proponents of mechanical splicing have recently been pushing mechanical splicing techniques for emerging local area network and subscriber loop applications. Mechanical splicing connecterization can claim advantages related to simplicity, speed and cost, these proponents say. 1/

Researchers continue to work on lowering the attenuation, or loss levels, of connectors and mechanical splicing devices. At the same time they are trying to develop new installation process that would further minimize loss levels. For an optical connector to be effective, the fiber must be protected, adequate strain relief provided, and the fibers properly aligned. In addition, the connector must be capable of accommodating fiber tolerances and must be easily coupled and uncoupled. 2/

1/ "Fiber to Home Expected to Spur Mechanical Splicing," Lightwave, August 1987, p. 33.
2/ "Optical Connectors Keep Pace," Electronic Products: Technology, January, February 1986, p. 52.

To permit more precise connections within fiber optic systems, some advanced designs emerging from the laboratory take advantage of precision tolerances available in standard watch jewels to center the optical fiber in a contact assembly. With the available jewels, very close fits to fiber optic design dimensions can be achieved. 1/

Currently, a major drawback to further advances in lightwave transmission result from the optical-electronic interfaces at various junctions in fiber optic systems. This is particularly a problem in local area networks and intelligent office network systems where many interconnections are involved in linking electronic tramsmission, receiving, and repeating devices to terminals, computers, and data communication systems. Since electronics transmissions are usually not as efficient as the purely optical transmission characteristics of lightwave, significant losses occur at these interfaces. In addition, the connections themselves result in substantial losses; thus, much of the advantage of efficient, broadband transmission of voice and data information is lost. Extensive research is being done to integrate optics and electronics in an effort to solve some of these problems. The goal of this research is for low-cost effective transmission over optical fiber to make fiber optics viable in the more component-intensive building premises, industrial process and control, and military system market segments.

One major area of research concerns opto-electronic integrated circuits (OEICs). A decade ago, many experts believed that the revolution in electronics resulting from the introduction of silicon-based integrated circuits had reached its limits. Faster circuits became increasingly difficult to fabricate as chips reached their wiring limits. Optoelectronic integrated circuits are "a step toward making chips that are able to perform logical computations at the speeds required for advanced computing and high-speed optical transmission." 2/

The idea of combining semiconductor lasers and electronic elements has been around for almost a decade.

> In 1978, Amnon Yariv, at the California Institute of Technology, produced on a single substrate, a semiconductor laser and a gun diode, a type of oscillator element. He later combined a semiconductor laser and an electronic field effect transistor (FET). 3/

Although Mr. Yariv's experiments did not appear to meet expectations, they have become cornerstones of current OEIC research. 4/ These efforts also prompted groups in Japan to organize OEIC task forces. In 1979, Japan's Ministry of International Trade and Industry (MITI) began a major optical project named the "large scale optical technology research project." Though in a much less systematic manner, government (especially military) and individual company research was also initiated in the United States and Western Europe. Much of the debate during this initial period was whether to make all-optical switches the focus of the research. However, it was argued that electronics should be included with optics for further development. A compromise included both optics and electronics, which led to work on OEICs.

1/ Ibid.
2/ "Opto-Electronics: The Outlook in Japan," Lightwave, February 1987, p. 35.
3/ Ibid., p. 35.
4/ Ibid., p. 35.

By 1986, most U.S. OEIC production was strongly dominated by silicon-based detector circuits. 1/ However, industry officials in the United States, Japan, and Western Europe believe that during the next decade, the balance will shift to gallium-arsenide and indium phosphide devices for lightwave transmission. 2/ Although Japanese domestic share of OEIC production is expected to slide from about 40 percent in 1986 to 35 percent in 1987, it is believed that Japanese companies like Nippon Electric Co. (NEC), Fujitsu-Ltd., and Sumitomo Electric Co. will establish North American OEIC production bases to boost participation in the world market. 3/

> Although the leading OEIC production will probably be in the United States, a significant share of North Ameican and European OEIC production will be in plants owned by Japanese companies, using Japanese wafers and producing advanced-technology chips designed in Japan. 4/

First generation OEICs are being used in optical fiber transmission systems as repeaters. Repeaters strengthen signals from an optical fiber, then transfer the amplified signals into another fiber. Photo diode detectors or semiconductor lightwave lasers are combined to make such repeaters. The components are then connected by metallic wire. In these initial OEICs, "pin-like" sources and detectors were used. In the next generation, linear optical devices are being designed as OEICs for computers. This is an important development because the less efficient electronic transmission and switching devices in computers create bottlenecks in the fiber optic data networks which cannot handle all of the data that optical fiber transmission systems can bring to them. In the "second generation" OEIC systems, "electrical circuitry will be replaced with optical switches, convertors and so forth, which are being brought onto one chip." 5/

The results of such integration of optics and electronics is an "order of magnitude reduction in prices" of performing functions.

> "This level of integration is needed to bring lightwave costs down to the level needed for loop applications," says one industry official. "They've got to be cheap as dirt. Even though we're light years away from seeing any OEICs for the loop, only that level of integration will bring costs, reliability and sizes to the right levels."

1/ "Japanese Companies Expected to Dominate OEIC Markets," Lightwave, February 1987, p. 33.
2/ Fieldwork conducted by the Commission with industry and government officials at various times during 1986 and 1987 in the United States, The Far East, and Western Europe.
3/ "Japanese Companies Expected to Dominate OEIC Markets," Lightwave, February 1987, p. 33.
4/ Ibid., p. 34
5/ "Opto-electronics: The Outlook in Japan," Lightwave, February 1987, p. 35.

The future progress of OEIC development and production will depend heavily on further advances in materials, processing, and device design. Poor quality materials are the largest roadblocks to further advances. Major progress in gallium-arsenide wafer quality, especially by Japanese producers, has been made over the past couple of years. Lithium niobate also promises to play a central role in OEIC chip development; its stronger than average electro-optic effects and relatively low optical losses make it one of the best materials for integrated optics today.

> Lithium niobate's new role is as the substrate for optical guided wave devices. Integrated optics devices using the material are starting to find application in modulators for high-speed lightwave communications, in fiber gyroscopes and in a range of sensor applications. 1/

Researchers believe that the materials problems will be solved sufficiently to allow high-yield, low-cost production by the early 1990s. 2/

Results of research in another area, superconductivity, may have a dramatic impact on the optical fiber market and industry. Since March 1987, when researchers at the University of Houston announced that a superconducting ceramic material had been developed that exhibited no electrical resistance at liquid nitrogen temperature (77°K), five major U.S. corporations and a dozen university laboratories have embarked on crash programs to improve the properties of superconductive materials further. 3/ Less than four months later, reports appeared almost daily on advances in superconductive materials. Because superconductivity increases the efficiency of electronic transmission by magnitudes, some optical industry officials were alarmed that at least some lightwave technology might be made obsolete by the new technology. Although it appears unlikely that superconductive wire will ever replace fiber optics for telecommunications lines, some applications for superconductive materials, including optical computing and switching could compete head-on with fiber optics, according to major researchers.

> It is widely assumed that superconductors will have application in the power industry where conventional wire and not fiber cable stands to be replaced. In essence, superconductors cannot challenge fiber optics in any communication applications until current-carrying densities achieved by the new materials far exceed those reported to date.

The advantage optical fiber transmission offers in telecommunication and data communications applications is its bandwidth, or information carrying capacity. According to industry officials, the most likely place for superconductor applications that would support fiber optic applications is in

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1/ "Lithium Niobate's Role in Integrated Optics," Lightwave, April 1986, p. 34.
2/ "Japanese Companies Expected to Dominate OEIC Markets," Lightwave, February 1987, p. 33.
3/ "Superconductors: Friend or Foe of Lightwave," Lightwave, July 1987, p. 17.

computer interconnects where the speed of connection is desired. 1/ Fiber optic interconnects, which only recently found a place inside a computer's central processing units, therefore, might be threatened by continued developments in this new technology. 2/

The technology and equipment used to manufacture optical fiber was designed principally by researchers in the United States and United Kingdom that were involved in the initial development of optical fibers. However, the equipment manufacture itself is contracted out to steel and machine tool and equipment producers. Much of the equipment in U.S. fiber manufacturing facilities appears to be of U.S. origin, though some drawing towers produced in the United Kingdom and Japan exist along with Japanese computer systems and terminals. United Kingdom and Japanese fiber testing equipment is also used in U.S. factories. 3/

There is more evidence of United Kingdom, Scandanavian, and West German fiber manufacturing equipment in various European optical fiber manufacturing operations. Many of the drawing towers are of United Kingdom origin, while furnaces tend to be of German manufacture. Finnish-made drawing towers are also in evidence. 4/

Kobe Steel in Japan became the first Japanese company to produce and sell an entire optical fiber drawing and coating system when it received permission from Nippon Telegraph and Telephones (NTT) to commercially market a continous fiber drawing system which NTT and Kobe had both developed. According to trade press reports, some U.S. firms have expressed interest in purchasing the new equipment.

1/ Ibid., p. 19.
2/ Other researchers disagree, saying that the two technologies may be more complementary than competitive, even in optical computing. John Caulfield of the University of Alabama states that because optical computing is limited by electronic input/output devices, "the faster electronics can be made to go, the faster optics may be allowed to go."
3/ Domestic field work by the Commission in Georgia and North Carolina in July 1986.
4/ Commission fieldwork in Western Europe in December 1986 and July 1987.

CHAPTER 4. GLOBAL MARKET DIMENSIONS

One of the major manufacturers of optical fiber in the world estimates that the global market for optical fiber, cable, and ancillary equipment will triple, from $1.5 billion in 1985 to $4.5 billion by 1990. 1/ Of those totals, it is expected that telephone communications will account for well over 70 percent of total world consumption until the end of this century (see table 4-1). Because of the increasing use of optical fiber in U.S. and overseas telecommunications systems, an understanding of the world telecommunications market will give some insight into future prospects for the U.S. and global optical fiber industries.

Table 4-1
Worldwide installations of fiber optics by applications and selected years, 1978 to 2000

(In percent)

Application	1978	1984	1985	1990	2000
Telephone	70	81	88	85	75
CATV	10	5	2	3	5
Military/government	10	7	5	5	6
Data lines	3	3	4	6	10
Power stations	3	2			
Process control/instrumentations	3	1	1	1	4
All other	1	1			
	100	100	100	100	100

Source: Information Gatekeepers (1986).

Global spending for telecommunications in adjusted U.S. dollars will reach $90.3 billion in 1987, up from $87.4 billion in 1986, and $75.8 billion in 1985. Real growth during 1987 is predicted to be 6.3 percent, down from 6.6 percent growth in 1986. 2/

In general, the industrialized countries continue to spend far greater amounts on their telecommunications systems than other countries. The extent to which world telecommunication's spending continues to be dominated by a small group of industrialized countries is illustrated in table 4-2. As the table shows, twelve countries will spend more than $1 billion on telecommunications. Seven are European countries led by West Germany, France, the United Kingdom, and Italy. Another three are Pacific Rim nations, with Japan accounting for $8.9 billion, South Korea, $1.47 billion, and Australia, $1.04 billion. The remaining two are the United States, which will spend an estimated $24.56 billion, and Canada which will spend $2.1 billion.

1/ H. E. Shollmeyer, Corning Glassworks Company Report, Paine Webber, Inc., 1986, p. 6.
2/ Larry Lannon, and Czatdana Inan, "Targeting World Telecom Spending," Telephony, February 23, 1987, p. 37.

> The importance of the big 12 to the world telecommunications market cannot be overestimated. As a group the 12 biggest spenders will spend 66% of the total amount spent on telecommunications equipment this year. The entire rest of the world will account for only one-third of all telecommunications expenditures. The rest of the world - a group which includes smaller but highly industrialized nations such as the Netherlands and Taiwan - will spend a total of $30.09 billion less than the Big 12. 1/

A close review of table 4-2 indicates the continuing importance of Western Europe, Japan, and the United States and Canada to the international telecommunications industry. The United States, Japan, West Germany, France, the United Kingdom, Italy, and Canada together account for $53.3 billion or over one-half of total world telecommunications-construction expenditures. These countries also have the strongest telecommunications and optical fiber industries. Although the Pacific Rim may be the most dynamic economic region in the world today, and also represents a growing strength with respect to its telecommunications and fiber optic industries, except for Japan, the region "must rank behind Europe and North America in terms of its importance to the international telecommunications industry,"2/ and consequently to the global optical fiber and cable industry. Although expenditures on fiber optic systems generally follow these trends, there may be some exceptions such as Australia and Korea. 3/

The United States, Japan, the United Kingdom, West Germany, Canada, France, and Italy accounted for an estimated 95 percent of total optical fiber installed during 1985. 4/ The United States alone accounted for almost 70 percent of total world consumption in 1985, and is expected to increase its portion to three-quarters of the global market by 1990 (table 4-3). Japan remained the second largest market for optical fiber in 1985, accounting for an estimated 12 percent of consumption. Japan's share has been falling in recent years, down from almost one-fifth of the world market in 1985, as the country's major fiber-telecommunications-backbone networks were completed in 1984 and 1985. Japanese industry estimates indicate, however, that the Japanese market will grow considerably as the country develops local area networks and subscriber link systems. However, increased future consumption by various countries in East Asia, as well as Australia, is expected to

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1/ Larry Lannon Op. cit., p. 38.
2/ Op. cit., Larry Lannon p. 37. None of the Big 12 nations is located in Africa or South America, and only one, South Korea, is on the Asian mainland. No Middle Eastern country is among the Big 12, either. Of course, many countries in the developing world continue to strive to upgrade their telecommunications networks. Brazil for instance will spend a projected $889 million in 1987, up from an estimated $850 million it spent last year, an increase of 3.5 percent.
3/ Fiber Optics Magazine: 1987 Handbook and Buyers Guide, Information Gatekeepers, Inc., Boston, MA, 1986, p. 24.
4/ Commission estimates based on data provided by Australian and Korean industry and Government sources show that Australian expenditures on fiber optic systems exceeded Korean expenditures in 1987. In future years, Australian demand is expected to grow considerably, whereas Korean demand is projected to decrease. (See chapter 10).

Table 4-2
Top 12 countries in world telecommunications construction (expenditures in 1987 to exceed $1 billion) 1/

Rank	Country	1986 expenditures (US$000,000)	1987 expenditures (US$000,000)	Increase (Decrease)	(%)	1987 percent share
1.	United States...	24,544.7	24,522.8	(22.4)	(0.1)	
2.	Japan...........	9,388.9	8,900.0	(488.9)	(5.2)	
3.	West Germany....	6,705.2	7,141.5	436.3	(6.5)	
4.	France..........	4,750.5	4,853.0	102.5	(2.2)	
5.	United Kingdom..	3,032.3	2,935.4	(96.9)	(3.2)	
6.	Italy...........	2,782.4	2,850.0	67.6	2.4	
7.	Canada..........	2,112.0	1,901.5	210.5	(11.1)	
8.	Spain...........	1,494.1	1,981.4	487.3	(32.6)	
9.	South Korea.....	1,399.0	1,469.6	70.6	(5.0)	
10.	Switzerland.....	1,254.2	1,243.7	(10.5)	(0.8)	
11.	Sweden..........	903.6	1,140.0	210.4	23.3	
12.	Australia.......	1,043.3	1,042.0	(1.3)	(0.1)	

1/

Source: Telephony, Feb. 23, 1987.

continue to make the Pacific Rim a growing and increasingly important market for fiber optic systems.

Table 4-3
Optical fiber installed worldwide

(Percent)

Country	1978	1984	1985	1990
United States.......	29	50	69	75
Japan...............	31	20	12	10
Canada..............	22	12	3	2
United Kingdom......	2	4	5	6
France..............	4	3	2	2
West Germany........	5	4	3	2
Italy...............	3	2	1	1
Others..............	4	5	5	2
Total..........	100	100	100	100

Source: Information Gateskeepers, Inc. (1986).

Canada, which through 1984 had accounted for over 10 percent of the total global market for optical fiber and cable, declined in importance as a consumer, to 3 percent of the market in 1985, as it completed a major nationwide telecommunications network. It is expected to be a net exporter of optical fiber and cable in the future. Western Europe as a whole remains a significant and fairly stable market for optical fiber, though its total share of the world market fell from 11 to 9 percent of the overall market from 1984 to 1985.

The projected decline in Canadian and European consumption may be offset by increases in U.S. consumption of fiber to be used in local area and subscriber networks. In addition, industry officials expect markets in other areas of the world such as East Asia, South America, China, and India to continue to develop, these officials believe that additional markets will emerge in Africa as countries in that region begin to install planned telecommunications infrastructures. Because many of the planned networks represent significant additions to existing networks, it is expected that they will incorporate the latest telecommunications, including fiber optic systems technology. For example, the People's Republic of China represents such a large potential market for telecommunications equipment that fiber optics manufacturers in each of the major producer countries in North America, Western Europe, and Japan are making a concentrated effort to develop contacts with the various central and regional Government and telecommunications authorities with the expectation that China's plans for an extensive telecommunications network will begin to advance rapidly over the next twenty years.

In the following sections, we will look more closely at some of the more important foreign markets for optical fiber, and then discuss some of the dynamics that may have implications for global competition in optical fiber and associated technology and equipment.

The Internationalization of the Global Optical Fiber and Cable Industries

During the first half of the 1980s, the U.S. market was the largest, fastest growing, and most open market in the world, with respect to telecommunications services and equipment. It was also the center of most global activity in fiber optics. The breakup of AT&T provided opportunities not only for domestic suppliers of optical fiber and cable but also for foreign sources to sell to the newly independent Bell Operating Companies which were permitted, and even obligated, to consider foreign purchases under the open procurement requirements of the AT&T Consent Decree. 1/ The substantial installations of optical fiber in existing and new networks planned by AT&T, MCI and U.S. Sprint also resulted in increases in demand growth in the U.S. market that ultimately resulted in increases in the production capacity of existing U.S. suppliers, including AT&T's own equipment manufacturing divisions. In addition, Foreign telecommunications equipment

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1/ Currently 4 Korean firms operate under technology transfer agreements with 4 major foreign optical fiber and cable producers. Although Corning is not one of these foreign companies, its patents effectively block the Korean producers from exporting to most of the important markets in North America and Western Europe.

firms such as Pirelli (Italy), Ericsson (Sweden), and Sumitomo (Japan), established optical-cable-manufac- turing capabilities in the United States. A joint venture of Corning Glassworks and Siemens (West Germany) resulted in what is one of the world's two largest optical-cable-manufacturing facilities. 2/

Potential foreign suppliers of optical fiber, especially Sumitomo, met resistance from Corning Glassworks when they tried to import fiber into the U.S. market, in violation of what Corning maintained were its patented rights. Still, large volumes of optical cable were imported in 1985, which was the peak year for optical fiber and cable sales in the United States. The bulk of the imported optical cable came from Canada, though the cable essentially contained U.S.-made optical fiber. Other imports from West Germany and the United Kingdom interparty transactions between U.S. and related foreign manufacturers or licensees.

Because of the U.S. technology lead in the development of optical fiber and certain related optoelectronic equipment, U.S. firms did enjoy a certain amount of success in the traditionally closed telecommunications markets of Western Europe throughout the early 1980s. This success came primarily through the development of overseas joint ventures and licensing arrangements which provided for the production of optical fiber and cable in the foreign markets themselves. However, as the growth of market demand for optical fiber and cable slowed down in the United States in 1986, U.S. firms were able to take advantage of an increasing demand for fiber and some opening up of telecommunications markets in Europe to increase their exports to that part of the world.

With rapidly plunging prices in optical fiber and cable in the European markets during 1985 and 1986, a number of industry officials began to view optical fiber as a commodity product, in which only the largest manufacturers would be able to remain competitive. 3/ Although several West German optical cable producers formed a consortium in order to manufacture optical fiber, the consortium reportedly was

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1/ See chapter 5 for a detailed description of the consequences of AT&T's breakup.
2/ The facility is located in North Carolina.
3/ Examples of such manufacturers include Optical Fibers (a Corning-BICC joint venture in the United Kingdom), Siecor (a Corning-Siemens join venture in West Germany), Sumitomo, AT&T, Pirelli, and Philips.

reconsidering this action in light of current excess capacity in the West German and the international market. 1/

According to U.S. industry and government officials, the Japanese market, until very recently, has remained virtually closed to most types of foreign-supplied telecommunications and optical fiber equipment. However, the deregulation of NTT, the main Japanese telecommunications service provider, and persistent efforts by U.S. trade officials to force Japan to open its telecommunications and other markets in market-oriented, sector-specific talks (MOSS negotiations) were just beginning to have a favorable impact on U.S. sales, in this sector, at the end of 1986, when several sales of optical cable by U.S. firms were made to Japan.

The biggest problem in markets such as Japan, Australia, and Korea is that their own fiber-manufacturing capacity far exceeds their own projected consumption for the forseeable future. Just when there is evidence that Japan's market may be opening up, major backbone networks are being completed in that country. Meanwhile, Korea has developed production capacity of its own that is approximately four times its current and expected consumption though foreign manufacturers in the United States and Japan have benefited from joint ventures and technology transfer agreements with the Korean firms involved in making optical fiber and cable.

Although the Australian market for fiber optics products is growing rapidly, it is protected through tariffs and local standards requirements. Because the Australian optical fiber and cable industry's current capacity exceeds current as well as expected consumption, it does not promise to be a very good market opportunity for optical fiber and cable suppliers, except perhaps for certain specialty fiber producers. However, the Australian market should prove to be a good opportunity for optoelectronic component producers willing to produce according to Australian standards.

As long-distance telecommunications fiber-optic networks have been completed in the major markets of the United States, Western Europe, Canada and Japan, producers in those countries are increasingly eyeing potential markets in developing areas of the world such as in Latin America, India, the Middle East, and especially China. Because countries in these regions of the world are behind countries such as the United States in establishing extensive telecommunications infrastructures, when they do finally move ahead in their development, industry sources indicated that in many instances their new networks would utilize fiber optic technology and equipment. Thus, these countries are expected to provide future market opportunities for foreign manufacturers.

However, the United States could be at somewhat of a competitive disadvantage in markets such as India, Malaysia, Hong Kong, Brazil, and in the countries of Africa since in many instances longstanding commercial relations dating from the colonial era, affected national telecommunications supplier relations. 2/

1/ Commission interviews with European industry officials in September 1987.
2/ NTIA Trade Report: The AT&T Consent Decree, U.S. Department of Commerce February, 1987, p. 53.

> Virtually all member countries of the French Union, for example, rely on French telecommunications equipment and service suppliers today. In other instances, foreign-based firms have long been entrenched in markets abroad. Ericsson subsidiaries, for example, dominate Mexico and Brazil's telecommunications equipment markets. A Siemens subsidiary has a large share of Argentina's market as does Pirelli, the Italian manufacturer of copper and optical fiber cable. Though ITT had a favorable commercial position in some overseas markets, its telecommunications equipment operations are now majority-owned by French Compagnie General de Electricite. 1/

A significant number of contracts with developing nations have traditionally been dependent upon "preferential" or concessionary financing, so called "soft loans," usually supplied by the supplier's government. For example, equipment suppliers in Japan and Scandinavia are often able to win contracts away from potential U.S. suppliers which are not able to secure similar financing from the Export-Import Bank in this sector, according to U.S. industry sources.

U.S. industry officials assert that they also are being hurt in potentially lucrative non-Western markets such as China, by strict administration by the U.S. Government of export control laws devised to keep critical high technology products from reaching the U.S.S.R. and its allies. U.S. allies such as Japan, West Germany, and France are also discouraged under CoCom agreements from allowing exports of critical technology to restricted countries. However, U.S. industry spokesmen complain that the Commerce and Defense Departments are much more strict in enforcing export control laws than are its U.S. partners, and that the United States imposes substantial paperwork requirements on foreign customers of U.S. optical fiber and related technology and equipment. These not only discourage export penetration in controlled markets such as China and Eastern European countries but in other markets as well. These officials believe that Japanese and European firms are currently developing ties and relationships with government and industry officials in countries such as China and India that industry analysts state will eventually provide them with a competitive advantage when markets in these countries do begin to grow significantly.

In addition to the aforementioned obstacles that U.S. producers report that they have to overcome, there is a final obstacle. This obstacle is partly of their own making, according to Western European industry sources. In many instances, U.S. producers (particularly optoelectronic component manufacturers) are unwilling to produce according to European and Japanese standards. Since many of the NICs and less-developed countries follow these standards, U.S. manufactuurers have effectively closed themselves out of these markets.

1/ Ibid., NTIA Trade Report, p. 53.

The international submarine cable market

There is probably no better illustration of the internationalization that is taking place in the global market for optical fiber and cable than in the area of undersea optical cable links that are competing with satellite and microwave communications systems around the world.

Optical fiber has major advantages relative to microwave and satellite systems in that transmission over optical fibers is free from outside interference of any kind. Its long repeaterless distances also make it the ideal medium for long-haul transmission. 1/ Though optical fiber has some disadvantages when compared with satellite or microwave transmission, overall it still appears to be the medium of choice in heavily used long distance networks.

> Optical systems are economical against microwave systems for short-distances, including the local telephone distribution plant. At the other end of the market, they are economical against satellites. particularly for route cross sections of 8000 voice circuits and over. Since fiber optic transmission systems have not yet reached their potential we believe that further developments in optical technology will tilt the scales in favor of fiber optics at both ends of the market. By the criteria of quality of transmission, lack of interference, lack of delay, and low cost, fiber presents itself as a superior alternative to other media. 2/

Comsat International Laboratories Director John Evans said in 1986 that "it is hard to see how satellites can compete" with fiber optics over the next two decades as a carrier of international telecommunications and that Comsat would evolve into other businesses. 3/ Comsat itself last year signed a contract to develop its own terrestrial networks, utilizing large amounts of optical fiber to link Intelsat Business Service earth stations with fiber optic digital links.

According to a 1986 report by Kessler Marketing Intelligence, a Newport, Rhode Island consulting firm, the global market for undersea optical cable over the next 8-10 years will consume more than 100,000 kilometers of optical cable, incorporating 600,000 kilometers of optical fiber and almost 10,000 regenerators. In all, $4.67 billion in systems will be installed with over one-half of that amount accounted for by optical fiber and cable. 4/

1/ Robert Holtzman, "$3B Up For Grabs In Underwater Cable Market," Lightwave, December 1986, p. 1.
2/ Harvey Blustein, Richard Guenther, John Lawlor, Paul Polishuk U.S. Long Distance Fiber Opic Networks, IGC Consultions, October 1986, p. 31.
3/ Comsat Director: "Satellite Can't Compete with Fiber," Optic Engineering Reports, September 1986, p. 3.
4/ Op. cit., Robert Holtzman, p. 1.

Five undersea systems are planned for the North Atlantic alone between 1988 and 1992, and at least three for the Pacific Basin by 1995.

As a result of the size and international character of these undersea systems, which involve landing rights onto the shores of a number of different countries, consortiums of telecommunications equipment and service firms of many nationalities are involved in the planned construction of the networks.

> AT&T Network Systems, the largest member of two international consortia will install TAT-8 (trans-Atlantic telecommunications cable No. 8) in 1988, and TAT-9 in 1991. Market Link, a joint venture of Washington-based Tel Optik which Nynex is seeking permission to purchase and Cable and Wireless plc. of Britain also plans two systems: PTAT-1 (private trans-Atlantic Telecommunication: 1989.) and PTAT-2 (1992). Another Washington firm plans to install Trans-Atlantic Video No. 1 (TAV-1) in 1989. 1/

In the Pacific, another consortium headed by AT&T and KDD of Japan, will install an undersea cable system linking California, Hawaii, Japan, and Guam. In 1989, Pacific Telecommunications Cable Inc. plans a system from Washington to Alaska and Japan. And a joint venture of the Australian Overseas Telecommunications Commission and the New Zealand Post Office plans to have its own Asia-Australia-New Zealand-North America network in place by 1995. A number of other cables are scheduled to "crisscross the Mediteranean Sea and the western rim of the Pacific Basin."

The installation of the TAT-8 cable is already well underway and will, along with the other planned cable systems, increase international telecommunications traffic (including voice, video and data communications) capacity considerably.

> TAT-8 and both Market Link Systems will operate at 280 megabits per second over two fiber pairs with another pair as backup. Using various techniques to achieve five-to-one voice-circuit compression, each system will be able to transmit almost 40,000 telephone conversations simultaneously.
>
> The growth of bandwidth will be spectacular. This year, there are 23,000 [copper] cable-based voice circuits available for the North Atlantic route. By 1992 there will be 383,000. This represents an average annual growth of 49 percent. Growth of demand for services in the region is estimated at only 10 percent and 20 percent annually. 2/

1/ Ibid., p. 30.
2/ Ibid., p. 31.

However, some industry officials believe that the size of the market may have been underestimated, particularly with respect to an expected increase in the use of data communications over transoceanic telecommunications lines.

> London's "big bang" last October, the substantial deregulation of its stock exchange has paved the way for round-the-clock, round-the-world trading. When financial firms begin to lease circuits on the new fiber optic cables; bandwidth is expected to be consumed quickly. Japan has also begun to deregulate its financial industry, and both Australia and Hong Kong are beginning to fight for increased shares in the international financial markets. 1/

The U.S. manufacturer Simplex Wire and Cable is expected to be a major supplier of equipment for underseas fiber optic systems, but Japanese suppliers like Ocean Cable Company, the British cable producer Standard Telephone and Cables, and the French Cable de Lyon will also obtain substantial optical cable contracts for planned underwater systems. In addition, there will be a new entry in the international market when the contract for the Tasman-2 cable linking Australia and New Zealand is awarded. Because of Australia's local content requirements and its substantial control over this segment, as well as their portions of planned submarine cables linking Australia with Japan and Guam, a submarine cable facility is to be constructed in Australia. To date, the identity of this manufacturer is not known, although various foreign as well as Australian manufacturers have considered undertaking the project. 2/ U.S. industry analysts have pointed out that an imbalance exists in the submarine cable market; while various foreign countries have not allowed U.S.-made international cables to land on their shores, the United States encourages a free-market policy that allows foreign manufacturers to land on the U.S. shore. Furthermore, according to U.S. industry anslysts, each of the major foreign competitors has access to various types of Government support that U.S. industry officials contend give these firms an advantage in the market.

1/ Ibid., p. 31.
2/ Commission staff interviews with various industry representatives in Australia, August 1987.

CHAPTER 5. DIMENSIONS OF THE U.S. MARKET FOR OPTICAL FIBER AND CABLE

The U.S. market for optical fiber, optical cable, and other optical fiber forms can be divided into five major segments: telecommunications, military/government, industrial/process and control, medical, and other. Although initial commercial uses of optical fiber were made in the medical and automotive industries, telecommunications networks have dominated the use of optical fiber in the 1980s, and presently account for well over 80 percent of the U.S. market. Although this segment grew at a phenomenal pace in the first half of this decade, it is currently experiencing some sluggishness. However, the increasing use of optical fiber in business premises and local area networks, and the eventual use of optical fiber in subscriber links to the home is expected to result in increases in U.S. consumption of optical fiber that will far exceed the initial use of optical fiber in long distance telecommunications markets.

Remaining market segments that are becoming more dependent upon fiber optic technology include the military and industrial/process and control as well as segments utilizing plastic optical fiber. Furthermore, recent developments in fiber optic and laser technologies are stimulating new uses for fiber in the medical industry. In these non-telecommunications segments, non-data types of fiber such as fiber optic sensors, faceplates, and other types of bundles are playing an increasingly important role in broadening the role of fiber optics in the U.S. market. In this chapter, each of the major segments for optical fiber will be analyzed and discussed with respect to present and possible future applications for optical fiber.

Market Segments and Demand

Telecommunications

Long distance communications

To understand the increasing use of optical fiber in the long distance telecommunications markets during 1983-86, it is necessary to have some understanding of the background behind the 1984 court-approved agreement that led to the breakup of AT&T. This breakup resulted in a comprehensive restructuring of the U.S. telecommunications industry, which up until then was characterized by very extensive vertical integration on the part of several principal players. AT&T, a government regulated monopoly, was by far the largest and most integrated firm in the industry; it controlled a major part of the U.S. long distance and local telephone services market, and obtained equipment from its own telecommunications equipment manufacturing arm, the Western Electric Company. 1/

Before the 1984 breakup of the Bell System, AT&T's extensive vertical integration into equipment manufacturing was justified on a number of related grounds:

> Manufacturing equipment ensured a more predictable supply of consistently high quality products ...

1/ NTIA Trade Report: Assessing the Effects of Changing the AT&T Antitrust Consent Decree, U.S. Department of Commerce, February 4, 1987, p. 56.

> Close collaboration between commonly owned manufacturing and service operations fostered production of products responsive to user needs, and which reliably worked. Such organization also tended to minimize overall equipment costs, thus in the final analysis contributing to lower rates and telephone service. 1/

Common ownership and control of its local and long distance communications services was also justified on the basis that this situation led to significant production efficiencies. Critics, however, argued that AT&T's extensive vertical integration foreclosed competitive opportunities to potential alternative equipment suppliers, and permitted it to circumvent regulation and capture monopoly profits by selling overpriced telecommunications equipment to its local Bell Operating Companies (BOCs).

In 1956, a Consent Decree between AT&T and the Justice Department restricted AT&T to the provision of only regulated telephone services. This arrangement proved to be unsatisfactory:

> AT&T for its part, was dissatisfied with its exclusion from the data processing services and equipment market. Losing out on those lucrative opportunities became even more galling because, due to technological advances, the already fuzzy boundaries between regulated telecommunications and unregulated data services were becoming increasingly arbitrary. Other communication venders were unhappy with their own inability to enter the telecommunications market. Users for their part were dissatisfied with what they saw as AT&T's unresponsiveness to their needs and with a pricing structure that did not reflect the actual cost of providing services. 2/

This was the background behind a 1974 decision by the Justice Department to bring an antitrust suit against AT&T, charging it with using its monopoly power to limit competition. In 1984, the Department settled its case against AT&T through a Modified Final Judgment of the AT&T Consent Decree, ending the monopoly relationship between the AT&T network and its Western Electric manufacturing arm. It accomplished this by divesting the company of its 22 local Bell Operating Companies (BOCs), thus effectively prohibiting AT&T from operating in the local telephone exchange business. However, AT&T did retain its long distance network, its manufacturing equipment facilities (renamed AT&T Technologies), and its Bell Laboratories research and development facilities. In addition, it was allowed to enter the unregulated computer, data, and enhanced network markets. The BOCs, owned and run by several Regional Bell Operating Companies (RBOCs), now are the primary suppliers of local voice telephone services within their geographical areas.

1/ Ibid.
2/ Harvey Blustein, Richard Guenther, John Lawler, and Paul Polishuk, U.S. Long Distance Fiber Optics Networks, Vol. II, IGI Consulting, Ind., October 1986, pp. 71, 72.

Divestiture and deregulation of the Bell system in 1984 engendered a new wave of competition in the U.S. long distance market in the 1980s that rapidly expanded demand for new network systems and equipment, including fiber optic cable. Five national (including MCI and U.S. Sprint), and 16 regional companies (including the 7 RBOCs and other independents) initiated or expanded networks in an attempt to win some of AT&T's long distance business (table 5-1). As telecommunications rates declined, traffic between local switching offices increased, creating a larger revenue pie. 1/ Even AT&T's own long distance business increased as its prices declined to meet the competition of MCI and U.S. Sprint (table 5-1).

Table 5-1
U.S. customers for fiber optic cable, 1985

Customers	Fiber-km
AT&T	47,000
OCCs	253,000
TAT-8	15,000
BOCs	525,000
Independent telcos	50,000
Data and military	240,000
Other	70,000
Total	1,200,000

Source: U.S. Long Distance Fiber Optic Networks, October 1986.

At the same time, the U.S. economy was undergoing a transition that emphasized the increasing importance of telecommunications, and information and data processing. This led to increasing demand in the information technology and telecommunications industries to provide additional services to U.S. business and industry. According to AT&T's chairman, the overall information goods and services market, which encompassed both traditional telecommunications, most office equipment, and many computer industry products, accounted for about $620 billion in worldwide sales in 1986, and is forecast to total more than $1 trillion a year by 1990. 2/ The United States alone is estimated to account for more than 40 percent of the world market for these goods.

The rapid expansion of the U.S. telecommunications market resulted in a situation whereby demand could no longer be satisfied solely through traditional means of supply. The RBOC's were prohibited by the 1984 Consent Decree from manufacturing equipment, and yet were themselves rapidly increasing capacity on their own networks. Expansion of networks for traditional and enhanced data services in the long distance service market could barely be met by AT&T Technologies. This provided opportunities for new entrants to the market, both domestic and foreign, which were able to take advantage of the openness of the newly-restructured U.S. telecommunications environment. Foreign telecommunications equipment manufacturers from such countries as Canada, Japan, West Germany, the United Kingdom, Sweden, Italy,

1/ Ibid., p. 72.
2/ NTIA Trade Report: Assessing the Effects of Changing the AT&T Antitrust Decree, U.S. Department of Commerce, February, 1987, p. 10.

and France have all become active participants in all facets of the U.S. telecommunications equipment supply industry.

> Except for the Bell companies, virtually all U.S. foreign based participants in our telecommunications markets, including AT&T, have extensive foreign commercial relations. There are, moreover, no restrictions on Bell Company procurement of foreign products today. Indeed, existing "open procurement" requirements in the AT&T decree obligate Bell firms to consider foreign purchases. 1/

The following tabulation shows the decreasing reliance of the divested Bell Operating Companies on AT&T Technologies for telecommunications equipment procurement: 2/

Bell Company Equipment Procurement
(Percent purchased from AT&T Technologies)

1982	1983	1984	1985	1986
92.0	80.0	71.8	64.2	57.6

During 1984-86, when market demand for existing and new telecommunications services was increasing and new network capacity was being planned by a number of operators, optical fiber transmission technology was introduced into the market as a commercially viable means for handling the growing long distance market. Because of the relatively narrow bandwidth 3/ of copper wire and cable, and overcrowding and delays of signals in radio spectrums encountered with satellites and digital microwave, "carriers turned to fiber optics to handle the growing long distance traffic." 4/ The plans of two major long distance carriers (table 5-2) show the increasing reliance of telecommunications service companies on fiber optics as their primary transmission medium by 1990.

After the breakup, AT&T continued to be by far the largest single consumer of telecommunications equipment in the United States (and the world). However, its competitors-including the RBOCs, major common carriers like MCI and U.S. Telecom and GTE-Sprint-5/ and other independent companies and consortiums increased their share of the total U.S. market. Although the AT&T Communications network benefited from the new surge in demand for telecommunication services, increasing its total in-service capacity from 987 million circuit miles in 1984 to 1.04 billion circuit miles in 1985, its competitors as a group increased their total in-service capacity by 43 percent from 1.2 billion circuit miles (or 20 percent more than AT&T) in 1984 to

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1/ Ibid., p. 5.
2/ Ibid., p. 2.
3/ See app. F for the glossary of technical terms.
4/ Op. cit., Blustein et. al., U.S. Long Distance Fiber Optic Networks, p. 73.
5/ U.S. Telecom and GTE-Sprint merged in 1985 becoming U.S. Sprint.

Table 5-2
Shift of transmission media for two major networks 1/

(Percent of total route miles)	1984	1990
AT&T:		
Microwave	33	25
Copper wire	35	20
Coaxial cable	10	10
Satellite	12	4
Fiber optics	10	41
MCI:		
Microwave	99	40
Fiber Optics	1	60

1/ Op. cit., NTIA Trade Report.

1.7 billion miles in 1985 (64 percent more than AT&T). 1/ Much of the rapid increase in network capacity was due to the installation of substantial fiber optic capacity as shown in table 5-3.

Table 5-3
U.S. long-distance fiber optic networks 1/

Network	Planned miles	Miles in service (11/86)
U.S. Sprint	23,000	6,500
AT&T	10,800	5,200
MCI	7,000	5,000
National Telecommunications Network	11,951	6,983
Regional Networks	9,126	2,480
Total	61,357	26,163

1/ Op. cit., Blustein, et. al, U.S. Long Distance Fiber Optic Networks.

According to industry sources, the 26,163 miles of fiber optic networks in service by November 1986, shown in table 5-3, represented over 42 percent of the planned capacity in those networks. Industry officials estimate that by the summer of 1987, over 70 percent of such planned network optical fiber capacity had been cutover. 2/

1/ NTIA Trade Report: Assessing the Effects of Changing the AT&T Antitrust Consent Decree, U.S. Department of Commerce, February 1987, p. 47.
2/ Commission staff interviews with representatives of U.S. optical fiber producers and purchasers during fieldwork in July and August, 1987.

Although the early 1980s witnessed the market entry of a number of long distance and regional telecommunications network competitors, by 1986 a number of these entrants had either fallen by the wayside or merged with other competitors. AT&T Technologies, a major supplier of optical fiber, cable, and lightwave optoelectronic equipment, found itself competing with alternative domestic suppliers and U.S. subsidiaries of foreign suppliers, including Rockwell-Collins, Telco Systems, Philips CSD, NEC America, and Hitachi, to provide electronics and optoelectronics for the AT&T network. 1/

MCI, second-largest long distance carrier in the United States, invested heavily in fiber optics beginning in 1983 to supplement its analog and digital microwave and satellite transmission systems. When the fiber optic system is completed and hooked up with its microwave system, MCI's total network will encompass 28,000 route miles, with 350 million miles of circuits. 2/ In January 1986, the third and fourth largest telecommunications carriers in the United States, GTE and United Telecommunications merged their long distance and data communication subsidiaries to form U.S. Sprint. The new network now controls approximately 4 percent of the long distance market. 3/ Cable suppliers to U.S. Sprint have included the U.S. firm, General Cable Company; Siecor, a U.S.-based joint venture of the West German firm Siemens and Corning Glassworks; and Ericsson Systems, Inc., the U.S. cable manufacturing subsidiary of a major Swedish telecommunications equipment firm. Ericsson and Fujitsu (Japanese) supplied optoelectronics components to the system, all of which were supplied from their respective foreign-based manufacturing operations in Sweden and Japan. 4/

The National Telecommunications Network (NTN) is a consortium of regional fiber optic networks that decided to consolidate forces to form their own nationwide network to compete with the three larger long distance companies. While maintaining their respective regional fiber optic networks, the members of this consortium decided to interconnect their individual networks at designated cities to provide national telecommunications services. As of January 1986, the network comprised almost 11,000 route miles across the United States.

In addition to these networks, the RBOCs (as a group) represented a substantial market for optical fiber. In 1984, industry officials estimated that total demand for optical fiber by these companies was 250,000 fiber kilometers and that the RBOCs increased their purchases to almost double this amount in 1985. 5/

Another entrant to the optical fiber market is a consortium of five electric and gas utilities in the Midwest that joined to develop a fiber optic system to handle their own private communications and to lease their excess

1/ Op. cit., Blustein et al., pp. 86-93
2/ Ibid., Blustein et al., p. 96.
3/ Ibid., p. 105.
4/ Ibid., p. 105.
5/ Interviews by the Commission with U.S. industry officials during July, 1986.

capacity. Even though public utility companies in the United States own extensive rights-of-way across the country, it has been difficult until recently to utilize these rights-of-way for even their own internal communications and monitoring needs because of the electromagnetic interference existing in high power electric lines. However, optical fiber, unlike copper, is unaffected by electromagnetic interference, and thus is an ideal medium to use in overhead power networks. Several foreign optical cable firms, one Italian, one Swedish, and the others Japanese have moved into the U.S. market to take advantage of this potential market by creating joint ventures with U.S. and Canadian aluminum companies. They produce over-power line groundwire cables (OPGW) incorporating optical fiber as the telecommunications medium. Suppliers of OPGW cable to the U.S. market include Alcoa-Fujikura, Sumitomo, Ericsson Lightwave, Pirelli Cable Corp., and Siecor.

All of the new telecommunications activity expanded business substantially for the U.S. and foreign telecommunications equipment firms in the first several years following the AT&T breakup. By the end of 1985, and throughout 1986, increasing competition and the near completion of the networks generated a rapid price decline, making it difficult for firms to remain competitive in the U.S. market. From 1982 to 1985, U.S. spending for telephone and telegraph wire and cable apparatus and equipment rose by 42 percent from $7.6 billion to $10.7 billion. 1/ Spending for optical fiber cable increased during the same period almost seven-fold from $88.6 million, the first year that significant amounts of optical fiber cable were laid, to $594.5 million in 1985. 2/ Telephone and telegraph wire and apparatus spending declined by over 1 percent from 1985 to 1986 when total U.S. shipments were down slightly to $10.6 billion. U.S. shipments of telegraph and telephone wire declined by over 2 percent from 1985 to 1986 to less than $1.4 million as long-distance network providers switched to optical cable. 3/ U.S. optical fiber cable shipments continued to rise from 1985 to 1986, increasing by 11 percent to $675.5 in 1986, although for the first time exports represented a significant portion of the value of telephone cable and optical cable shipments (about 8 percent) as overall U.S. spending began to subside. 4/

Although U.S. industry officials knew that the long-distance optical cable business would eventually decline as major new networks were completed, they did not believe this would occur until the late 1980s or early 1990s. By then, they hoped that increased interest in broadband metropolitan and local area networks, and finally subscriber links to the home, would fuel another wave of demand for optical fiber. 5/ However, industry officials have indicated to the Commission that they were caught by surprise when the market slowed down in 1986, after extensive fiber and cable production capacity had been added by major U.S. and foreign suppliers. This slowdown continued through 1986 and into 1987.

1/ U.S. Department of Commerce, Bureau of the Census, Current Industrial Report MA36P(86)-1, September 1987.
2/ U.S. Department of Commerce, Bureau of the Census, Current Industrial Report MA33L(86), September 1986.
3/ Ibid.
4/ Ibid.
5/ The subscriber links ultimately would offer new broadband services such as picture phone, high definition TV, access to various data bases, and other interactive services.

Although the larger U.S. manufacturers claim that their unit shipments of optical fiber actually increased from 1985 to 1986-partly due to increased exports-other industry officials maintain that the rest of the telecommunications fiber and cable industry is in a recession and in the throes of a shakeout. In fact, even the largest firms reported significant layoffs in the fiber and cable manufacturing divisions in 1986. Although official U.S. statistics separating optical fiber and cable from other fiber optics products were not collected until 1986, and other estimates vary considerably, there is no question that by mid-1987 sales had flattened considerably from 1983-85 levels (see chapter 8) and that business prospects had not yet picked up significantly in local loop and local area networks or subscriber links to the home.

Market analysts explain that industry projections made during the peak years of 1983-85, did not predict the rapid developments that have taken place in optoelectronic transmission and multiplexing equipment which increased the amount of voice, video, and data information capable of being transmitted over a single line. Industry officials also underestimated the number of new telecommunications networks that would fail to get off the ground or would consolidate their efforts with other rivals in an effort to compete with AT&T, MCI and U.S. Sprint. Consequently, these officials say that they were caught by surprise when sales leveled off in 1986. 1/

Local area and data communications networks

Industry officials interviewed by the Commission, indicated that fiber-optic telecommunications cable and optoelectronic equipment makers are increasing their attention on the local loop in order to get the industry back on track. To do this they must "push fiber into the gap between central telephone switching offices and business customers' premises." 2/ The optical fibers, lightwave sources and detectors, and other optoelectronic devices and circuits that have made fiber-optic transmission the long-haul carrier of choice must now be applied to local, short-haul communications. There is already some evidence that fiber has begun to go into the loop, the last few kilometers between local telephone switching offices and the subscriber's business. Although official U.S. Government statistics do not show the end uses for optical cable shipments, a major marketing research firm that follows the fiber optics industry estimates that shipments for optical fiber cable in the loop was up 15 percent in 1986 over 1985 to about 245,000 fiber kilometers, constituting almost 22 percent of fiber installations for telephony. 3/ In 1987, the firm projected shipments would increase by 22 percent to an indicated 290,000 fiber kilometers, and that the loop would constitute 42 percent of a smaller output for telephony. Although, most industry officials interviewed by Commission staff viewed these estimates as highly optimistic, there is little question that much of the marketing effort by the U.S. industry at the present time is directed to this business. 4/

1/ Pat Rosenbert, "Next Step for Fiber Optics: The Local Loop," Electronics, November 27, 1986, p. 62.
2/ Interviews by the Commission with U.S. industry officials during fieldwork in 1985 and 1986.
3/ Howard Rausch, "The Loop Looms Larger," Lightwave, December 1986, p. 4.
4/ Commission staff inteviews with U.S. industry officials during field work during June and August of 1986, and July and August of 1987.

> Since the subscriber loop contains three-quarters of all links within a telephone system - 90%, if you define "loop" more broadly to include what United States telephone companies call the feeder portion - a small inroad for lightwave can translate into a big spurt for orders. 1/

The cost of components and the lack of easily installable connectors have prevented even faster growth into local loop, building premises, and local area networks. Local networks are much more component-intensive, linking shorter-length networks from local switching offices to building-campus networks in which complex data networks themselves connect mainframe and personal computers, word processors, and other office equipment. Because the many connections, retransmissions, switches, and terminations comprise such a significant portion of the total costs of such systems (compared to long-distance transmission systems), costs must come down significantly to make them economically justifiable.

The lack of standards has also held back further progress in fiber optic local networks. Before they purchase complex data networks, customers want to be assured of the interconnectibility of all components of such systems, such as wall plugs, telephones, personal computers, mainframes, terminals, facsimile machines and other equipment. One idea that holds promise for the fiber optics industry is an integrated services digital network (ISDN) 2/ being promoted by U.S. and international standards-setting organizations, such as the American National Standards Group, the International Consultative Committee on Telephone and Telegraphy (ICCTT), and the International Standards Organization, to help ease the transition to a new "telematics" age, merging information technology with telecommunications. Under ISDN, voice, data, and video information would share digital transmission facilities. Although ISDN networks do not in themselves mandate use of optical fiber as a transmission medium, the ability of fiber optics to combine and transmit substantial amounts of data information from different sources, whether they enter the system as voice, video, or data signals, makes fiber a logical choice as the dominant medium to be used in such networks.

RBOCs, which are responsible for control of local loop and subscriber network telecommunications traffic, are preparing for ISDN implementation by installing fiber and digital systems, and increasingly are focusing on broadband bit rates and optical network interfaces. But for ISDN to receive widespread acceptance, a plethora of communications standards must be agreed upon.

> Standards would prevent proliferation of different broadband systems with incompatible technologies and interfaces. Furthermore, since telephone companies want international telecommunications traffic to grow, ISDN standards have to be set by slow moving standards committees. 3/

1/ Op. cit., Howard Rausch, p. 4.
2/ See app. F for the glossary of technical terms.
3/ Paul Susca, "Growing Interest in ISDN Standards," <u>Lightwave</u>, July 1986, p. 43.

A proposed fiber distributed data interface (FDDI) draft standard would offer an industry-standard model for integrating voice and data onto a variable-to-high speed fiber-based local area network (LAN). In addition to gaining support among communications and data processing companies, FDDI would lead to increased deployment of fiber optic LANS.

> Moreover, the FDDI would set standards by which manufacturers would design both voice and data switching, processing and transport systems. In this way it could support the convergence of telecommunications with data processing industries. At present, transport technologies for voice and data are incompatible. 1/

FDDI is the first non-proprietary, wide-spread data-communications application of optical-fiber technology. As a standard, it also would provide users with a greater degree of compatibility in multiple-vendor component sourcing. "A network manager will be free to choose components from multiple vendors and get the best components for his or her particular application," stated one industry executive. 2/

The continuing inability of public networks to efficiently perform metropolitan networking of LANs is forcing LAN users to rely increasingly on lightwave technology. The BOCs are working to outfit public networks with metropolitan area networking capabilities that, once installed, would allow the networks to cost-effectively perform much of the inter-LAN traffic that is presently the target market of LAN vendors. The trend toward private-network solutions is "helping to move fiber into the user's premises particularly for data communications." 3/

As more fiber is installed inside building premises, firms are likely to discover additional applications that utilize the increased information carrying capacities of broad bandwidth fiber-optic LAN systems. For example, video conferencing networks have been envisioned for some time. Until recently, video conferencing has had trouble getting off the ground because of the inability of copper-based cable systems to economically transmit the large amounts of video and data information required to successfully conduct a conference. Video transmission and interactive systems require considerable bandwidth, and optical fiber is proving to be an ideal medium, since one single fiber is capable of simultaneously transmitting and receiving large quantities of voice, video, and data information.

Securities brokerage houses have found that they can utilize fiber optic systems to provide their customers with a wide range of interactive services such as the provision of stock quotes and account information; and services also allow customers to buy and sell stock by utilizing the touch tone features of their home telephones. Other businesses and organizations using the large bandwidth capabilities of fiber optic LANS and systems are those with extensive computer/data network installations such as airlines, government agencies, universities, and hospitals. Federal agencies with

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1/ "FDDI Proposal Would Boost Fiber LANS," Lightwave, October 1986, p. 1.
2/ Op. cit., "One Size Does Not Fit All," p. 2.
3/ Bruce Page, "Using Fiber to Link LANs in Metropolitan Nets," Lightwave, September 1987, p. 18.

critical security requirements such as the FBI, CIA, and National Security Agency have utilized optical fiber in their internal communications networks to take advantage of the non-electromagnetic characteristics of fiber transmissions which make the networks difficult to tap.

Subscriber networks

The final target of fiber optics and telecommunications officials is fiber to the home subscriber. Many industry officials believe that "two-thirds of all subscriber loops will eventually be for residential use, and the remainder will be for businesses." 1/ As envisioned, such networks will deliver telephone, data, radio, cable television, pay TV, and other services to the residential customer. A single fiber will carry signals bi-directionally, permitting television program selection to be performed at the central switching office in response to signals received from the subscriber.

Extensive installation of subscriber links to the home is not expected until the mid-1990s, by most industry forecasters, though at least several trials have been initiated in joint ventures established between RBOCs and residential housing construction concerns. Industry sources believe that the initial residential rewiring in optical cable will be driven by the falling costs of the cable itself since the size of the market for the variety of services fiber optic systems offer is difficult to predict, much as the size of the home computer market was difficult to forecast. Indeed, many envisioned fiber optic applications for the home, such as "smart appliances" are not even available yet. 2/ Optical cable prices have already fallen from about $1 per meter in 1984 to about 17¢ per meter - pushing down the overall cost of wiring a home to $9,000, or about four times the cost of laying conventional TV and cable TV-lines. 3/

Southern Bell and the U.S. subsidiary of a Canadian telecommunications equipment firm, Northern Telecom, have formed a partnership with a real-estate developer to install an optical cable subscriber network in a new community to be developed near Orlando, Florida. AT&T and Southwestern Bell are also teaming up on a pilot project including 100 homes in Leewood, Kansas, while GTE has requested regulatory approval to wire more than 5,000 homes in Cerritos, California.

> These are the first serious experiments in the U.S., says John P. Ryan, manager of the fiber optics group at Electronicast Corp. a San Mateo (Calif.) market researcher. Ryan thinks the home market for fiber-optic technology is poised to take off early in the next decade. He figures some $900 million worth of fiber optic cable will be sold to regional phone companies this year, though almost exclusively for business applications. But

1/ Roger Adams and John Ryan, "The Shape of ISDN Begins to Emerge," Lightwave, August, 1986, p. 15.
2/ Scott Ticer, "Jenó Paulucci's Dream: Bring Fiber Optics Home," Business Week, Sept. 21, 1987, p. 34.
3/ Ibid., p. 34.

> by 1995, Ryan anticipates residential sales could account for 75% of a market worth some $4 billion. "Ultimately these trials will drive the technology," he says, "it's where the economics will be sorted out." 1/

RBOCs like Bell South and network equipment suppliers like AT&T are trying to promote the use of fiber in the home by installing fiber optic cable throughout their systems. Bell South expects to begin installing fiber optic cable by using it on all new and refurbished wiring. Although, RBOCs are prohibited by the AT&T Antitrust Decree from offering information services, Bell South hopes to eventually use optical fiber to link homes to its integrated services digital network. Over the long term, this will permit it to "pump into the home an almost infinite amount of information, including voice, data, video, and high fidelity music for a fraction of the cost of conventional lines." 2/ Over the short-haul, ISDN will permit Bell South to offer dual lines to single phones, sophisticated redialling and call-tracing features, and the ability for subscribers to send and receive computer data while talking on the phone. AT&T Technologies recently announced a new optical cable product that incorporates both copper wire and optical fiber to ease and quicken the transition of installing fiber based systems into the home.

Military/Government

Based on recent estimates by a major fiber optic industry marketing research firm, the U.S. government is expected to spend up to $2 billion on fiber optics from 1986 to 1990. 3/ All but $300,000 of this amount is expected to go to military systems (tables 5-4 and 5-5).

Spending on military optical fiber-based telecommunications networks is expected to average about $150 million a year, with less than a 5-percent per-year increase over the period. About four-fifths of the military's requirements for telecom and data communications are for optical fiber and cable, and only 20-percent for components such as connectors, sources, and detectors. In 1986, it is estimated that the military purchased $186 million worth of fiber optic telecom systems.

The Army estimates that it will spend up to $600 million in 1987 for the research and development of a fiber optic guided missile called FOG-1 (fig. 5-1), and may spend an additional $1.65 billion in 1988 and 1989, the peak years for deployment of the system. 4/ Over $100 million of the amount allocated for such systems would be for optical fiber for 150,000 fiber kilometers, or about one-fifth of the total amount of optical fiber sold in the United States in 1986.

1/ Op. cit., Howard Rausch, p. 4.
2/ Op. cit., Scott Ticer, Business Week, p. 35.
3/ John Kreidl, "Washington to spend $2 billion on Fiber Optics," Lightwave, Dec. 1, 1986, p. 23.
4/ Ibid., p. 24.

Table 5-4
Military fiber budget (est.) by service, 1986-1990 1/

(In million of dollars)

Year	Total	Air Force	Air Force Telecom	Air Force F.O. Gyro	Total Navy and Marine Cps	Navy Telcom	Navy Anitsub	Total Army	Army Telcom	Army FOG-M
1986........	186	84	57	10	53	42	11	49	36	13
1987........	286	75	55	15	67	50	17	126	37	83
1988........	333	98	58	25	70	52	18	165	42	123
1989........	412	119	59	50	72	55	17	221	48	173
1990........	509	131	62	62	74	57	17	304	51	253
Totals..	1,708	507	291	162	336	256	80	865	214	645

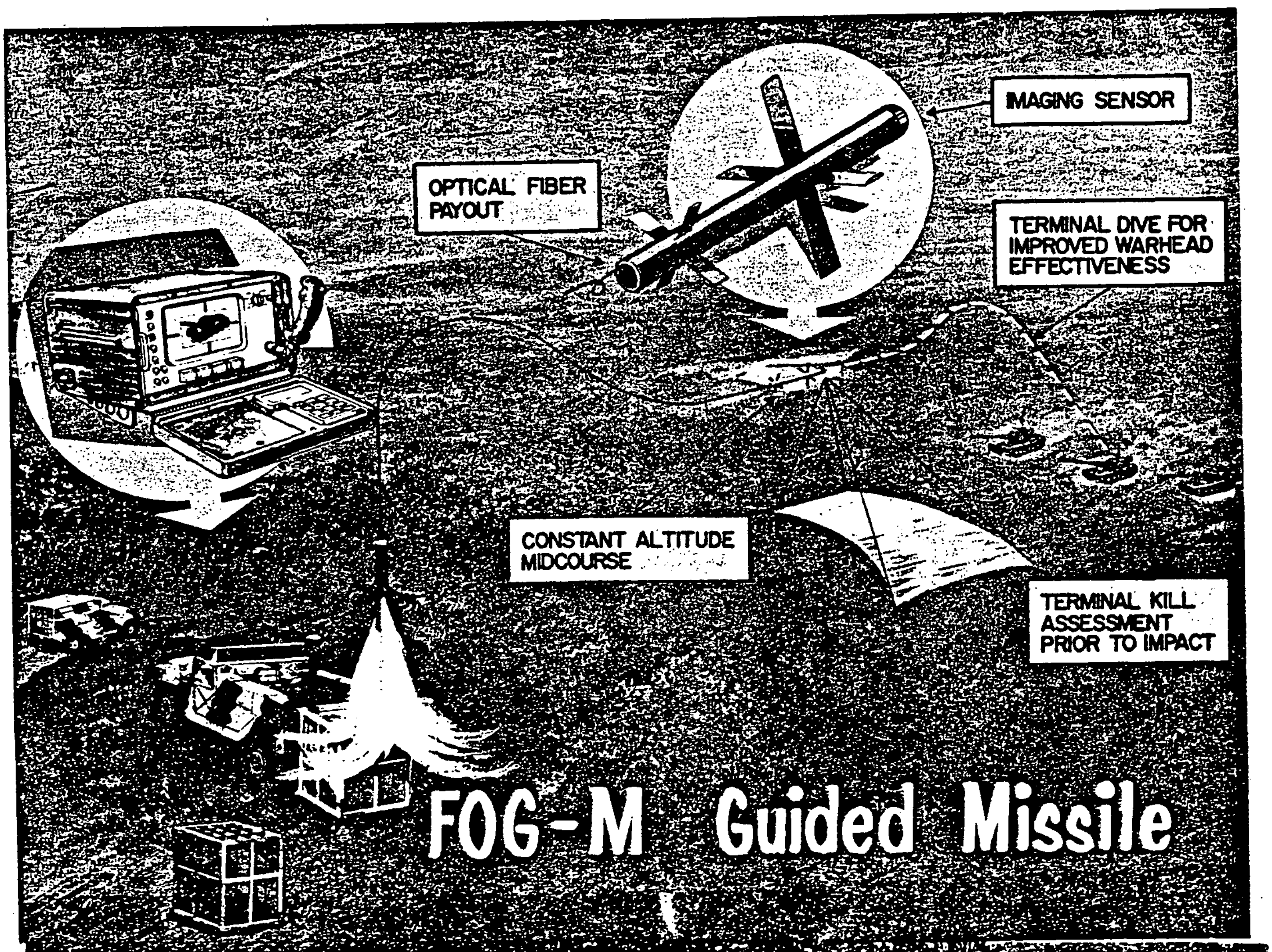
1/ Op. cit., John Kreidl, p. 23.

Table 5-5
Military fiber budget (est.) by service, 1986-1990 1/

Year	Total	Total growth	Telecom 2/	Total growth	Non-telcom 3/	Army FOG-M
	Million dollars	Percent	Million dollars	Percent	Million dollars	Percent
1986.........	186	-	135	-	51	-
1987.........	268	44	142	5.0	126	150
1988.........	333	20	152	6.5	181	44
1989.........	412	24	162	6.0	250	38
1990.........	509	23	170	5.0	339	36
	1,708		761		947	

1/ Op. cit., John Kreidl, p. 23.
2/ 80% of telecom is fiber; 20% is systems components.
3/ 2% of non-telecom is fiber; 98% is systems components.

Figure 5-1
Fiber Optic Guided Missile System 1/



The FOG-M operator fires the missile and tracks the target on his video screen. The visual information transmitted through a fiber letter attached to the missile allows the operator to guide the missile towards the target with a joystick. When the tank is in range, the generator electronically "locks it" in a glide path toward the tank.

1/ John Kreidl, "Washington to spend $2 billion on Fiber Optics, " Lightwave, December 1, 1986, p. 23.

Another increasingly important application of fiber by the military is in night-vision devices which incorporate non-data, fiber-optic faceplates. "Nightwave" fiber optics is sought for combat situations. A dozen night-vision devices have been deployed in the past five years and are now being used in large quantities by the Army. Devices already in the Army arsenal include night goggles, tank vision systems, tank periscopes, long-range observation tubes and gun sights. Newer night-vision devices use fiber optics for image enhancement. 1/

The fused fiber optic faceplate accounts for about 10 percent of the cost of a total night-vision system, according to Army officials. They estimate that the Army will spend up to $1 billion for night-vision devices over the next five years, of which about $100 million will go for faceplates. According to an official of one of the major manufacturers of faceplates, the total U.S. market in 1986 for faceplates was $40 million. 2/ Sales of total fiber-optic night-vision systems in 1987 to the military are expected to reach $200 million.

Other Armed Forces applications include long-distance and inter-bunker communications systems, intrusion-resistant information systems, computer-to-computer links, local area networks for tactical platforms and weapons systems, base telecommunications, radiation-hard communications, and field tactical links. 3/

The military has learned that optical fiber communications can provide significant advantages in battlefield environments and has awarded a number of contracts for the development of lightwave tactical field cable technology. Optical fiber cables provide secure communications because they are more difficult to tap than conventional copper cables. They are also easy to deploy because of their substantial weight and diameter savings over metallic cables. 4/ Tactical field cables are constructed differently than are civilian telecommunications-grade optical cables in order to meet the military field environment specifications. The optical cables must be able to resist high impact, tolerate vehicular traffic such as heavy tanks, be flexible, and maintain such characteristics over a high temperature range. 5/ Such cables must also be able to resist nuclear radiation.

The lightness and immunity of optical fiber cable to electronic and other environmental disturbances has also made optical fiber an ideal medium for integrated on-board communication and data transmission systems on ships and airplanes.

> The Air Force Systems Command has made a good deal of progress with its "integrated communications, navigation and identification in its aircraft" program. With fiber, the aircraft is not only lighter, but is much more survivable in a hostile environment with electromagnetic interference. 6/

1/ Ibid., p. 39.
2/ Ibid., p. 38.
3/ Ibid., p. 39.
4/ John C. Smith, "Using Fiber in Military Tactical Cables," Lightwave, p. 34.
5/ Ibid., p. 34.
6/ John Vernon, "Corning Sees Bright Prospect for Military Applications," Lightwave, June 1987, p. 40.

The Navy has also been actively involved in fiber optic research and deployment through its Naval Research Laboratories. In 1986, the Navy allocated over $2 million and will allocate an additional $9 million in 1987 for its Adriadne telemetry system that will use acoustic hydrophone arrays connected to underwater fiber sensing cables linked to shore detectors for monitoring submarines. 1/ A study on Naval deployment conducted by Arthur D. Little Inc. of Cambridge, Massachusetts reported that fiber installations on Navy ships in 1986 were close to zero, but that they would pick up slightly in 1987. The study predicts geometric growth after 1987, declaring that "there will be 16 times as much Navy telecommunications and data communications cable purchased for use aboard ship.

As growth in the long distance telecommunications network demand for optical fiber and cable has leveled off in the U.S., the larger manufacturers have begun placing more emphasis on developing optical fiber systems for the military uses. At least several firms that previously concentrated more on civilian telecommunications segments have now created advanced fiber products departments to focus research and development effects on developing optical fiber products that meet the unique requirements of the military.

Industrial/Process Control

Although fiber optics has thus far made relatively slow progress into factory and industrial environments when compared to long distance, or even local loop and business telecommunications, it promises in the future to have as much an impact as any other new technology on U.S. industry. Officials of Westinghouse Coroporation have predicted that most factories will eventually switch over to optical fiber networks. 2/

The automated factory has become the focal point of U.S. industry efforts to improve the quality, productivity, and cost effectiveness of its manufacturing activities. To realize automation's full potential, an efficient and cost-effective means of communication needs to be developed and supported that transports information across proprietary equipment boundaries, say industry officials. Broadband fiber optics systems are a likely medium to bridge this communications gap that will help U.S. industry tie together its present "islands of automation". 3/ However, for the U.S. industry to continue its efforts at automation without communications and fiber optics standards for industrial networks will cause frustration and stifle the trend to automate U.S. industries. 4/

One such standard for automating factory systems and processes is the Manufacturing Automation Protocol (MAP). General Motors, the pioneer of MAP, is providing great impetus to the standardizing movement by planning to spend $4 billion for MAP-based factory automation over the next few years. During 1985 and 1986, over 160 companies have joined MAP user groups in the United States, Canada, and Europe, and suppliers, including producers of fiber optic goods, are beginning to announce MAP demonstration projects.

1/ Op. cit., John Kreidl, p. 23.
2/ Paul Susca, "Map Expected to Spur Fiber in Factory Networks," Lightwave, March, 1987, p. 33.
3/ Lewis I. Solomon, "MAP: A Standard for Survival," I&CS, November, 1986, p. 57.
4/ Ibid.

Both data and non-data types of optical fiber are expected to find increasing applications in factory and materials processing environments. For example, fiber optic sensors are already being used to replace electronically-based conventional sensors that measure such phenomena as temperature, pressure, flow rate and over 50 other variables in noisy and sensitive factory environments because of optical fiber's immunity from electrical and electromagnetic interference, greater sensitivity, and compactness. In order to broaden the scope of their markets, even larger manufacturers of telecommunications grade optical fiber are increasing their development efforts with respect to specialty fiber products such as sensors. Corning Glassworks recently purchased a 50 percent interest in Technology Dynamics Inc., a sensor maker with patented sensor technology. The firm has targeted applications of its sensors to research and development, chemical processing, petroleum processing, semiconductor processing, food processing, and industrial battery testing.

Because of its immunity to electromagnetic interference, optical fiber has been utilized effectively in continuous process industries such as petroleum, chemicals, and mining and other potentially hazardous environments where there are often lightning or electrical ground loop problems. Fiber optic systems should also make it easier to accomodate the process industry's goal to easily refigure plants to make different products. Some control system users are hesitant to move controls around "because of constraints in the placement of cables due to noisy, corrosive, and hazardous environments." 1/ Optical fiber systems solve that problem, permitting an easier configuration of processes.

More traditional discrete and batch manufacturing companies have been less adventurous in using fiber optic and computer technology to control their manufacturing. However, through MAP, discrete manufacturing firms like General Motors are taking the lead in integrating manufacturing with information handling. As a result, "fully automated discrete and batch manufacturing factories of the future will closely resemble continuous process plants." 2/ A fully integrated manufacturing system such as is used in manufacturing automobiles requires continuous monitoring and control of thousands of operations occuring simultaneously. At the heart of one automobile plant, for example, distributed data methods and machine controls allow for the greater flexibility in production according to one GM company spokesman. 3/

Although complete flexibility is not always possible, a goal is to allow "soft" changes that accomplish redesigns of vehicles without installing new equipment. Ultimately, there would be engineering based totally on software whereby simple changes in instructions to programmable devices would result in immediate changes to vehicle models. 4/ According to one automobile manufacturing executive, a long-term goal for manufacturing automation protocol in his industry is to "reduce the cost of traditional changes."

If major manufacturers such as GM, Ford, DuPont, Exxon, and Proctor and Gamble embrace MAP, smaller companies are likely to follow their lead. The

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1/ Ibid.
2/ Op. cit., Lewis Solomon, p. 59.
3/ William Ferell, "Factory Standard Moving Ahead-With Little Fiber So Far," Lightwave, September 1987, p. 31.
4/ Ibid.

conversion of this group would rapidly accelerate the automobile and process-industry dominated movement. 1/ In 1985, $150 million worth of industrial local area networks were shipped; of this amount, only 3 percent were MAP-based. However, recent formalization of certain MAP specifications by the IEEE standards committee related to fiber optics components should help increase the demand for MAP-based networks.

> The specifications are bound to stir vendors to action. Some vendors have already begun to adapt their components (cable-connectors, repeaters, multiplexers, and modems) to the existing MAP specifications. Other vendors, who have the foresight to appreciate the extent of the potential MAP market, will begin to offer dozens of components designed for the MAP customer (for example, modems, fiber optic cables of different sizes, connector types, or the use of active or passive stem types). 2/

The acceptance of MAP and the decline of proprietary networks are expected to accelerate in 1987, and by 1990, MAP networks will account for 78 percent of the $472.9 million value of industrial LANs expected to be shipped. 3/ By that time, MAP broadband networks incorporating significant amounts of optical fiber should be the leading industrial LAN segment with shipments of $214.1 million, followed by MAP carrier band, or backbone networks, at the $155 million level. 4/ MAP may or may not proceed at the rates currently forcast, but over 30 percent of factory LANs should be optical fiber-based by 1990. 5/

In addition to increased shipments of optical cable for data transmission that should be required by a modernized and automated industrial infrastructure, spending for non-data fiber optic elements such as sensors should increase to $1.1 billion by 1994, from $68 million in 1986. Of the sensor fiber-optic components manufactured in 1986, over 11 percent were designated for industrial purposes. Thus, this would translate into over a potential $100 million industrial market for non-data fiber components alone by the mid-1980s.

Medical

Implementation of the Federal Government's Prospective Payment System (PPS), which places a cap on Federal health benefit expenditures under Medicare, as well as pressures in the private sector to reduce health care costs, have had significant effects on medical equipment suppliers. Historically, medical equipment suppliers have competed primarily on the basis of technological and therapeutic innovation. However, public and private pressures to contain costs have led to declines in hospital admissions and surgical procedures, which has led to increased competition among suppliers of medical equipment. Competition focuses increasingly on price. 6/

1/ Ibid., p. 32
2/ Mike Sablehaus, "Fiber Optics and MAP," I and CS, November, 1986, p. 64.
3/ Op. cit., Solomon, p. 58.
4/ Ibid., p. 58.
5/ Op, cit., Paul Susca, p. 33.
6/ "Medical and Dental Instruments and Supplies," U.S. Industrial Outlook 1987, p. 34-1, U.S. Department of Commerce.

Although the change in the U.S. market will make competitiion difficult for many U.S. manufacturers of medical equipment, those supplying equipment that help reduce the time and expense of lengthy hospitalization may be expected to benefit from the more price-competitive market. Fiber optics promises to be one of several high technologies that may have an important impact on the ability of medical equipment suppliers to contend with this recent emphasis on cost reductions.

Recent developments in fiber optic endoscopes for instance, are allowing doctors to perform outpatient surgery that in the past would have required open surgery. For example, a menisectomy, a knee operation that would previously have left a 6-inch scar, can now be done with arthroscopic instruments through several incisions that can be closed with a couple of stiches and a bandaid permitting the patient to return home on the same day as surgery. There is a new trend for such endoscopes to get smaller and smaller to address joints other than the knee. The knee is the largest joint in the body and therefore that is where the initial arthroscopic applications began. However, applications are now going into what are known as small joints in the shoulder, wrist, ankle, and jawbone.

Another trend is in the use of video. In the United States surgeons now typically use an endoscope with a video camera attached instead of using an eyepiece.

> Video lets you do the procedure in a heads-up position instead of bending down over the patient, where your head gets in the way of other instruments. Video is also great for recording the procedures and for teaching. Something like 80% of all arthroscopes in the United States now use videos. 2/

As technology advances, allowing more flexible fiber with smaller core diameters, the use of fiber optics in medicine promises to expand. Already, over $30 million is spent annually on medical instruments that use fiber optics. 3/ Laser angioplasty is a new technology that use optical fibers to deliver laser radiation to blocked arteries. It combines in one catheter the functions of a fiber optic bundle for viewing and a single energy carrying optical fiber for vaporizing artherosclerotic plaque. Another device, the laserprobe made by a medical instruments manufacturer in California is used to halt bleeding in ulcers and repair tissue in blood vessels or lymphatic channels.

> [The laser probe] sends continuous output from an argon ion laser through a quartz fiber. The laser power is converted to heat in a metal alloy tip, which is then applied to a tissue. The laser probe can either be used in open surgery or as a catheter that is inserted through a small incision. For bleeding ulcers, the probe uses heat to halt the bleeding. 4/

1/ "Medical and Dental Instruments and Supplies," U.S. Industrial Outlook 1987, p. 34-1, U.S. Department of Commerce.
2/ "Delicate Surgery Possible Using Fiber Optics," Lightwave, May, 1987, p. 41.
3/ Shelly Francis, "The Heading Light: Fiber Optic's Role in Medicine", Photonics Spectra, April 1987.
4/ Op. cit., Shelly Francis, p. 40.

Before compact optical fiber bundles were technologically feasible, endoscopes were more than 15 millimeters (mm) in diameter and consequently had to be inserted through existing body openings. Such endoscopes were primarily used for viewing the stomach and colon. However, endoscopes have now been devised that have diameters as small as 1.5 mm so that doctors may either make small incisions or insert the endoscopes in smaller cavities, such as sinus passages. The image bundles in thin line endoscopes have 2,000 fibers each while older conventional endoscopes had as many as 30,000 fibers per bundle. Olympus Corporation, a major Japanese supplier of fiber optic medical instrumentation to the United States has five ultra thin endoscopes ranging from 1.5 to 2.4 mm in diameter. 1/

Much research is being done today to develop an infrared fiber for medical laser cutting and coagulation procedures. The carbon dioxide laser is widely believed to have the most potential for such biological work but is limited by lack of a suitable fiber for beam delivery. The problem is that carbon dioxide transmits at 10.6 microns 2/ while the quartz fiber commonly used with other lasers transmits at wavelengths only up to 10.5 microns.

> Available fibers for infrared suffer from one of several fatal drawbacks: some are toxic, others too fragile or not flexible enough. In addition, many are sensitive to ultraviolet light, so in a room with florescent lighting the fiber turns black and stops transmitting. 3/

If these problems can be overcome, some fibers that look promising are silver choride, zinc selenide, chalcogenide, KRS-5, and silver halides. At the present time the alternative to such fibers for use with carbon dioxide lasers are hollow waveguides. Other medical specialities that would benefit from improved infrared optical fibers include external modalities (outside the body) such as dermatology, and podiatry, and internal specialties like bronchoscopy, gynecology, and urology. 4/

Fiber optic sensors are also finding increasing applications in other areas of medicine. The hair-thin size and flexibility of such sensors enables physicians and surgeons to measure patients' vital signs in otherwise hard-to-reach areas of the body. A number of medical instruments in use that employ optical fibers as sensors include oximeters for measuring the oxygenated fraction of hemoglobin in blood, thermometers, and immunoassy test apparatus to sense antibodies-antigens. Reportedly, a considerable amount of research and development activity is being conducted and additional fiber optic medical instrumentation should continue to be introduced on a steady basis in the future.

Although fiber optics applications in medicine and surgery have been overshadowed in the past five years by the tremendous growth of optical fiber use in telecommunications, and still account for less than 5 percent of the optical fiber market, this portion of the industry has fared much better over the past two years than has the telecommunications sector where growth in

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1/ Ibid., p. 42.
2/ See app. F for the glossary of technical terms.
3/ Op. cit., Shelly Francis, p. 42.
4/ James A. Harrington, M.D. "Medical Needs Drive IR Fiber Development," Photonics Spectra, July 1987, p. 61.

demand is sagging. Because of the new procedures that are being developed, fiber optic technologies "will continue to revolutionize medicine by replacing costly and traumatic surgeries with relatively minor medical procedures." 1/

Other Markets

Plastic optical fibers were introduced into the U.S. market over 15 years ago and enjoyed commercial success in the U.S. automobile industry where they were used extensively for the transmission of light in automobile dashboard displays and lamp monitoring. Other initial uses of plastic optical fiber included uses in lighted signs and displays and various decorative applications.

More recently, additional uses for plastic optical fiber have been found in such applications as short data links between computers, other automotive applications, and in fiber optic faceplates for cathode ray tubes. However, until the last year or so, plastic fiber's role in the U.S. market never really grew to the extent promised by its initial successes a decade and a half ago. In fact, several years ago the DuPont Company, previously the largest manufacturer of plastic optical fiber in the world, sold its entire manufacturing technology to the Japanese textile manufacturer, Mitsubishi Rayon Company, and exited the market. Only two, much smaller, firms continue to produce plastic fiber in the United States, primarily concentrating on products such as illumination devices.

Though plastic fiber has a number of advantages over glass silica fiber, such as flexibility, resistance to vibration, larger numerical aperture, ease of terminating and connecting fiber ends, and lower system cost, its much lower bandwidth and higher attenuation (or loss) has prevented it from gaining much success against glass optical fiber in the area of data communications. Difficulty in developing fiber that could withstand very high temperatures has also prevented additional potential applications for plastic in automotives and other industrial uses that could otherwise take advantage of plastic's low cost, flexibility, and easy installation.

Despite its shortcomings, 250,000 kilometers of plastic optical fiber valued at between $5 and $10 million were used in the United States in 1986; 2/ over 90 percent of that amount was supplied by three Japanese manufacturers. Applications included automotives, other illumination and display uses, photoelectric switches, various types of sensors. and other short data links.

There was some evidence in 1987 that recent developments in plastic technology, particularly by Japanese manufacturers, may result in a resurgence in sales of plastic fiber. After purchasing DuPont's plastic fiber technology five years ago, Mitsubishi began substantial research efforts of its own, particularly with respect to developing a higher temperature fiber, reducing its attenuation, and devising new applications.

1/ Paul Susca, "Delicate Surgeries Possible Using Fiber Optics," Lightwave, May 1987, p. 41.

2/ Paul Susca, "Plastic Fibers' Dramatic Resurgence," Lightwave, February, 1987, p. 40.

Mitsubishi's efforts appear to be paying off. In 1987, Mitsubishi's sales volume of plastic fiber rose 40 percent and its revenues increased 20 percent. 1/ A large portion of these sales went to the U.S. automotive industry, but increasing sales were made to U.S. computer manufacturers for use in short data links. Optimists in the industry believe that advanced plastic fibers in the United States will permit sales of such fiber to increase ten-fold in the next decade to $100 million in 1995. 2/ However, Electronicast, a U.S. fiber optic market research firm is more pessimistic, predicting that although U.S. shipments of plastic fiber will soar to 20 million meters in 1990 (from 250,000 last year) a price plunge of comparable magnitude will hold the sales value to last years' (1986) $2-3 million level. Mitsubishi's own optimism for its advanced plastic fiber in the U.S. market is underscored by its purchase in 1987 of a 10-percent interest in the largest of the remaining two U.S. plastic optical fiber manufacturers with an option to purchase the firm's remaining interest if the venture proves to be successful.

The General Motors Corporation had been Mitsubishi Rayon's largest U.S. customer, purchasing almost half of Mitsubishi's exports to the United States in 1985. 3/ However, Advanced Display Technologies Inc. (ADTI) of Golden, Colorado may well compete with the huge automotive concern as the largest purchaser of plastic fiber with a new giant fiber optic video screen it has developed which has better resolution than high definition television for new forms of advertising and for large-audience events. 4/ The first ADTI screens were to be installed in September 1987, in the baggage claim area of the Las Vegas McCarran Field Airport where they will project local casino advertising and convention information. The total cost of the screens was $960,000.

> One founding executive at Advanced Display Technologies Inc. said ADTI, the company making the screens, has "been the largest buyer of plastic fiber in the world for the last-year and a half." Each 6-by 8-foot screen contains more than 500 miles of 486/500-micron (core/cladding diameter) fiber, manufactured in Japan by Mitsubishi. 5/

The new developments in plastic fiber have attracted additional firms into the industry. In 1986, Asahi Engineering Industries of Japan announced that it would begin producing plastic fiber to challenge Mitsubishi Rayon. Asahi has been able to produce only samples so far, while developing its technology under license from Nippon Telegraph and Telephone's Iboraki Electric Company. However, it expects to start commercial production by 1988. 6/ In July, 1986, another Japanese firm, Toray Industries, indicated that it had started manufacturing plastic optical fiber.

1/ George Faas, Lightwave, April 1987, p. 45.
2/ Op. cit., Paul Susca, "Plastic Fibers . . . , p. 40.
3/ Op. cit., George Adams, "Video Displays Based on Plastic Fiber," p. 15.
4/ Ibid., p. 15.
5/ Ibid., p. 15.
6/ George Fass "Mitsubishi Producing Heat-Resistant Plastic Fiber," Lightwave, January, 1986, p. 27.

> Some Japanese specialists speculated that the introduction would touch off price competition but price reductions haven't resulted yet. Asahi says it doesn't want to spark a price war, and Toray has entered the market quietly, with little of the publicity that often accompanies Japanese product introductions. 1/

There is also evidence that U.S. manufacturers may be re-entering the plastic optical fiber business in a bigger way than before. In early 1987, Dow Chemical Corporation publicly announced it would enter with a line of low attenuation polyestrene fibers. Dow officials believe that they are the only company in the world that can manipulate the optical properties of plastic fibers by varying the polymer composition. 2/ One Dow company official says:

> . . . Dow will be taking a different approach to the business than Mitsubishi has. Dow will be end-use market-driven." "The 'real guts' of the company's product line are "unique profile waveguides" such as a seven by seven array of 49 cores inside one fiber. One advantage of such waveguides would be enhancing resolution in imaging applications. 3/

There are also rumors that DuPont, may be preparing to re-enter the plastic fiber business. However, rumors of DuPont's re-entry remain only that--rumors. 4/ One Mitsubishi Rayon executive does not see why anyone would consider getting into the market at the present time.

> Market conditions have not changed much since DuPont got out he explains, "Its just not big enough and the growth isn't there." Still he says, the Dupont rumors are "not so far-fetched." 5/

Whether the re-entry of major U.S. firms into the plastic market now dominated by Mitsubishi is too late to make them a competitive factor in the U.S. market remains to be seen. According to another Mitsubishi Rayon official, "we want Asahi and maybe one other maker to enter the plastic fiber field . . . . Two or three manufacturers will help the plastic fiber business - but not more." 6/

1/ Lightwave, July, 1986, p. 18.
2/ Op. cit., Paul Susca, "Plastic Fiber' . . . .," p. 43.
3/ Ibid.
4/ Ibid., p. 43.
5/ Op. cit., George Fass, p. 27.
6/ Ibid.

CHAPTER 6. STRUCTURE OF THE U.S. OPTICAL FIBER AND CABLE INDUSTRY

U.S. Optical Fiber Producers

The U.S. industry can be analyzed along three basic product divisions: glass fiber used for voice, data, and video transmission; (2) plastic optical fiber used for data and nondata purposes; and (3) glass fiber used primarily for nondata purposes. The U.S. optical fiber industry is very concentrated, with producers of telecommunications and data transmission grade fibers limited to only those companies to whom Corning has granted licenses to produce fiber. Table 6-1 shows the estimated market share of Corning and its licensees. 1/

Table 6-1
U.S. optical fiber producers 1/

Company	Estimated U.S. market share 2/
Corning and AT&T	Over 80 percent
Alcatel-Celwave 3/	8-10 percent
Spectran	2 percent

1/ Another, smaller U.S. producer, Lightwave Technologies Inc. is currently fighting Corning's claim that it had violated Corning's patents by producing optical fiber. In addition, Sumitomo Electric Research Triangle, a U.S. subsidiary of Sumitomo Electric (Japan), currently has ceased production of optical fiber as a result of Corning's recent victory in its patent litigation against Corning in Federal court. (See Chapter 3).
2/ Refers to the market for telecommunications grade optical fiber.
3/ Formerly ITT-Valtec.

Source: Kessler Marketing Intelligence.

With the exception of Spectran, all of these companies are large, diversified companies. AT&T, however, is the only fully vertically integrated concern with most of its operations in the United States; consequently, AT&T is the only U.S. fiber producer capable of producing and marketing complete fiber optic communications systems. 2/

Although there may be as many as 20 U.S. producers of glass fiber used for nondata purposes, all but several medium-sized firms, such as Galileo Electro-Optics Corporation, and Schott Fiber Optics (formerly American Optical, later Reichert Jung), are small firms. These firms generally produce not only the fiber that is used in medical and other types of equipment but

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1/ Questionnaires were sent to 47 producers of optical fiber, optical cable, and optical fiber in other multiple fiber forms. Usable responses were received from 33 firms, a response rate of 70 percent. The firms are estimated to have accounted for between 85 and 90 percent of total producers' shipments during 1983-86.
2/ However, it is important to note that Alcatel-Celwave (with its world wide facilities) has the capability of producing systems as well. AT&T's advantage is that its operations are closer together.

also the equipment itself. In the past year there have been a handful of new entrants into the fiber optic sensor market; however responses to the Commission questionnaire indicate that many of these firms purchase the fused fibers for use in their instrumentation from some of the larger firms such as Galileo or Schott. In short, the fiber is simply one of the inputs of the final products of these companies. Although Corning dominates much of the international market for optical fiber used for voice, data, and video transmission, there are a number of U.S. producers of optical fiber used chiefly for nondata purposes. There also are a number of foreign producers that serve this sector, primarily Japanese and West German firms.

The production of plastic optical fiber used to be dominated by E. I. Dupont, with a few smaller U.S. producers manufacturing relatively small quantities of the product. Dupont discontinued production in 1982, and sold its technical knowledge and production rights to Mitsubishi Rayon, a Japanese firm. Whereas there still are at least two remaining U.S. producers of plastic fiber, Mitsubishi Rayon and two other Japanese firms (to a lesser extent) dominate most of the U.S. and international markets. 1/ The remaining U.S. manufacturers reportedly produce fiber that is used almost entirely for nondata purposes (in particular, for illumination purposes). The fiber produced by the Japanese companies can be used for a variety of applications; according to some industry analysts, this portion of the market is expected to grow rapidly over the next 5 years. 2/

U.S. Optical Cable Producers

For the most part, U.S. optical cable producers began as telecommunications cable producers, using copper wire rather than optical fiber. As the demand for optical fiber cable developed, these manufacturers expanded their production facilities to include optical cable. These producers continue to produce the older types of telecommunications or data communications cable as well. In addition, since the 1984 AT&T Consent Decree, the U.S. market has seen the entry of several additional cable (including optical cable) manufacturing subsidiaries of foreign-based telecommunications equipment manufacturers, including Ericcson Lightwave (Sweden) and Pirelli Wire and Cable (Italian). These firms have gathered significant shares of the RBOC and OCC (other common carrier) markets for optical cable. Table 6-2 shows the major U.S. optical cable producers with their estimated share of the U.S. market.

Optical cable manufacturers can be characterized in two basic ways. Some are manufacturers of various types of cable, changing their production mix to match changes in demand. Others are vertically integrated, producing various

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1/ According to some estimates, Mitsubishi Rayon accounts for 90 percent of the international market. There have been some indications that E. I. DePont may reenter the U.S. market as a manufacturer of advanced heat resistant and lower attenuation plastic fibers. Dow Chemical also announced in 1987, its intention to enter this market.

2/ Interviews by Commission staff with officials of manufacturers of optical fiber, cable, and other optical fiber forms at various times during July 1986-September 1987.

Table 6-2
Major Cable Producers in the United States (1986), by shares of the market

Company	Estimated share of the U.S. market (Percent)	Foreign affilation
Siecor	41	Joint venture of Corning Glassworks (U.S.A.) and Siemens (W. Germany)
AT&T	37	
General Cable	5	
Northern Telecom 1/	4	Canada
Ericsson	4	Sweden
ITT (Celwave-Valtec) 2/	2	France
Pirelli	2	Italy
Sumitomo Electric Research Triangle	1	Japan
Others 3/	0	

1/ Although Northern Telecom is based in Canada and manufactures its cable in Canada, it produces other telecom equipment such as switches in the United States.
2/ Now Alcatel-Celwave.
3/ Submarine Cable is produced by Simplex Cable Company in the United States; this type of cable is expected to increase rapidly over the next 5 years as various submarine projects come on line. Thus, this breakdown is likely to change somewhat over the next few years.

Source: William Ferrall and John Kreidl, "Fiber and Cable Design and Price Trends," Lightwave, April 1987, p. 31.

types of cable and other components used in fiber optic telecommunication systems.

As noted in table 6-2, a number of the optical cable companies located in the United States are subsidiaries of foreign multinationals or in the case of Siecor, a joint venture with a foreign multinational. Entering into joint ventures or establishing subsidiaries has allowed foreign multinationals to achieve a toe hold in the U.S. market. In addition, by increasing the number of firms in the U.S. industry, the influx of foreign subsidiaries has provided more choices of supply to buyers in the U.S. market. However, the market is dominated by Siecor and AT&T, which account for an estimated 78 percent of the market.

Because of the high degree of concentration in the optical fiber and cable industries, much of the data furnished by firms responding to the Commission questionnaire cannot be reported. Consequently, much of the discussion below is limited to trends reported for the 1983-86 period and/or to information derived from secondary sources.

U.S. Capacity

Production Capacity

Over the 1983-86 period, total production capacity for optical fiber in the United States increased substantially as the four major producers as well as Sumitomo Electric Research Triangle Corporation expanded production facilities to meet the growing demand of the U.S. telecommunications market during this period. The concentration of this industry precludes the Commission from presenting the total capacity data from its own questionnaire survey for each of the years in question. However, table 6-3 presents some published estimates of total optical fiber capacity for each of the U.S.

Table 6-3
U.S. production capacity for optical fiber, 1986

Manufacturer	Capacity in fiber/km
Corning	1,700,000
AT&T Technologies	1,000,000
IT&T-Valtec (now Alcatel)	160,000
Spectran	100,000
Sumitomo Electric Research Triangle	70,000
Total	3,030,000

Source: Official Journal of the European Communities, August 22, 1986.

fiber firms. 1/ In addition to the above five companies it should be noted that two smaller manufacturers, Lightwave Technologies Inc. and Schott Fiber Optics (formerly American Optical), also had established less significant amounts of fiber making capacity by 1986.

Questionnaire responses indicated that practical U.S. capacity in glass telecommunications grade optical fiber increased more than sixfold from 1983 to 1986, and more than doubled between 1985 and 1986 alone:

Percent increase in single mode and multimode glass optical fiber production capacity from previous year 1/

1984	1985	1986
85	53	112

1/ Derived from responses to the Commission questionnaire.

Source: Data furnished by U.S. industry in response to the Commission questionnaire.

The increases in capacity during the period included the construction of additional manufacturing facilities by the two largest companies in the

1/ Official Journal of the European Communities, Aug. 22, 1986, p. L 236/30-L 236/44.

industry as well as new capacity by the more recent entrants to the market during the 1983-86 period. Industry sources indicate that the more than doubling of telecommunications grade single mode and multimode glass optical fiber capacity was because of rapid and extensive installation of long distance telecommunications networks by AT&T, the Regional Bell Operating Companies, MCI, U.S. Sprint, and other operating common carriers (OCCs) that entered the market after the AT&T divestiture.

Single mode fiber capacity increased from 78 percent of total telecommunications-grade fiber capacity in 1983 to 91 percent in 1986 as improved laser transmission devices and coupling techniques over the period increasingly made this the preferred medium over multimode fiber in long distance networks. Prior to 1983, multimode fibers, which are easier to couple light into and splice but produce greater dispersion (or mixing of signals) were the medium of choice in long distance networks.

Because of the concentration of a large portion of optical cable capacity in the hands of only several major producers, only general discussion may be made of capacity trends in this sector of the market. Questionnaire responses indicated that capacity for telecommunications grade single mode and multimode optical cable grew substantially, almost doubling from 1983 to 1986, though at a less dramamtic pace than capacity for optical fiber:

Percent increase in U.S. single mode and multimode optical cable production capacity from previous year during 1983-86 1/

1984	1985	1986
7	39	33

1/ Derived from responses to the Commission questionnaire.

There are several reasons for the less rapid rise in optical cable capacity compared with that for optical fiber during 1983-86. Though many important foreign markets have been relatively closed to the foreign supply of most telecommunications equipment, they have, for a variety of licensing and internal supply reasons, relied to a greater extent on imports of optical fiber than on optical cable. For example, much of the optical cable exported to the United States from Canada contains U.S.-made fiber as the result of a licensing agreement the major telecommunications cablemaker in Canada has with a major U.S. fiber producer. Thus, a greater portion of U.S. capacity has been developed for optical fiber than it has been for optical cable for export markets. Moreover, for optical cable during the period, an increasing portion of U.S. consumption of optical cable was supplied by foreign suppliers from such countries as Canada, Italy, and Sweden. Meanwhile, licensing agreements and patents held by the major U.S. producers with respect to optical fiber discouraged imports of optical fiber. Now that foreign-based firms have developed or added optical cable manufacturing capacity in the United States, such cable imports should continue to decrease, at least until substantial new uses for optical cable arise in the local loop and subscriber network environment. Though significant gains over the 1983-86 period were made in the growth of capacity for multimode cables designed for the local area network (LAN) and military tactical markets, such capacity still represents less than 3 percent of total cable capacity with most of the remaining capacity devoted to single mode fiber used extensively in long-distance networks. 1/ Cable capacity for these markets, however, is expected by industry analysts to grow rapidly beginning at the end of this decade or early in the next decade. 2/

Commission questionnaire responses also showed that overall production capacity increased for other types of optical fiber used primarily for nondata (nontelecommunications and nondata purposes). However, the capacity for noncoherent bundles increased only moderately each year and by only 12 percent during the entire 1983-86 period, while the capacity for noncoherent bundles declined by 79 percent over the period, suffering its largest decline from 1985 to 1986. These types of multifiber forms are used principally for illumination and for the transmission of images in medical and industrial instrumentation. During 1983, the U.S. medical equipment market suffered as the result of cost-containment measures instituted by the U.S. government and private insurance sectors. The relatively strong U.S. dollar also made imports of medical instrumentation as well as non-data fiber optic bundles from such countries as Japan (Olympus) and West Germany (Karl Storz Endoscopy) more attractive in the U.S. market; several U.S. firms consequently decreased their production capacity in this sector of the market.

Much of the increase in production capacity for non-data fibers occurred in 1986, and was accounted for principally by increased capacity for manufacturing fiber optic faceplates and sensors. These products went into such wide ranging military applications as night vision goggles, submarine detection systems, and industrial sensing instrumentation. During 1983-85, production capacity for both faceplates and sensors increased only slightly; however, in 1986, capacity for faceplates increased substantially, by 43 percent, as major military contracts were obtained by principal defense suppliers of equipment (especially night vision devices) which utilize faceplates. Manufacturing capacity for sensors also remained constant during 1983-85, but increased by 37 percent from 1985 to 1986. Although the questionnaire from one important manufacturer of nondata types of fiber was not received in time for the Commission to incorporate its data into its analysis, a review of the questionnaire showed that company's trends generally followed those above.

Capacity Utilization

U.S. producers of optical fiber for telecommunications and other data transmission purposes were operating at or near 100 percent capacity in each of the years of 1983 to 1985. U.S. manufacturing capacity for optical fiber more than doubled from 1985 to 1986. Although there was a significant increase in export shipments, there was only a small increase in domestic shipments. As a result capacity utilization for optical fiber fell to less than 60 percent in 1980 (table 6-4). U.S. capacity utilization in the

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1/ Derived from responses to the Commission questionnaire.
2/ Interviews by Commission staff with U.S. industry officials and marketing analysts at various trade shows and during fieldwork during 1986 and 1987.

cable manufacturing sector was slightly higher, approaching 65 percent in 1986, and the overall capacity utilization in the sectors of the industry producing nondata fibers was close to the 80-percent capacity utilization figure for all U.S. manufacturing industries during the first half of 1986.

Table 6-4
U.S. capacity utilization for optical fiber and cable

Industry sector	1983	1984	1985	1986
Optical fiber (for telecommunication and data transmission purposes) 1/	100	100	100	59
Optical cable (for telecommunication and data transmission purposes) 1/	100	100	100	64
Optical fiber (for non-data purposes) 1/	76	82	81	80
All U.S. manufacturing industries 2/	74	81	80	80

1/ Derived from responses to the Commission questionnaire to U.S. producers of optical fiber cable, and other fiber forms, and estimates from U.S. industry officials interviewed by Commission staff during 1986 and 1987.
2/ Source: Statistical Abstract of the United States: 1987, U.S. Department of Commerce, p. 734, table no. 1312.

U.S. Producer Shipments

Because of the degree of concentration in the optical fiber and cable industry as well as data limitations, much of the information supplied by U.S. producers in response to the Commission questionnaire with regard to producer shipments can only be discussed in general terms.

According to U.S. Department of Commerce data, domestic shipments of optical fiber cable increased from $88.6 million in 1982, to $594.6 million in 1985, and to $657.5 million in 1986. Other estimates, including aggregate data provided to the Commission by U.S. producers, reflect similar trends.

Industry estimates for 1987 do not show a continuation of this trend, however, but rather reflect the downturn in U.S. consumption of long-haul optical fiber cable. Estimates for 1986 and 1987 are shown in table 6-5.

Shipments of optical fiber for nondata purposes also increased across most categories. Noncoherent bundles increased, but not by a significant amount during the 1983-86 period according to the six questionnaire respondents. Coherent bundles reportedly decreased during the same period.

Shipments of faceplates have risen substantially over the 4-year period, reflecting increases in production for the various reporting companies rather than an increase in the number of producers. Though shipments of these products showed only modest growth between 1983 and 1985, domestic shipments

Table 6-5
Estimated shipments of U.S. optical fiber, by types, 1986-87

Fiber	1986 Shipment (km)	1986 Price per meter	1987 Shipped (km)	1987 Price per meter
Singlemode.......	1,171,000	$0.30	868,000	$0.28
Multimode.......	232,000	$0.51*	284,000	$0.48

*Multimode prices were slightly higher for specific applications such as military where the average price was $0.56 per meter.

Source: Kessler Market Intelligence, Newport, R.I.

of faceplates in 1986 increased over 1985 by 42 percent. U.S. producer shipments of sensors also increased substantially during the 1983-86 period, rising by 50 percent a year between 1983-84, and 1984-85, but by only 25 percent between 1985-86. Other assorted optical fiber products reportedly declined between 1983 and 1984 by 10 percent before increasing by 4 percent in 1985 and jumping by nearly 60 percent in 1986.

The rapid rise in U.S. domestic shipments of faceplates in 1986 was attributed largely to U.S. Army contracts totaling over $1 billion awarded to five companies that manufacture night-vision devices incorporating faceplates. 1/ The new contracts are the first large military orders for a new generation of night-vision combat systems based on optical fiber rather than on older thermal sensing devices. The night-vision business is shared by about 17 companies, including component makers. The companies receiving contracts from the Army did not all manufacture fiber optic faceplates themselves, but purchased the components from U.S. companies such as Galileo, Incom, and Schott Fiber Optics (formerly Reichert-Jung). 2/

These new applications have made the nondata sector of the fiber optics industry a bright spot in an otherwise stagnant optical fiber and cable market in 1986. Fiber optic night vision sales to the military in 1986 amounted to over $200 million, according to a recent trade press article, eight times the amount of shipments to the military of cabled fiber, which sales totaled only $25 million in 1986, according to a report by Arthur D. Little in Commerce Business Daily. 3/ However, industry officials point out that the fiber optic components in such devices only represent a fraction (less than 10 percent) of the total cost of such night vision systems.

Production Costs

Given the sensitive nature of this information, the majority of the optical fiber and cable manufacturers were reluctant to provide much detailed information either in interviews with Commission staff or in questionnaire responses. As a result, it is difficult to draw more than very general conclusions regarding levels of and trends in production costs for these industries.

1/ John Kreidl, "Night Vision is Becoming Important Fiber Application," Lightwave, June 1987, p. 38.
2/ Ibid.
3/ Ibid., p. 38.

As the U.S. fiber optics industry expanded its production over the past decade, learning curve effects enabled U.S. producers to reduce their unit costs substantially. 1/ The unit cost of optical fiber over the past decade "has been reduced by a factor of more than 10," according to one trade press report. 2/ Manufacturing costs (consisting of labor, raw materials and factory overhead costs) have fallen by two orders of magnitude, though the distribution of such costs has changed. Until 1980, factory overhead and labor costs dominated overall costs of producing optical fiber; at that time raw materials constituted only about 5 percent of the total cost of single mode fiber. However, during the past 5 years, while factory overhead costs fell significantly, materials costs remained constant. Presently, about one-third of the cost of optical fiber is in the materials, whereas two-thirds of fiber costs results from the manufacturing processes. 3/

To the extent that learning curve effects continue to operate in the future for singlemode and multimode optical fiber and cable, the industry's unit costs will consist of proportionately more material costs and less labor and capital costs. Thus, to the extent that prices of the materials used for these products fluctuate (and are affected by fluctuations in the value of the U.S. dollar), unit costs may vary more extensively than in the past. In spite of this, a number of industry officials believe that future cost reductions will come not in reductions in materials costs but in manufacturing. Because manufacturing costs have aready been lowered substantially in the current batch mode of producing fiber, future reductions in cost will likely come from new production processes such as the continous fiber production methods being developed by Japanese and Dutch manufacturers (See Ch. 3).

Employment levels and trends

During the 1983-86 period, the optical fiber and cable producers reported a 46-percent increase in the total workforce and a 29-percent increase in production and related workers as shown in table 6-6. Because the number of reporting firms differs between these two categories, it is difficult to draw strong conclusions from these data. However it seems fairly clear that as production processes are modified, and as companies move down their respective learning curves, they may be able to reduce the number of production and related workers involved in the various stages of production. In addition, some of the decline in production workers shown in the tabulation below for 1986 were due to layoffs resulting from the slump in demand for long-haul telecommunications fiber and cable. 4/

1/ Chapter 9 discusses the relationship between the learning curve and average unit costs. In particular, see p. 9-5 for a definition of the term, learning curve.
2/ Ibid.
3/ Ibid., p. 17.
4/ John Ryan, "Fiber's Woes Attributed to Surfeit of Successes," Lightwave, July, 1986, pp. 1 and 21; also (same author) "Cable Demand Cooling," Lightwave, June 1986, pp. 1, 24, and 25.

Table 6-6
Employment

Item	1983	1984	1985	1986
	Number of workers			
All persons	2,741	3,494	3,985	4,014
Number respondents	18	23	24	26
Production and related workers	1,226	1,622	1,627	1,580
Number respondents	14	17	17	18
	Wages (1,000 dollars)			
All products	17,526	3,885,532	4,012,205	4,500,092
Number respondents	11	17	17	18

Source: Respondents to Commission questionnaire

Distribution Channels and Marketing Strategies

Optical fiber manufacturers rely on various strategies for marketing their products. Nonintegrated producers of telecommunications grade optical fiber principally sell their fiber to various cable manufacturers who assemble them into cables for resale in various configurations of their own design. The products of these companies are marketed largely through direct sales; sales through distributors and sales representatives have been minimal. Although AT&T's production of fiber through 1985 was primarily for internal consumption in the manufacture of optical cables, the company announced in 1986 that it would begin offering optical fiber in the open market as well.

Optical cable for long distance communications is often sold directly to the major long distance carriers such as AT&T, MCI, U.S. Sprint, the RBOCs, and other operating common carriers (OCCs). Responses to the Commission questionnaire, however, indicated that different RBOCs had different policies with respect to purchasing; in some instances the local companies of an RBOC made their own purchasing decisions, whereas in others the RBOC centralised the purchasing decisions of its local operating companies. Long distance-data-communications cable was also sold directly to various network contractors.

Shorter distance data communications and local area network cables, including specialized computer-interconnect cables, were distributed in a more diverse fashion. In some instances they were sold directly to computer firms or to manufacturers of cables or connectors who developed particular office and industrial systems. Over the past couple of years there has been an increasing number of middlemen and contractors operating in this end of the markets who sometimes negotiate purchases of cable directly on behalf of their customers.

Optical fiber and cable designated for military-tactical applications may be sold directly to military procurement officials. However, it is sold more often to defense contracting and subcontracting firms for use in various systems these firms have been contracted to develop for the military.

Nondata fibers, cables, bundles, and other fiber forms such as faceplates, sensors and fiber optic gyros are marketed in diverse ways to medical and industrial equipment manufacturers, automobile manufacturers or subcontractors, through dealers, agents, and middlemen, to military procurement officials of subcontractors, or used directly by the producer as components in their own instrumentation or systems.

The following tabulation indicates the most important marketing strategies of U.S. firms responding to the Commission questionnaire:

Marketing Strategies:

	Frequency of reliance on strategy			
	Heavy	Moderate	Slight	Number of non-responses
Pricing..........	41	19	13	
Product quality..	49	20	5	
Technical service........	34	26	13	1
Advertising......	14	28	28	4
Intracompany.....	10	7	13	44
Barter/counter-trade..........	2	2	19	51
All other........	8	3	5	58

The strategy of the greatest number of firms responding to the survey indicated a heavy reliance on product quality, followed by pricing and technical service for marketing their products. The pricing and product quality of optical fiber appeared, however, to be of lessening importance among the larger producers of telecommunications grade optical fiber; as fiber has evolved into a more homogenous lower priced commodity item, technical service appears to have increased in importance. Pricing and quality also have become less of an influence for the larger cablemakers, especially with respect to cable manufactured for the long-distance market. However, many smaller producers of specialty cables indicated a heavy or moderate reliance on product quality to differentiate their products in the market. Manufacturers of non-data fibers, bundles, and other fiber forms were also more likely to show a heavy reliance on pricing and product quality as a marketing strategy.

Advertising, mostly in trade journals, was only relied on moderately or slightly by most of the firms responding to the questionnaire. This was due to the nature of these businesses, which generally do not market their products to households or individuals, but to telecommunications service providers, or to industrial, medical, or military component or system manufacturers and markets.

Financial Experience of U.S. Producers

The two industry leaders did not supply income-and-loss data for their optical fiber manufacturing operations. Although industry experts are mixed in their analyses of 1986 industry earnings performance, most report that industry earnings at best were flat when compared to 1985, after recording substantial growth in revenues between 1983-85. Corning indicated that their overall optical fiber business was strong in 1986, but this strength was primarily in their overseas markets. 1/ There is no question, however, that smaller fiber and cable firms were hard hit by the downturn for optical fiber and cable that began in 1986. One company official explained that several factors related to the downturn adversely affected his company's performance in 1986:

> [Spectran] is a second source for several large cable makers, [the official] says, primarily for Corning Glassworks. Corning has long-term contracts with many cable makers, and these contracts exact financial penalities if orders fall short. So [the company official] reasons, when demand for cable slackens, the cable makers keep buying from Corning and cut their orders from secondary suppliers. Spectran's layoffs affect both Spectran and Sonetran, joint-venture of Spectran and Southern New England Telephone. Sonetran's rights to fiber-making patents have come under legal challenge from Corning.... 2/

Several smaller companies furnished income-and-loss data for the 1983-86 period (table 6-7). The rapid growth of the industry is reflected in the increasing number of firms that reported data between 1983 and 1986. In 1986, 15 firms supplied financial information, whereas, only 8 firms furnished such data in 1983. Voice, video and other data information applications accounted for most of the industry growth. Net sales rose 440.8 percent from $56.3 million in 1983 to $304.3 million in 1986. An operating loss of $7.8 million was incurred in 1983. Operating income was $11.7 million in 1984 and rose to 33.6 million in 1985. In 1986, operating income declined to $15.6 million as telephone network demand declined over the previous year. Operating income (loss) margins as a percent of sales were (13.8), 9.9, 13.3, and 5.1 in 1983, 1984, 1985, and 1986, respectively. Three firms reported operating losses in 1983, 1984, and 1985. Five firms reported such losses in 1986.

Although revenues for manufacturers of optical fiber, optical cable, and other optical fiber forms used for nondata purposes increased annually during 1983-86, severe price reduction in the medical goods industry, which accounted for a significant portion of nondata fiber, was responsible for some of the decline in operating income for the industry from 1985 to 1986, as shown in table 6-2. However, certain segments of the nondata optical fiber industry performed remarkably well, primarily because of increased sales of fiber optic faceplates and sensors for use in military applications. According to one trade article, the three largest manufacturers of fused fiber optic faceplates, Galileo Electro-Optical Company, Incom, and Schott Fiber Optics 3/ all showed excellent earnings resulting from their sales of fused fiber optic faceplates to military contactors for use in night-vision devices. According

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1/ Corning Glass Works-1986 Annual Report, pp. 2 and 3.
2/ John P. Ryan, "Cable demand cooling; 2 firms order layoffs," Lightwave, June 1986, p. 1.
3/ Questionnaires were not received or were not received in time to include in the Commission's analysis in this report for 2 of these 3 firms.

Table 6-7
Income-and-loss experience of 15 U.S. producers on the overall operations of their firms in which optical fiber, and optical cable used for voice, video, and data purposes, and non-data purposes were produced, 1983-86 1/

(In thousands of dollars)

Item	1983	1984	1985	1986
Net sales:				
Optical fiber and cable used for voice, video, and other data purposes	46,847	104,112	237,680	289,322
Optical fiber and cable used for non-data purposes	9,418	13,544	13,612	14,980
Total	56,265	117,656	251,292	304,302
Operating income (loss):				
Optical fiber and cable used for voice, video, and other data purposes	(8,859)	9,826	32,756	14,936
Optical fiber and cable used for non-data purposes	1,081	1,864	811	657
Total	(7,778)	11,690	33,567	15,593
	Share of net sales (percent)			
Operating income (loss):				
Optical fiber and cable used for voice, video, and other data purposes	(18.9)	9.4	13.8	5.2
Optical fiber and cable used for non-data purposes	11.5	13.8	6.0	4.4
Weighted average	(13.8)	9.9	13.3	5.1
	Number of firms reporting			
Operating losses:				
Optical fiber and cable used for voice, video, and other data purposes	2	2	2	4
Optical fiber and cable used for non-data purposes	1	1	1	1
Total	3	3	3	5
Data:				
Optical fiber and cable used for voice, video, and other data purposes	3	5	7	10
Optical fiber and cable used for non-data purposes	5	5	5	5
Total	8	10	12	15

1/ Based on responses to the Commisson questionnaire used in this investigation.

Note: These data do not include the two largest firms, Corning and AT&T.

to the report, Galileo "reported record earnings in 1986, and had its best year since it emerged as a spinoff of Bendix Inc. in 1973.

> Last year, 59% of Galileo's sales came from its night-vision products.
> Better yields and margins on fiber optic products, including faceplates, were directly responsible for Galileo's success last year. Sales of all fiber optic products increased by 73% to $16.42 million but profit on those items soared 500% to $5.6 million in 1986. 1/

Industry sources indicate that growth of night-vision systems in other areas, such as U.S. scientific and foreign military organizations, as well as steady business for the U.S. military sector should continue to fuel demand for fiber optic faceplates. 2/

1/ John Kreidl, "Night Vision is Becoming Important Fiber Application," Lightwave, June, 1987, p. 39.
2/ Interviews by Commission staff with U.S. and foreign producers and purchasers of optical fiber and cable during fieldwork in the United States and Western Europe in 1986 and 1987.

CHAPTER 7. LEVELS AND TRENDS IN U.S. TRADE

Trade Balance

U.S. imports of optical fiber and cable increased approximately tenfold, from less than $10 million in value in 1983 to over $97 million in 1985, before declining 26 percent to less than $72 million in 1986. U.S. exports, meanwhile, grew less rapidly than in the 1983-85 period, rising by less than 72 percent to $34 million in 1985, which represented only slightly more than one-third the value of imports in that year. However, from 1985 to 1986 exports almost doubled to $68 million, closing a 1985 trade deficit of almost $63 million in optical fiber and cable to less than $4 million in 1986 (table 7-1).

Table 7-1
U.S. imports, exports, and balance of trade for optical fibers and cable, 1983-86

	1983	1984	1985	1986
U.S. imports........	10,568	40,410	97,324	71,678
U.S. exports........	20,086	26,270	34,465	68,102
U.S. trade surplus (deficit).........	9,518	(14,140)	(62,859)	(3,576)

Source: Compiled from official statistics of the U.S. Department of Commerce.

During the first 6 months of 1987, the U.S. industry showed a $24 billion surplus in its balance of trade. Though U.S. exports only increased negligibly to $34 billion during that period from the comparable period in 1986, imports dropped considerably to less than $10 million in the January-June 1987 period from over $50 million in the comparable 1986 period. Official data and estimates by industry sources 1/ indicate that over 85 percent of the optical fiber and cable trade during 1983-86 was accounted for by optical cable used for telecommunication transmissions of voice, video, and data information.

U.S. Imports

The tenfold increase in U.S. imports during the 1983-85 period occurred during a period of very rapid expansion of telecommunications network capacity in the United States, which was able to utilize the large bandwidth and information-carrying capacity of optical fiber cable. As orders for optical fiber and optical cable increased during this period, the U.S. industry's capacity utilization approached 100 percent, and additional business went offshore. During 1985, U.S. imports accounted for nearly 15 percent of U.S. domestic consumption, up from 5 percent of consumption in 1982 (table 7-2). However, when major long-distance networks were completed in the U.S. market

1/ Derived from responses to the Commission questionnaire.

during 1986, imports tapered off even faster and only accounted for about 11 percent of U.S. consumption in that year. Through the first 6 months of 1987, imports dropped precipitously to less than $10 million and at the present pace may account for less than 5 percent of U.S. consumption at the end of 1987.

Table 7-2
Optical fibers and cable: U.S. producer shipments, exports of domestic merchandise, imports for consumption, and apparent consumption, 1982, 1985, and 1986

Year	Producer Shipments	Exports	Imports	Apparent Consumption	Ratio of imports to consumption
	1000 dollars				Percent
1982	88,600	6,501	4,770	86,869	5
1985	94,600	34,465	97,324	675,459	15
1986	657,516	68,102	71,678	661,092	11

Source: Compiled from official statistics of the U.S. Department of Commerce.

Canada was by far the largest supplier of optical fiber and cable to the United States in 1986, accounting for $42 million, or almost 59 percent, of total U.S. imports in that year (table 7-3). However, that amount represented a 37-percent decline from the $67 million level of imports supplied by Canada in the previous year, when it enjoyed a 69-percent share of U.S. imports. A large portion of the Canadian imports consisted of U.S.-made optical fiber.

Table 7-3
Optical fibers and cable: U.S. imports for consumption, by principal sources, 1983-86

Source	1983 1/	1984 1/	1985	1986
	Value (1,000 dollars)			
Canada	6,848	24,861	67,103	42,161
United Kingdom	173	974	12,607	15,075
Japan	2,172	5,601	10,049	7,370
West Germany	850	7,229	3,325	2,391
Korea	0	209	1,771	2,269
France	21	11	429	746
Italy	0	20	61	591
Israel	82	224	913	590
Switzerland	121	90	200	160
Sweden	24	67	318	86
All Other	82	224	913	590
Total Imports	10,568	40,410	97,324	71,678

Source: Compiled from official statistics of the U.S. Department of Commerce.

into cable by a large Canadian-based telecommunications equipment manufacturer. This company had been responsible (through its U.S. subsidiaries) for the installation of substantial portions of the telecommunication network capacity established by new competitors to AT&T, including that of several RBOCs in the U.S. telecommunication services market. During the first 6 months of 1987, imports from Canada had fallen to $6 million from almost $30 million during the same period of 1986.

The United Kingdom and Japan were the second and third largest sources of optical fiber and cable in 1986, accounting for $15 million and $7 million, or 21 percent and 10 percent, respectively, of total U.S. imports. At least a portion of the United Kingdom imports represented uncabled optical fiber imported early in the year by a major U.S. manufacturer to supplement its own production before sales leveled off later in the year. The bulk of the remaining United Kingdom imports of optical fiber, however, were of a United Kingdom manufacturer of specialty fibers.

A significant portion of the optical cable supplied to the United States by the United Kingdom was utilized in the data communications segment of the U.S. market. Over $2.5 million, or 17 percent, of United Kingdom exports to the United States were nondata fiber bundles and other multiple fiber forms for use in medical, scientific, and industrial instrumentation. The United Kingdom was the largest foreign supplier of such fiber to the U.S. market in this relatively stable portion of the optical fiber market. Unlike its competitors in Japan and Canada, the United Kingdom industry's sales to the increasingly sluggish U.S. market in 1986, represented an increase over the previous year when sales were almost 20 percent lower.

Although Japan remained the third leading supplier of fiber and cable to the U.S. market in 1986, sales slumped by almost $3 million from the previous year to $7 million. This was due partly to completion of optical fiber and cable production capacity in 1986 by the largest Japanese supplier (Sumitomo) which supplanted at least temporarily the firm's need to export cable to the U.S. market. There were indications too that Sumitomo eased its exports of optical fiber to the United States in view of several pending patent litigation actions, including an unfair trade complaint brought before the International Trade Commission by Corning Glassworks, alleging that Sumitomo's imports of optical fiber and cable containing the fiber were in violation of the U.S. company's basic patents (See Ch. 3).

Japan was still able to maintain its third-place position in the U.S. market because of a significant increase in exports to the United States of plastic optical fiber (principally by Mitsubishi Rayon Company). Industry sources indicated that Japanese plastic fiber exports increased from approximately $560,000 in 1983 to nearly $2 million in 1985 1/ and may have amounted to $3 million in 1986, as improvements in the transmission and physical characteristics of such fiber broadened plastic fiber's applications in the U.S. automobile as well as computer industries.

Though official U.S. import data indicated that almost one-quarter of the Japanese imports in 1986 were for nondata purposes, they did not separately identify the portion of such imports accounted for by plastic fiber forms.

Industry officials indicate, however, that Japan continued to be the second largest supplier of nondata fibers, bundles, and other multiple fiber forms, which were supplied chiefly by Mitsubishi (plastic) and Olympus Optical Company (glass) for purposes of illumination and image transfer for uses in medical, scientific, and industrial instrumentation.

Imports from West Germany were valued at $2.4 million in 1986, primarily optical cable. This was down 28 percent from 1985, as an important West German telecommunications cable supplier with important contracts in the U.S. market suffered when some major fiber optic networks it was involved in approached completion.

Other suppliers of optical fiber and cable to the United States in 1986 included France, Italy, Israel, Switzerland, and Sweden. In general, the imports from these countries were down from 1985. Of special note are Israeli imports of optical cable, amounting to slightly over $0.5 million. They were imported by a U.S.-based company specializing in the data communications and local area network (LAN) market, which has established all of its fiber-manufacturing facilities in Israel to take advantage of various tax breaks afforded it there.

Exports

There were several reasons for the relatively slower growth in U.S. exports compared with imports during the 1983-85 period. First of all, the deregulation and opening up of the U.S. telecommunications market in the first several years after the AT&T breakup had no parallels in the rest of the world, which was still dominated chiefly by closed government PTT-controlled markets. Secondly, the United States was at least several years ahead of other countries in the planning and installation of long-distance fiber optic telecommunications networks. As a consequence, the U.S. market was essentially the world market during that period.

With the faster than expected development of U.S. optical fiber service capacity in the United States, and with the expectation of future growth in local area network and subscriber linkups to the home, U.S. producers (including new entrants to the industry) almost doubled capacity between 1985 and 1986. They did anticpate the sudden downturn in the growth of the U.S. market that was to occur in 1986. Secondary entrants to the optical fiber industry were particularly hard hit. The largest firms were able to adjust fairly rapidly by increasing exports, particularly to Western Europe, Canada, and Australia. The U.S. industry was fortunate that plans for installing fiber optic telecommunications backbone

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1/ Interviews by Commission staff with industry and government officials, in West Germany during fieldwork in Western Europe during December, 1986.

networks in areas such as Western Europe, the United Kingdom, and France were just coming to fruition at the end of 1985 and into 1986 at just the time growth was dampening in the United States. There was even some evidence that telecommunications authorities in at least several countries (the United Kingdom, France, and Japan) were showing some liberalization in their procurement policies to promote more competition and lower costs in their own markets.

In 1986, the value of U.S. exports to West Germany rose more than two and one-half times over 1985 to almost $25 million, which represented 36 percent of total U.S. exports of optical fiber and cable (table 7-4). Extensive plans by the Deutsche Bundespost (the German telecommunications agency, or PTT) forlaying a fiber optic backbone network connecting major cities were heavily underway by 1986. The optical fiber requirements of these plans exceeded West Germany's own capacity for producing optical fiber. Furthermore, a major plant established by a joint venture of the U.S. fiber producer Corning Glassworks and the West German cable manufacturer Siemens was not ready for full production until the end of the year. Thus major German cablers depended to a fairly significant extent on imports of U.S.-made optical fiber so installation of the planned fiber optic networks could proceed according to the planned time schedules of the Bundespost. Industry officials believe that future exports to the West German market will fall off over the next several years, now that

Table 7-4
Optical fibers and cable: U.S. exports, by principal markets, 1983-86

Market	1983	1984	1985	1986
	Value (1,000 dollars)			
West Germany	5,246	11,855	9,043	24,773
Canada	397	1,732	5,396	10,219
Australia	11	174	2,185	6,994
France	1,670	817	876	5,828
United Kingdom	173	5,501	4,544	4,016
Netherland	254	54	164	3,791
Japan	242	483	4,416	2,897
Norway	1	77	1,171	1,649
Nigeria	0	0	0	1,340
Italy	889	1,821	1,767	1,329
All other	3,203	3,756	4,904	5,268
Total imports	20,086	26,270	34,465	68,102

Source: Compiled from official statistics of the U.S. Department of Commerce.

West German fiber-making capacity has been increased. In fact, U.S. exports to West Germany in the first half of 1987 are down almost 70 percent from the comparable period in 1986, dropping West Germany to third place during that period among leading export markets for U.S. optical fiber and cable.

U.S. exports of optical fiber and cable to the Canadian market, the second largest overseas market for the U.S. industry in 1986, almost doubled to $10 million. This occurred notwithstanding complaints by a number of U.S. industry officials that the Canadian market is relatively closed to U.S. imports of telecommunications equipment because of the captive supplier relationship Northern Telecom enjoys with Bell Canada, the national telecommunications services provider. 1/ It is believed that the increased installation of optical cable in new long distance networks and nondata types of fiber in Canada accounted for much of the increase in U.S. exports. Industry sources also point out that related-party transactions accounted for a large portion of the exports.

U.S. exports to the Australian market more than tripled to nearly $7 million in 1986 from 1985, enabling that country to overtake the United Kingdom as the third largest market for U.S.-made optical fiber and cable from the previous year. In 1985/86, Telecom Australia, a semigovernmental authority that controls the domestic market for telecommunications services, increased by a factor of four its purchases of optical cable to 32,000 fiber kilometers from 1984/85, largely for high-capacity interexchange and long distance routes (See Ch. 10). In addition that country's Overseas Telecommuncations Commission, which controls telecommunications links between Australia and other countries, ships, and external territories, initiated several submarine cable networks that also increased its purchases of optical fiber cable in the Australian network. Though Australia recently instituted changes in tariffs in an attempt to promote the development of its own optical fiber and cable capacity, significant increases in demand in that market provided opportunities for foreign suppliers such as the United States, the United Kingdom, and Japan, in 1986.

Exports to the French market were a pleasant surprise in 1986, improving to almost $6 million from less than $1 million in the previous year. Interviews with officials of the French Government indicated a desire to open its market to more suppliers so as to lower historically high costs for products and services in the telecommunications sector. 1/ U.S. suppliers were also able to benefit from licensing relationships and technology transfer agreements which resulted in increased export sales to related parties and licensees. The French market more than any other, including that of the United States, has experimented with fairly extensive subscriber network experiments in such cities as Biarritz and Montpellier to introduce into homes a variety of new services such as picture telephone, facsimile, cable television, and a number of interactive services requiring the bandwidth only optical fiber can provide.

1/ Both Bell Canada and Northern Telecom are owned by Bell Canada Enterprises, a holding company. Though Corning Glasswork's fiber licensing arrangement with Northern Telecom requires a substantial portion of U.S.-bound Canadian manufactured optical fiber cable to contain Corning-made fiber, the declining U.S. imports of such cable from Canada could not have by themselves accounted for such an improvement in U.S. imports.

Exports to the United Kingdom from the United States dropped in total value from the previous year by nearly 12 percent, to $4 million. Industry sources in Great Britain pointed out that though fiber optic backbone networks continued to be installed in 1986, increased capacity in the United Kingdom, including that of BICC-Corning Glassworks joint venture, resulted in lower requirements from foreign suppliers.

The Netherlands purchased just under $4 million worth of optical fiber and cable from U.S. producers in 1986, after purchasing less than $200,000 in 1985. Dutch telecommunications authorities indicated that they are trying to lower costs of their telecommunications services by encouraging optical cable manufacturers to consider alternative sources of supply to Philips for optical fiber. The telecommunications authorities also indicated displeasure with the quality of recent cable purchased for a major fiber optic project that contained Philips fiber. 1/ According to U.S. and Netherlands industry officials these open procurement policies assisted U.S. exporters in 1986, though the relatively small Netherlands market does not represent much future potential for U.S. suppliers, particularly in the long-distance telephone market, which is practically nonexistent because of the relatively short distances between Netherlands borders.

Japanese purchases of U.S.-made cable dropped by 34 percent to just under $3 million from $4.4 million in 1985, despite market-oriented-sector selective negotiations (MOSS talks) conducted by U.S. trade officials in 1985 in an attempt to open Japanese telecommunications and other important markets to U.S. goods. There were some signs that things would improve, however, when in 1986, the U.S. cable manufacturer Siecor reported it had obtained its first contract for supply of optical cable to the Japanese market.

Other markets for U.S. optical fiber and cable in 1986 (mostly cable) that should be noted were Norway, Nigeria, and Italy, each of which purchased in excess of $1 million worth of U.S.-made goods in 1986.

Present and Future Prospects for U.S. International Trade

Through the end of this decade, U.S. market opportunities for optical fiber and cable are expected by industry analysts to decrease as major long distance fiber optic networks are completed. 1/ During the first 6 months of 1987, imports of optical fiber cable had fallen to less than $10 million from $51 million in the similar period of 1986. Canadian imports dropped by 78 percent to $6.5 million from almost $30 million in the comparable period a year earlier and United Kingdom imports dropped to almost none from $14 million in the January-June 1986 period. Northern Telecom's exports to the United States dropped during this period because of the completion of several important RBOC networks this company was involved in. U.S. imports from the Canadian manufacturing facilities of Pirelli slowed after the 1986 completion of a U.S. optical cable plan in Lexington, North Carolina, by the Italian-

1/ Interviews by the Commission with Netherlands telecommunications authorities in the Hague on Sept. 8, 1987.
2/ Commission interviews with French Government officials in December, 1986.

based company. Exports from the United Kingdom of optical fiber to the U.S. market by the largest British producer, also slowed in 1986. Optical cable sales, including those for data communication purposes also suffered.

U.S. imports of optical fiber are not expected to increase significantly before 1990, when local area networks and finally subscriber linkups to the home finally develop during the next decade. However, many of the major foreign suppliers involved in this market now have production facilities in the United States and will make their production and marketing decisions based on such criteria as exchange rates, transportation costs, and labor costs, and other factors. The expiration of basic Corning patents is also expected to greatly influence prospects for U.S. imports of optical fiber. Up until the present time, the bulk of U.S. imports of optical fiber and cable have consisted primarily of optical cable for telecommunications purposes, as well as plastic, and nondata and nontelecommunications-grade optical fibers not affected by the Corning patents. With the expiration of Corning patents, optical fiber manufactured by large foreign producers such as Sumitomo in Japan, Philips in the Netherlands, Goldstar in Korea, as well as current Corning joint-venture partners and licensees, in the United Kingdom, West Germany, and Italy, are expected to enter the U.S. market when mor intensive local area and subscriber networks will bring about another period of high demand for optical fiber in the world's largest and most open market for telecommunications products.

U.S. exports of optical fiber and cable are expected by industry sources to generally maintain their present level in overseas markets, subsiding slightly by the end of the decade as European long-distance telecommunications markets mature and complete manufacturing facilities of their own. During the first 6 months of 1987, exports rose negligibly over those in the same period in 1986 to $34 million. Increased shipments to Canada (up 36 percent to $6.7 million), France, (up more than threefold to $5 million), Japan (up more than 175 percent to $2.7 million), and the Netherlands (more than double to $3.8 million) made up for a substantial decline in exports to West Germany, which were down 69 percent to $4 million from almost $13 million in 1986. Prospects for exporting optical fiber to West Germany diminished considerably with the 1986 completion of the Corning-Siemens joint venture (Siecor) to manufacture optical fiber in West Germany, which now possesses the second largest fiber making capacity in Western Europe.

The largest growth in demand for optical fiber during the next several years in Western Europe should be in the nonproducer country markets of Spain, Portugal, Switzerland, and Austria. Although both AT&T and Corning had developed plans for establishing fiber-manufacturing plants in Spain, European industry and government officials believe that those plans have been put on hold because of excess global capacity in 1986. 1/ It remains to be seen whether potential markets such as Spain will be supplied from outside or will develop their own manufacturing capabilities.

1/ Interviews by Commission staff with U.S. optical fiber and cable producers during investigative fieldwork on 1986 and 1987.
2/ Commission staff interviews with European industry and Government officials, Sept., 1987.

Industry analysts and officials interviewed by the Commission in the United States during 1986 and 1987, believe that the best prospects for U.S. exports will occur in developing areas of the world such as Brazil, Argentina, the Peoples Republic of China, Southeast Asia, the Middle East, and India as these areas complete long-planned comprehensive telecommunications infrastructure. They also expect that U.S. suppliers to these regions will face formidable challenges from Western European, Japanese, and other Asian suppliers (including Korean) of both optical fiber and cable. The United States will have to overcome the considerable advantage many European suppliers have in former colonial areas in Asia and Africa and other areas where historical ties have been developed, like Pirelli's long-standing relationship with African and South American markets. In addition, as fiber becomes more and more of a commodity, industry officials fear that newer, low-cost manufacturers in such East Asian countries as South Korea will take significant business away from mature firms in the United States and West Europe.

U.S. industry representatives point to the Peoples Republic of China as a country with an outstanding potential market for future exports of optical fiber and cable. Though Chinese officials have indicated a desire to develop their own fiber optics industry, both U.S. and European officials indicate that if the Chinese market develops as expected, it will still provide ample room for imports. The U.S. industry officials warned, however, that U.S. export administration law, regulations, and procedures will have to be extensively revised and streamlined if U.S. manufacturers of optical fiber, cable, and especially optoelectronic components and systems, are to be able to take advantage of the potential of the Chinese market. They point out that Japanese and even European manufacturers are establishing relationships with Chinese Government and telecommunications authorities to position themselves well for the future, when larger contracts will be awarded. Trade officials at the U.S. Department of Commerce and the Defense Department advised the Commission that efforts were being made to reduce the burden of U.S. export administration procedures, including the removal of readily available products such as optical fiber and cable from official lists of controlled items. 1/ U.S. industry officials, though, continue to be concerned that more advanced technology and products such as specialty fibers and newly developed optoelectronics components and systems will continue to be penalized by extensive and painstakingly slow Commerce Department review and conservative Defense Department oversight. 2/

1/ Telephone interviews with officials of the Commerce Department's Office of Export Administration and the Defense Department's Director of Strategic Trade on Nov. 27, 1987.

3/ Interviews by Commission staff with industry officials and marketing anaylsts covering the fiber optics market at various occasions during 1986 and 1987.

CHAPTER 8. OVERVIEW AND STRUCTURE OF RELATED OPTOELECTRONICS INDUSTRIES

The optoelectronic component segments of the U.S. fiber optics industry is structured very much differently than the optical fiber and cable segment. Whereas this latter segment is dominated in the United States by several major manufacturers like Corning, AT&T, and Siecor, that together account for the bulk of the market, the producers of such components as lasers, light-emitting diodes, detectors, and receivers consist generally of much smaller, more specialized firms whose average total sales range from less than $5 million to $25 million per year.

Many of these firms enjoyed rapid success in U.S. and global markets as the optical fiber industry expanded during the first half of the 1980s. However, the prospects of these relatively small firms have been dampened by the recent entry of large integrated manufacturers of electronic, telecommunication, and fiber optic apparatus and equipment in Japan and Western Europe.

Background and Profiles of the U.S. and Global Optoelectronics Industries

Until the late 1970s, there were only a handful of fiber optic laser suppliers in the United States, or even the world. These early suppliers were the U.S. firms Laser Diode and General Optronics, the Japanese firm Hitachi, and Standard Telephone and Cable (STC) of the United Kingdom. The first lasers were short window devices used principally with multimode optical fiber, the fiber of choice in fiber optic network systems until about 1984. At that time fiber optics moved into longer wavelength transmission, and single mode fiber replaced multimode fiber in rapidly expanding nationwide telecommunications networks. With the introduction of the longer wavelength systems and increasing demand for fiber optic systems, a number of new firms entered the lightwave source (lasers, light emitting diodes) and detector markets in the United States. One of these, Lasertron, a pioneer in long wavelength lasers based outside of Boston, is today the largest independent manufacturer of fiber optic, or lightwave, lasers in the United States, though with less than $25 million in total annual sales. This firm also has an estimated 12-15 percent of the global market 1/ for lasers used in long distance telecommunications systems.

Though large integrated manufacturers of electronic and telecommunications equipment like AT&T and RCA conducted much of the original research and development on lasers in their laboratories during the 1970s, for various reasons they did not find the commercialization of these products to be of sufficent commerical merit to supply these devices to the market, even during the rapid deployment of long-distance fiber optic systems during 1983-85. 2/ This provided an opportunity for a number of U.S. start-up companies, as well as larger Japanese and European integrated manufacturers, to enjoy very rapid

1/ Interviews by the Commission with major U.S. manfacturers of fiber optic systems in the United States during August 1987.
2/ Ibid.

growth and success in the U.S., and more recently, the European market. In fact, a number of U.S. optoelectronic component firms were begun by researchers and managers who had been responsible for much of the advanced laser research during the 1960s and 1970s in RCA's and AT&T's (Bell Labs) laboratories. 1/

Though there are larger integrated suppliers of fiber optic lightwave systems in the United States, including AT&T, RCA, Rockwell, General Electric, and GTE, at least until recently these firms depended upon other U.S. and foreign manufacturers (particularly Hitachi) for certain components (such as semiconductor lasers and detectors) of their systems. Recently, some of these larger U.S. manufacturers have announced that they are going to become increasingly involved in lightwave component manufacture so as to lessen their dependence on foreign sources of components for their systems. AT&T, for example, in 1986 severed its contractual ties with Hitachi to supply it with lasers and announced it was expanding its own laser production facilities. According to one trade magazine, "AT&T's efforts will presumably cut down on its purchases from Hitachi, which could also free the Japanese company to make other sales in the United States." 2/ Other U.S. component manufacturers indicated to the Commission their belief, though, that AT&T more than likely would be primarily a captive supplier of components and systems to AT&T Communications' own networks (though admittedly a very important part of the market). 3/ RCA has also announced that it will increase its emphasis on the manufacture of lightwave components for the open market and in 1986 combined its U.S.-based detector plant with light-source manufacturing facilities in a suburb outside of Montreal, Canada.

By 1986, the number of manufacturers of fiber optic lightwave sources in the world had increased to about 30, from only a handful several years before. About 10 of these firms are in the United States. A number of very large integrated manufacturers in Europe and especially Japan have now entered the market. A profile of the fiber optic long-distance laser industry in the United States, Europe, and Japan today is shown below:

United States	Western Europe	Japan
Lasertron	STC	Hitachi
	Plessey	
General Optronics	Philips	NEC
Laser Diode	Thompson-CSF	Sharp
	Atcatel	

1/ Ibid.
2/ "More Vendors Moving Into Long-Wave Lasers," Lightwave, November 1985, p. 1.
3/ Interviews by the Commission with U.S. and foreign manufacturers of fiber optic optoelectronic components in the United States, the Far East, and Western Europe during August and September 1987.

United States	Western Europe	Japan
Lytel	BT&D	Toshiba
Spectra Diode	Siemens	Matsushita
PCO		OKI
Lasercom		Fujitsu
AT&T		Mitsubishi
Rockwell		(More recently there has been evidence that Sumitomo Sony, and Sanyo are preparing to enter the market)
GTE		
Epitaxx		

It should also be noted that Northern Telecom, a Canadian-based supplier of telecommunications equipment that has become an increasingly important player in the U.S. market, has also supplied the lasers for several important fiber optic networks completed by its Northern Telecom subsidiary in the United States.

Although official U.S. statistics are not compiled separately for U.S. shipments of lightwave optoelectronic sources and detectors, several U.S. industry officials estimated that the U.S. market for long wavelength lasers for lightwave systems amounted to $150 million in 1986, though others interviewed by the Commmission believed that figure was much too high. 1/ There is little dispute, however, that the market grew rapidly (from less than $10 million in the early 1980s) as major fiber optic networks were installed .

In the early 1980s, AT&T and Rockwell optoelectronic systems (incorporating to a large extent Japanese-made components) accounted for such a large portion of the initial U.S. fiber optic long-distance networks, with the remainder of the market shared by the smaller U.S. optoelectronic component firms. However, the rapidly expanding U.S. market during 1983-85, including networks built by AT&T's new competitors in telecommunications services, provided additional opportunities for these smaller firms. Also, laser manufacturers like Lasertron and General Optronics were very successful in penetrating overseas markets, particularly in Western Europe. In fact, industry officials estimated that almost one-third of General Optronic's revenues and over two-thirds of Lasertron's total sales in 1985 and 1986 were achieved overeseas, even in the ordinarily closed telecommunications markets of West Germany and France. 2/ The overseas success of the U.S. firms was remarkable, considering the adverse exchange rate situation faced by U.S. firms during 1984 and 1985 when they were achieving their greatest success. The success of the U.S. firms is attributed by U.S. and West European industry

1/ Interviews by the Commission with U.S. manufacturers of fiber optic optoelectronic components and systems during investigative fieldwork in New Jersey, New England, Texas, and California during August and September 1987.
2/ Ibid.

sources to the superiority and reliability of the U.S. product and the fact that U.S. firms were careful not to compete for the customers of the large telecommunications systems manufacturers to which they supplied lasers and detectors.

Recent Developments

Commission interviews with U.S. optoelectronics component manufacturers toward the end of the summer of 1987, revealed that the U.S. lightwave and detector portion of the fiber optic industry has suffered along with the rest of the optical fiber and cable industry as major long distance networks have been completed in the United States and Europe. 1/ Moreover, firms specializing in the optoelectronics segment of the industry are in a more precarious position than the large and diversified firms that dominate the U.S. optical fiber industry.

With the entry of many foreign competitors, these smaller U.S. firms are facing what some industry officials describe as "cut throat" price competition in the United States and Europe. 2/ According to one major U.S. producer, long wavelength lasers used in long-distance telecommunications networks have fallen in price from $2,500 in 1985 to $800 today. 3/ The producer claimed that in the week previous to their interview with Commission officials, they had lost a sale to an important Italian customer when a Japanese firm under-bid by "a couple of hundred dollars" per laser its $600 offer to supply a planned fiber network system. An official of a U.S. firm specializing in fiber optic detectors indicated that detectors for long-distance telecommunications networks fell from $1200 in 1985 to $100 by August, 1987, and that they may fall to $35 to $40 in 1989. More sophisticated pinfet detectors 4/ had fallen in price from about $2500 in 1985 to $800 by the end of the summer of 1987, and are expected to fall to $200 by the end of 1987. 5/

The Commission staff, in interviews with various U.S. and European indusry officials, was supplied with the following anecdotal evidence regarding foreign competition in the U.S. and European markets. However, the Commission does not have empirical evidence to substantiate the comments in the following section. A number of European industry officials, including major customers of U.S. manufacturers of lightwave components, agreed with the reports of U.S. industry officials that increased competition from Japanese firms, including newer entrants to the market, were driving laser prices lower and lower in what one United Kingdom industry official described as "an all out war to gain market share" in the European market. European industry and

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1/ Interviews by the Commission with U.S. fiber optic optoelectronics firms in New Jersey, New England, California, and Texas during August and September 1987.
2/ Interview by the Commission with a U.S. manufacturer of optoelectronic light source and receiver components in New Jersey during August, 1987.
3/ Ibid.
4/ See app. F for the glossary of technical terms.
5/ Interview by the Commission with a U.S. manufacturer of lightwave detectors located in the Northeast during August 1987.

government officials appeared even more concerned about Japanese penetration than U.S. industry officials, who were more prone to blame U.S. Government policies, such as export controls, for any problems the industry faced. 1/ At least several West German and United Kingdom officials of major electronic and telecommunications equipment producers contended that Japanese firms had targeted, the largest independent U.S. manufacturer of long wavelength lasers, by undercutting over the past year the U.S. firm's bids on almost every major project to its traditional customers, including some of the firms interviewed. 2/

European industry officials feel particularly threatened by the new Japanese competition because they have themselves increased their commitment to the optoelectronic marketplace and fear that any gain in market share by the Japanese firms against either their own firms or the U.S. firms, will inhibit the growth of the European industry once the lightwave market gets back onto its feet, by penetrating loop, local area, and subscriber networks. The European officals noted that U.S. component manufacturers were being picked on rather than U.S. system suppliers because the component manufacturers do not have the extensive financial resources to fight them as do the larger firms.

U.S. industry officials admit that the rapid decline in prices in U.S. and important overseas markets has had an adverse impact on the U.S. industry, which they say may soon face a major shakeout. In 1987, a large portion of the U.S. component manufacturers may face losses or, at a minimum, declines in their growth rates. Some U.S. industry officials interviewed by the Commission from some of the component firms were pessimistic about the present state of the U.S. industry, comparing their plight with that of the semiconductor industry. 3/ They noted that in a certain sense their industry was in a more difficult situation presently, than was the semiconductor industry, in that the United States was a decade ahead of the Japanese in developing semiconductor technology before the Japanese caught up and took over important parts of that industry, whereas in optelectronics the Japanese essentially started out even with the United States. 4/

Though pessimistic, these U.S. officials stated that the U.S. fiber optic optoelectronic industry may continue to be viable if the more successful firms are acquired by much larger corporations with the financial resources necessary to allow these smaller operations to weather temporary market setbacks; that would permit them to continue the research and development that made the smaller firms competitive in the first place. The officials pointed out, however, that it is as likely, or perhaps more likely, that the acquisitions of these companies would be by foreign rather than by U.S. firms. In fact, one major U.S. producer of military tactical systems as well

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1/ Interviews by the Commission with industry and government officials in Western Europe during August and September 1987.
2/ Ibid.
3/ Interviews by the Commission with officials of the U.S. optoeletronics segment of the fiber optics industries during investigative fieldwork on the east coast in July and August, 1987.
4/ The Commission noted also the contrast with optical fiber conditions in the U.S. market rather than Japanese competitor pressures appear to have determined the rate of price reductions. See Chapters 4, 5, and 9, especially.

as lightwave fiber optic system lasers was recently acquired by a United Kingdom firm, and the West German electronic and telecommunications system giant Siemens has made a major investment in GTE's U.S. optoelectronic component product facilities as it begins a major foray into the global optoelectronics market. The U.S. industry officials interviewed believe that the Japanese are the most likely candidates to make future U.S. acquisitions. 1/

Other industry officials believe that U.S. Government policies must be changed if the United States is to remain competitive in the global market for optoelectronics. 2/ They point out that military and defense contracts favor larger traditional system suppliers like Rockwell, McDonnell Douglas, and TRW over the smaller market-driven component suppliers that were most responsible for bringing lightwave technology to the market in the first place. They also criticized recent trips by U.S. military procurement officials to Japan and statements by such officials that Japanese optoelectronics technology was more advanced than U.S. technology. U.S. industry officials were upset with announcements that the military would be pursuing more procurement contracts with the Japanese. The industry officials state that it was no accident that European purchasers sought U.S. lightwave technology when they were developing their fiber optic systems or that the Japanese are concentrating on advanced U.S. component manufacturers. These officials state that if the U.S. industry received more consideration in U.S. military and Government procurement policies and were provided perhaps with more basic and applied research and development grants that the U.S. industry could survive against Japanese and European conglomerates.

These officials also pointed out that U.S. export controls are adversely affecting the chances of U.S. lightwave optoelectronic companies from establishing ties in important markets of the future like the Peoples Republic of China; whereas, European and, especially, Japanese firms were agressively pursuing contacts with government and industry officials. The U.S. officials point out that U.S. Department of Commerce and particularly Defense Department oversight over Commerce export-licensing procedures are also affecting U.S. firms' opportunities in Western Europe because of the paperwork required by U.S. law, even of the prospective European purchasers of U.S. high technology equipment. European industry officials interviewed by Commission staff confirmed the statement of U.S. industry representatives that the "extraterritorial application of U.S. export control laws were an important factor in their decisions whether to purchase optoelectronic components such as lasers and detectors from U.S. or from Japanese suppliers." 3/ They point out that it has become even more of a factor in the more price-conscious environment existing today. What is disturbing to the U.S. industry officials is the amount of time it takes for the Commerce and Defense Department to approve licenses for optoelectronic apparatus that is "no longer even high technology" and has been readily available in the market for years. They explained that Japanese and European suppliers who are under similar (CoCom) requirements are not "cheating" in their more rapid approval of licenses for

1/ Interviews by the Commission with officials of U.S. optoelectronics component manufacturers during July-September 1987, in New Jersey, New England, California, and Texas.
2/ Ibid.
3/ Interviews by the Commission with West European industry and government officials during visits to the United Kingdom, West Germany, Italy, the Netherlands, Sweden, and Denmark during August and September, 1987.

sales of such equipment to foreign customers, but merely are placing greater emphasis and resources on expediting licensing procedures because of the their fiber optic systems or that the Japanese are targeting advanced importance of maintaining their industries' competitiveness in such a critical technology.

A U.S. Department of Defense official noted in response to these industry comments that:

> 1. U.S. lightwave optoelectronic component firms enjoy the same opportunities as companies from the other CoCom countries for establishing ties in future markets such as the PRC. They do not suffer any unfair restrictions in this area.
>
> 2. Case processing times have been reduced significantly over the past year - particularly within DoD. DoD processing times are down to an average of 9 days for exports to proscribed nations, and less than half that time for west-west sales.
>
> 3. The U.S. does enforce reexport controls for national security reasons. The U.S. did loosen these controls in 1987, however, by no longer requiring prior U.S. authorization for reexports to CoCom and some third world countries of goods with less than 25% U.S. content and to proscribed countries of goods in which the U.S. content is both less than 10% and $10,000 in value. 1/

Another well regarded U.S. industry specialist believes that neither export controls, nor European Community tariff differentials for imported optoelectronic components, nor even unfair trade practices such as Japanese dumping were the major threats to the United States industry. 2/ The specialist believed that the problem facing the smaller, independent-firm-dominated U.S. industry is a "critical mass" problem.

> $10 million firms in the United States are now facing competition with $20 billion firms in Japan. Japan is able to look at the long term, taking losses to build market share, while solo U.S. firms must earn profits as well as continue R&D. Japan looks at the value added aspect of lightwave transmission devices, while larger U.S. corporations that could make the U.S. industry competitive, neglect otherwise attractive market opportunities which do not produce immediate returns for their stock holders. 3/

1/ John R. Konfala, Director, Strategic Trade, Defense Technology Security Administration, U.S. Department of Defense, in a letter to Erland Heginbotham, Director, Office of Industries, U.S. International Trade Commission, December 29, 1987.
2/ Interview by the Commission with an official of a major east coast manufacturer of fiber optic optoelectronic components during August, 1987.
3/ Ibid.

The industry specialist explained that he was somewhat of a contrarian to other U.S. industry officials in that he believed that nonintegrated component manufacturers could succeed under the appropriate conditions and pointed out that some of the most successful Japanese companies in the lightwave market like Hitachi, OKI, and Toshiba are component suppliers. However, the expert reiterated his belief that component firms could be successful only if they developed the critical mass. He also pointed out that U.S. fiber optic transmission and detector firms would need some source of support and commitment from larger firms as well as the U.S. Government.

> My prior experience with **** shows that U.S. laser firms can succeed in countries like France. General Optronics, I understand, is selling more lasers in France today than anyone else and the French telecommunications [firm] SAT [Societe Anonyme de Telecommunications] has just formed a joint venture with a U.S. laser firm.
>
> However, firms like General Optronics and Epitaxx have disadvantages now of having to compete with the Japanese who take foreign technology and spend most of their resources on packaging the product, adding value while Epitexx and General Optonics keep having to re-invent the wheel in order to maintain their edge in technological changes and refinements. The Japanese firms have an edge in the mass production and packaging of their products. 1/

U.S. industry officials indicated to the Commission that about 80 percent of the laser and detector business is now in the production, packaging, and testing of such standard products as light emitting diodes, lasers, and detectors used in the fiber optic industry and only about 20 percent in the research, development, and design of new products and technology. They question whether advanced technology products such as the distributive feedback laser developed by AT&T are needed in the market since the bandwidth and information carrying capacity existing in current fiber optic systems was more than could ever be fully utilized during the next decade, or until subscriber markets developed. Siemens, a major West German manufacturer of advanced high-technology optoelectronic and microwave devices indicated that it would not even attempt to compete with AT&T or NEC in such advanced devices as distributed feedback lasers but instead would focus on developing hybrid devices such as tranceivers capable of being used in both long-distance and local loop systems. This would result in more standardized products that could be mass produced for the West German telecommunications networks. Because costs would be lowered considerably, shipments would be accelerated for incorporation of fiber optic technology into local loop, local area, and business premises networks, and eventually subscriber links to the home.

Until recently, long wavelength lasers have dominated single mode applications over long-distance telecommunications while the less powerful but more reliable and cheaper short-wave length light-emitting diodes have been used with multimode fibers for shorter distance loop and local area network applications. Recently, major developments have been changing the minds of

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1/ Ibid.

many who assumed that light-emitting diodes transmitted over multimode fiber would be prevalent in emerging short-haul applications to businesses and the home.

Since the emergence of longwave semiconductor devices around 1983, gallium arsenide and gallium aluminum arsenide lasers have played only a minor role in communications. 1/ However, this situation could be radically altered by the need for inexpensive light sources for link-intensive subscriber loop networks, and the fact that Japanese companies are mass-producing shortwave lasers for use in compact-disk audio players. Though U.S. firms such as TRW and PCO and the West German firm Siemens have been making intensive efforts to develop programs for manufacturing gallium arsenide lasers, the largest threat is expected to come from Japan.

> Mitsubishi makes some long wavelength lasers but sells few in the U.S.; that may change. The company recently introduced a new series of InGaAsP lasers, [2/] apparently featuring tolerance of a wider range of temperatures than previous devices. That might make them desirable for the subscriber loop. Matsushita, Japan's largest manufacturer of consumer electronics, also exhibited advanced long wavelength lasers in Tokyo recently.
>
> Japanese production of lasers for use in compact disks continues to increase meanwhile. Industry analysts had predicted that some manufacturers would fail to achieve market share and that vigorous competition in a crowded market would lead to price cuts. These developments would make switching laser production from GaAs [Gallium Arsenide] to InGaAsP [Indium Gallium Arsenide Phosphide] for communications an increasingly attractive option. [3/]

Japanese companies are reported unofficially to be manufacturing over one-half million shortwave lasers a month, driving the prices for some CD-player devices to about $6. At that price, fiber producers and cablers who are wishing to increase revenues with new subscriber-loop applications "cannot afford to ignore these devices." 4/

New entrants to the U.S. lightwave transmission and detector system market as it positions itself for more local area, computer-connect, and military applications include such firms as Hewlett Packard, Honeywell, ITT Cannon, Codenoll, McDonnell Douglas, and TRW. However, many of these firms are incorporating Japanese components into their systems and are themselves considering the possibility of using compact disk-type lasers in such systems.

1/ John Ryan, "A New Look at Shortwave Lasers and Longwave LEDs," Lightwave, November 1986, p. 31.
2/ See app. F for the glossary of technical terms.
3/ Op. cit., "More Vendors Moving Into Long-Wave Lasers," Lightwave, November 1985, p. 20.
4/ Op. cit., John Ryan, p. 31.

Because the Japanese are so far down the learning curve compared with their U.S. and European competitors with respect to the mass production, packaging, and testing of lasers, detectors, and light-emitting diodes, they represent a considerable threat to the U.S. and European industries in that which is fast becoming a cost-driven, commodity business. Based on Commission interviews with a number of European industry and government officials, including officials of the EC in December, 1986, and again in August and September, 1987, it was apparent that the Europeans are cognizant of the Japanese competitive threat and are investing billions of dollars in advanced joint precompetitive research and development programs (see chapter 10) to encourage large and small firms from different European Community member states to work together to develop and market that which they see as "critical high-technology optoelectronics technology." 1/ These industry and government officials believe that in the end only those industries with some degree of control over the optoelectronic technology that drives fiber optic systems will be in a position to profit in the coming revolution in fiber optics that will take optical transmission into the office and finally right into the home.

According to industry officials in the United States and Western Europe, the willingness of the Japanese to gain market share at substantial cost in East Asia, Europe, and the United States, demonstrates their optimism about the future prospects and profits to be gained from fiber optics in the long run. Though the U.S. optical fiber and optoelectronics industries up until now have been in the forefront of fiber optic developments and even its successful commercialization, much of their success was due to the rapid growth in U.S. demand for fiber optic long-distance telecommunications capacity. Now that that demand growth has begun to decline, industry analysts state that the more disparate segments of the U.S. optical fiber and optoelectronic industries are going to have to come together if they are to compete effectively with the large, integrated, well-supported telecommunications firms of Japan and even Western Europe. 2/ These industry experts believe that if this can be done shortly, the U.S. industry will be able to compete effectively in the global market but that time is at a premium, particularly in the present competitive environment in which, they claim, all out efforts, especially by Japanese suppliers, are being made to capture market share in a still sluggish market.

Industry Comments on U.S. Government Policies

At least several officials of major U.S. optoelectronic component firms expressed their concern that recent announcements by the U.S. Government that "export controls would be loosened, were only political not substantive commitments." 3/ They state that they have heard these promises before but do

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1/ Interviews by the Commission with West European industry and government officials during overseas fieldwork in the United Kingdom, France, West Germany, Italy, Sweden, Denmark, the Netherlands, and Belgium during December 1986, and August and September 1987.
2/ Interviews by the Commission with officals of optical fiber, cable and optoelectronic component firms at various times during July 1986-September 1987.
3/ Interviews by the Commission with officials of several major U.S. optoelectronics component manufacturing firms in the Northeast during July and August 1987.

not see any significant reduction in their paperwork or that of their foreign customers and continue to lose sales as U.S. export administration officials "seemingly take for ever" in processing their export-licenses. These officials would like to "get government (particularly Defense Department) officials involved in export control to understand that many of the controlled optoelectronic items are now generally available throughout the world and no longer need to be controlled." 2/ They suggest that Congress increase the staff and technical competence at Commerce to help process export licenses faster and would like to limit Defense Department oversight of the export administration process to that of only critical high technology devices.

A. U.S. Department of Defense Official noted in response to these industries that:

1. Mechanisms currently exist for industry representatives to substantiate claims of foreign availability of optoelectronics. The Commerce Department chairs Technical Advisory Committees made up of industry representatives for a variety of technologies. Frequently, however, industry allegations of wide foreign availability are found to be either inaccurate because the product is not available in either quality or quantity or because the country cited has entered into a bilateral agreement to abide by CoCom controls.

2. The Defense Department's review of export licenses is, in fact, already limited to about 15% of the cases received by the Commerce Department. 2/

Many industry officials also believe that the optoelectronics segment of the fiber optics industry would also be assisted if U.S. trade officials negotiated narrowing duty differentials with EC officials so that European firms, which actively participated in the U.S. market for telecommunications, would not have an unfair advantage over U.S. firms in their own markets. The officials suggested too that the U.S. Government should provide some funding for the generally smaller U.S. laser and detector industry to enable it to compete and survive against the larger, better-supported, fully-integrated Japanese and European electronics firms and that this should be done now as the market is now being bought up in view of impending shakeouts. The "importance of making investments now rather than later is serious" they emphasized. 3/ At a minimum, they suggested U.S. Government and military procurement policy should show more favor to smaller U.S. firms rather than continue to rely solely on traditional supplier relationships with large civilian and defense contractors.

1/ Ibid.
2/ John R. Konfala, op. cit.
3/ Ibid.

CHAPTER 9. ECONOMIC AND COMPETITIVE TRENDS IN THE U.S. FIBER OPTICS INDUSTRY

This chapter reviews trends in selected measures of competitiveness for the period under examination. For the most part, the discussion is limited to trends in the optical fiber and optical cable industries. However, to the extent that information is available, trends in related optoelectronics industries are reviewed as well. To begin with, trends in U.S. prices of optical fiber and cable are examined. During the 1980s, optical fiber and cable progressed out of the research stage to become a relatively mature commodity product. Accordingly, as producers have gained manufacturing experience and as the quantity of fiber and cable produced has increased, learning curve effects have led to declines in unit costs, and the prices of these products have decreased. These trends are examined in more detail in the section which follows.

In addition, technological innovation, market structure, and vertical integration affect the economic development and continued competitiveness of the fiber optics industry. We also review short-term, exogenous factors such as exchange rates, the lack of international standards, and fluctuations in demand (particularly in the telecommunications market), that have an impact on the industry.

Trends in prices of optical fiber and optical cable

For this investigation, price data for optical fiber and cable were collected from secondary sources and from questionnaires which were sent to U.S. producers, importers, and purchasers of optical fiber and cable products. Existing data on prices were limited in a number of areas. First, the data gathered by secondary sources were either anectodal or incomplete, and provided sparse information. Second, the recent introduction of these products into the market have not allowed industry analysts sufficient time to collect well-developed time-series data on prices. Nonetheless, all of the data gathered by this investigation confirm that, during the time period from 1983 to 1987, prices for optical fiber and cable used for telecommunications purposes have declined. This section presents a description of the product categories for which questionnaire data were collected and then examines price trends and other price information which were gathered from questionnaire data and other secondary sources.

Description of Questionnaire Data

Questionnaires requesting U.S.-market price data for optical fiber and cable were sent to 93 U.S. producers, U.S. importers, and U.S. purchasers of domestically produced fiber and cable. Each firm was asked to submit price data for the following product categories:

(1) Optical fiber for data purposes: glass single mode and glass multimode, by core diameter.

(2) Optical cable for data purposes: telco-direct-buried (single mode) and plenum (multimode), by number of fibers per cable.

(3) Optical fiber used for non-data purposes: noncoherent and coherent bundles, by number of fibers per bundle.

Of the 93 questionnaires returned, 45 provided some type of price data. The ratios of total questionnaires returned to the total that provided data were producer's, 35:11; importer's, 30:11; and purchaser's, 28:23.

Because of the proprietary nature of the information, respondents were, in general, reluctant to provide price data. 1/ As a result, the questionnaire data have a number of deficiencies.

First, because only annual observations for the years 1983 and 1984 were provided while quarterly data were provided from the first quarter of 1985 to the second quarter of 1987, price trends were limited to either four annual observations or ten quarterly observations. Second, for some categories, data were not distinguished by well defined categories. Hence, it was only possible to construct trends for general product categories. For instance, most respondents only provided prices for all single-mode fiber and all telecommunication cable rather than single-mode fiber distinguised by core diameter or telecommunication cable distinguished by number of fibers.

Price Trends

Because data were provided by only three domestic producers of fiber and three domestic producers of cable, it is not possible to discuss actual changes in producer-prices without breaching the confidentiality of the sources. Therefore, it will only be possible to describe general producer-price trends for these products. A similar problem arose for imports of fiber and cable from Canada, Japan, and the United Kingdom where only one or two firms responded for each country category. Of the data collected, it is possible to disclose average purchaser-prices for telecommunication (single mode) cable. In this instance, responses were gathered from six U.S. domestic purchasers. In other instances, an insufficient number of responses was collected with which to construct any type of meaningful trend. This was particularly the case for optical fiber for non-data purposes where the reported data were sparse.

1/ In some instances, respondents were firms that supplied the U.S. military with optical fiber products. In these cases, the data were considered government-classified information.

Telco cable 1/

Table 9-1 indicates that, between 1983 and 1986, annual average purchaser prices for telecommunication (single mode) cable decreased by 25 percent from $517 to $387 per fiber kilometer. However, the downward trend for annual

Table 9-1
Domestic optical cable for data purposes--telecommunication: Average net selling prices and quantities reported by purchasers of U.S. produced optical cable, by years, 1983-1986

	Telecommunication Telco-direct-buried (single mode)	
Year of sale	Quantity purchased (fiber kilometers)	Average price per fiber km (dollars)
1983	3,266	$517
1984	149,335	459
1985	479,282	493
1986	411,245	387

Source: Compiled by the staff of the USITC.

prices was not continuous; prices increased by 7 percent between 1984 and 1985 and then continued the downward trend between 1985 and 1986.

Similarly, Table 9-2 indicates that, between the first quarter of 1985 and the second quarter of 1987, average prices decreased by 51 percent from $498 to $244 per fiber kilometer. As with the annual price trend, the quarterly price trend did not show a continuous decline. Prices increased by approximately one percent between the first and second quarter of 1985 and by 29 percent between the third and fourth quarter of 1986.

1/ Telco cable is cable used for telecommunications purposes. Appendix F provides definitions of the various types of optical fiber and cable discussed in this section.

Table 9-2
Domestic optical cable for data purposes--telecommunication: Average net selling prices and quantities reported by purchasers of U.S. produced optical cable, by quarters, January 1985-June 1987

Quarter of sale	Telecommunication Telco-direct-buried (single mode) Quantity purchased (fiber kilometers)	Average price per fiber km (dollars)
1985:		
January-March	83,263	$498
April-June	149,429	501
July-September	145,414	494
October-December	101,175	477
1986:		
January-March	99,922	381
April-June	111,853	368
July-September	118,767	357
October-December	80,701	462
1987:		
January-March	85,990	293
April-June	113,178	244

Source: Compiled by the International Trade Commission staff.

The purchaser prices in table 9-1 and table 9-2 appear very similar to telecommunication-cable prices reported by three U.S. producers. 1/ As noted above, it is not possible to disclose these prices. Nonetheless, it is possible to indicate that, in most instances, producer and purchaser prices fell within relatively close ranges. And, similar to purchaser prices, a large drop in producer prices occurred between 1983 and 1987. Between 1983 and 1986, annual producer prices dropped by 49 percent. 2/

According to one U.S. industry source, prices in the United States for telecommunication cable were averaging $500 per fiber kilometer in 1983. In 1984, prices experienced a large drop attributed mainly to production learning curve effects and additional capacity. 3/ Because of strong demand in 1984 and

1/ In the case of prices reported by U.S. producers of optical cable used for data purposes, the average prices constructed represented approximately 45 percent of domestic shipments for cable. This estimate was constructed from information in Lightwave, April 1987.
2/ Between the first quarter of 1985 and the second quarter of 1987, quarterly producer prices decreased by 41 percent. However, unlike purchaser prices, producer prices showed a continuous decline for both annual and quarterly prices.
3/ The learning curve, shows how average costs for a specific activity or product decline with time or output, as production experience is acquired. William G. Shepherd, The Economics of Industrial Organization, (Englewood Cliffs, N.J.: Prentice-Hall, Inc.), 1979, p.235.

1985, prices remained relatively stable. In fact, demand was so strong during this period that most orders for cable carried a six- to nine-month lead time. 1/ Finally, between 1986 and 1987, prices dropped to approximately $320 per fiber kilometer because of a simultaneous decrease in demand and increase in supply. The shifts in demand and supply were attributed to the completion of U.S. long-distance networks 2/ and the opening of new U.S. plants, respectively.

The telco-cable price data reported by both purchasers and producers appear relatively consistent with the preceding explanation of price trends. Data reported by both purchasers and producers indicate that, during the period when prices were purported to have declined mainly because of learning curve effects, i.e., between 1983 and 1984, prices indeed fell by relatively large percentages. Annual purchaser prices in table 10-1 declined by 11 percent while annual producer prices declined by 30 percent between 1983 and 1984.

During the period when demand was strong, 1984 and 1985, reported prices appear to have remained relatively stable. For instance, during 1985, quarterly purchaser-prices did not vary by more than 3 percent between any two continuous quarters. (table 10-2.) Similarly, quarterly producer prices in 1985 did not vary by more than one percent between any two continuous quarters.

Between the last quarter of 1985 and the first quarter of 1986--i.e., during the period when, purportedly, demand decreased and supply simultaneously increased--purchaser and producer prices decreased by 20 percent and 9 percent, respectively. However, the largest price decline between any two continuous quarters for both purchasers and producers occurred between the last quarter of 1986 and the first quarter of 1987. These were a 43-percent decline for purchaser prices and a 25-percent decline for producer prices. (table 10-2.)

As noted above, telco-cable prices were received from importers of Canadian, Japanese, and British cable. However, because only four firms responded for these country categories, it is only possible to discuss general trends without breaching confidentiality.

Of the reponses received, only the Canadian importers provided a sufficient number of price observations with which to construct meaningful

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1/ Another source confirmed that, during this period, cable prices were dependent heavily on delivery time. For instance, "cable needed in a hurry could command" a premium price of 50 cents per meter. See Lightwave, September 1985, page 1.
2/ Some industry analysts projected a 40-60 percent drop in long-distance demand for cable in 1987. See Lightwave, February 1987.

price trends. 1/ Between 1983 and 1986, average annual importer prices declined by 17 percent. 2/

LAN-campus cable

With the exception of the data received from one U.S. producer, most of the price data for plenum (LAN-campus) cable was insufficient to construct meaningful trends of average prices. The data collected from the single reporting U.S. producer indicated that average annual prices for plenum cable decreased by 66 percent between 1983 and 1986. The average annual-price trend showed a continuous decline. 3/

In comparison to average annual prices for telco-cable, average annual prices for plenum or LAN-campus cable declined more rapidly. For instance, the percentage change in annual average prices between 1983 and 1986 for U.S. purchasers and producers of telco-cable and for the single U.S. producer of LAN-campus cable was 25 percent, 49 percent, and 66 percent, respectively.

The more rapid decline of LAN-campus prices occurred even though demand for LAN-campus cable appears to have remained relatively stable. 4/ This contrasts to the demand for long-distance (telco) cable which has dropped dramatically. In addition, the quantities of LAN-campus cable production are relatively small in comparison to the quantities of telco-cable production. Therefore, it does not appear that the more rapid decline in LAN-campus cable prices could be attributed to dramatic decreases in demand. Rather, the more rapid decline in LAN prices is more likely explained by learning curve effects or possibly by the wide range of product variability 5/ for which LAN cable average prices were constructed.

1/ The average prices constructed for 1985 and 1986 represent 89 percent and 62 percent, respectively, of optical fiber and cable imports from Canada. Source: U.S. Department of Commerce.

2/ The decline in both annual and quarterly Canadian prices was significantly smaller than the decline for U.S. producer and purchaser prices. Between 1983 and 1986, the decline in annual Canadian, U.S. purchaser, and U.S. producer prices for telco-cable were 17 percent, 25 percent, and 49 percent, respectively. Between 1985 and 1987, the decline in quarterly Canadian, U.S. purchaser, and U.S. producer prices prices for telco-cable were 7 percent, 51 percent, and 41 percent, respectively. In addition, unlike U.S. purchaser and producer prices, Canadian quarterly prices showed a continuous increase between the first and last quarter of 1985.

3/ The average prices constructed for this one producer represent XX percent of domestic shipments for plenum cable. Between the first quarter of 1985 and the last quarter of 1987, average quarterly prices declined by 27 percent. With the one exception of a 37-percent increase between the last quarter of 1986 and the first quarter of 1987, the quarterly-price trend showed a continuous decline.

4/ Industry analysts are anticipating LAN-campus demand to increase dramatically within the next few years.

5/ In general, telco cable is more standardized than LAN-campus cable.

Optical fiber

Price data for glass single mode fiber were provided by two U.S. producers. Prices for multimode fiber were provided by three U.S. producers. Again, because of the propietary nature of the data, it is only possible to discuss general trends.

Between 1983 and 1986, average-annual prices for glass-single mode dropped 65 percent with the annual price trend showing a continuous decline. Between 1983 and 1985, average-annual glass-multimode prices showed a 15-percent decline. However, unlike annual single mode prices, multimode prices showed a continuous annual increase from 1984 to 1986.

This marked distinction between both the magnitude of the declines and the pattern of the annual trends of single mode and multimode fiber prices can probably best be attributed to the fact that singlemode fiber is more commonly used in long distance networks while multimode fiber is more commonly used in LAN-campus networks. 1/ As noted above, the demand for long-distance cable dropped dramatically while LAN-campus demand appeared to remain relatively stable. Indeed, the explanation of the decrease of telco-cable prices presented earlier could be used for the single mode fiber prices. For instance, similar to telco-cable prices, the average annual price for single mode fiber took a large drop, 51 percent, between 1983 and 1984. 2/ During this period, the corresponding telco-cable price drop (U.S. purchasers, 25 percent; U.S. producers, 49 percent) was attributed to learning curve effects. During the period when strong demand kept cable prices stable in 1984 and 1985, average quarterly prices for single mode fiber varied, on average, by three percent between continuous quarters during 1985. Finally, similar to telco-cable prices, the largest decline in quarterly prices between the first quarter of 1985 and the second quarter of 1987 occurred between the last quarter of 1986 and the first quarter of 1987. This was a decline of 16 percent.

While it is not possible to disclose the fiber prices obtained from questionnaires, it is possible to construct annual price trends of fiber from data that were obtained from secondary sources. These price trends are presented in table 9-3. In most instances, the questionnaire prices reported by producers fell within approximate ranges of the prices reported by secondary sources. However, there were a few prices estimated by secondary sources which appear quite divergent from those reported in the questionnaires.

In general, pricing data received through questionnaires substantiate that prices from both fiber and cable used in both long-distance and LAN's have declined markedly. A number of inferences can be drawn from the data. First, both fiber and cable used in long-distance and LAN's showed a very

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1/ Lightguide Digest, 1987, Issue No. 2, page 2.
2/ During the same period, between 1983 and 1984, average annual prices of multimode decline by 31 percent.

Table 9-3
Domestic optical fiber for data purposes--glass single mode and glass multimode: U.S. market prices gathered by secondary sources, by years, 1983-1987

Year	Fiber for data purposes	
	Single mode	Multimode
	Price per meter (dollars)	Price per meter (dollars
1983	1/ .50	-
1984	1/ .25	-
1985	2/ .30	-
1986	3/ .30	3/ .51
1987	4/ .20 - .30	4/ .35 - .60

1/ Source: Lightwave, April 1985, page 20.
2/ Source: Lightwave, September 1985, page 1.
3/ Source: Lightwave, April 1987, page 32.
4/ Source: Lightguide Digest, 1987, Issue No. 2, page 2.

rapid decline between 1983 and 1984. Future research should examine whether these rapid decreases in price during this period were mainly the result of learning curve effects or related expansions of production capability. Second, starting in the last quarter of 1985, prices for telco-cable and single-mode fiber showed steady decreases, with the largest reported quarterly decline occurring between the last quarter of 1986 and the first quarter of 1987. The decrease in prices which started in 1985 appears to have been mainly the result of the slump in demand as optical fiber long-distance networks in the United States were completed.

The downward trend in prices revealed in questionnaire data was expected. Fiber and cable manufacturers' costs have decreased considerably over the past decade or so. Prior to 1980, manufacturing costs constituted the most significant portion of the overall cost of fiber production. By 1985, manufacturing costs had been reduced substantially, and materials costs counted for approximately one third of total production costs.

The reduction in operating costs stems from improvements in the production process; for example, there have been a number of improvements in the drawing process that have resulted in decreasing production costs. Fiber manufacturers continue to look for ways to lower these costs. The development of continuous rather than batch processing is one example of this pursuit of ways to lower costs. As manufacturing costs continue to represent proportionately smaller amounts of total production costs, firms are expected to concentrate also on ways to lower the costs of the material inputs as well. 1/

1/ Lightwave, April 1986.

The implications of the overall price decline for the competitiveness of U.S. fiber and cable producers are not clear. The decline in domestic market prices was more the result of the aformentioned slump in long-distance demand and learning curve effects rather than from any downward pressure on prices exerted by imports. In this light, it appears that U.S. firms which best anticipated the slump in market demand by finding some market niche, such as the military market or specialty-fiber market, or which more rapidly experienced economies of scale or learning curve effects, are likely to remain in the market, whereas other firms may face pressures to exit the industry. Indeed, any type of serious foreign price competition with U.S. fiber and cable producers, at least in the domestic market, appears precluded by the existence of patents belonging to U.S. firms and the resultant licensing agreements which are strongly enforced. Even though pricing data for foreign markets were not collected, it appears from information gathered by staff interviews 1/ that, in foreign markets also, the competitiveness of U.S. fiber and cable producers is more dependent on patents and licensing agreements than on pricing or marketing strategies by foreign firms to obtain market share.

Other factors affecting competitiveness

Prices provide one measure of competitiveness. However, as fiber becomes a commodity in the medium term, there is a corresponding downward pressure on prices. This has shifted the focus of many producers to fiber optic systems rather than to certain components of the systems such as optical fiber or cable. It is clear that pricing policies currently are not the most significant factor in the overall competitiveness of the U.S. fiber optics industry. Of particular importance in the fiber optics industry is the degree and pace of technological innovation. 2/ In the following sections two general issues are examined. The first concerns the nature and scope of technological innovation in the U.S. industry. The second concerns the relationship between market and industry structure and technological innovation.

1/ From Commission interviews with representatives of the EC in Brussels during September 1987, as well as other industry officals in Australia and Asia during August.

2/ There are two general types of technological innovation: that which contributes to refinements in production processes, and that which results in new products or features. It is generally believed that there is a positive relationship between both types of technological innovation in an industry and the industry's competitive position in the international market. Technological innovation is especially important when the consumer of the products in question is concerned with reliability and quality. Thus, such innovation is very important to the fiber optics industry. To maintain technological superiority, firms in expanding industries typically allocate relatively large portions of their sales revenues for research and development purposes. Gareth Locksley, The EEC Telecommunications Industry: Competition, Concentration & Competitiveness, Commission of the European Communities (Collection Studies -- Evolution of Concentration and Competition Series No.51) Brussels, December 1982, p. 18.

Technological innovation

To assess the state of technological innovation in an industry, analysts rely on various measures, one of which is the industry's expenditure on research and development. 1/ Much of the more productive research and development work in high-tech fields such as fiber optics tends to be long run in nature. However, according to various representatives of the fiber optics industry, there is a bias among U.S. firms against such long term projects. These industry representatives, interviewed by the Commission during the course of the investigation, noted that most of the R&D work going on in their companies is internally generated and that the long run nature of much fiber optics research conflicts with the firms' emphasis on realizing short-run profits. These individuals pointed out that foreign manufacturers often are at an advantage since much of the research being conducted is funded through joint efforts of the government and industry and is consequently of a longer duration. 2/ Given the problems associated with these measures of technological innovation, it is not possible to construct hypotheses regarding technological innovation within the U.S. fiber optics industry or to subject the hypotheses to rigorous tests.

Historically, the United States has benefited from technological superiority in the telecommunications sector. In recent years, various analysts have concluded, however, that the United States is beginning to fall behind certain Western European and particularly Japanese competitors in telecommunications and optoelectronic research and development. Both Western Europe and Japan have committed considerable resources to the computer and

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1/ However, the amount of revenues allocated to research and development is not a very good measure of innovation in and of itself. R&D is an extremely heterogeneous and broad category. Research and development data are also difficult to evaluate because there is little agreement regarding what should properly be classified as R&D. Spending that is classified as marketing by one firm may fall into another firm's R&D category. R&D data does not reveal the length of programs being funded, nor does it reveal how productive the activity is. Thus, comparative analysis of international research and development spending may be misleading. For further discussion of research and development expenditures in the U.S. telecommunications and electronics industries, see NTIA Trade Report: Assessing the Effects of Changing the AT&T Antitrust Consent Decree, U.S. Department of Commerce, February, 1987.
Another measure that has been used in an effort to correct for the problems associated with aggregate R&D expenditures is the number of patents filed by firms in the industry. However, this measure also is not a very good indicator of innovation. "First, patents are issued for minor innovations as well as for major ones....Second, many patented products and processes are never commercialized. Third, many innovations are not patented." Kamien and Schwartz, Market Structure and Innovation, pp. 49-50. In addition, because of cultural and legal differences, the number of patents is particularly inappropiate as a comparative measure between countries.
2/ According to the producers that responded to the questionnaire, over 95 percent of total fiber optics research and development is supported by interna-generated funds. Whether this is a representative sample for the entire U.S. fiber optics industry is not possible to determine.

telecommunications industries. 1/ In addition, the deregulation and break-up of AT&T resulted in opening up the U.S. market to imports, with the Bell operating companies purchasing from foreign-based as well as U.S.-based companies. No corresponding liberalization of foreign telecommunication markets was sought, nor did any result from the U.S. liberalization. Thus, as the Department of Commerce notes, revenues which formerly could have been earned by U.S. firms and possibly allocated to U.S. R&D, currently end up as foreign profits and potential funds for foreign R&D. 2/

Despite the concerns of many industry analysts and government officials, it appears that the U.S. fiber optics industry is continuing to invest increasing amounts in research and development programs. During the period under review, research and development expenditures reported by U.S. producers in response to the Commission questionnaire increased substantially. Total research and development expenditures grew from $21 million to $66 million between 1983 and 1986. Most of this increase occurred during the second half of the period, with a 63-percent increase in spending reported between 1984 and 1985 and a 78-percent increase between 1985 and 1986. In interviews with the Commission, various industry analysts indicated that R&D activity was expected to continue at the same pace as it had during the 1983-86 review period. 3/ In particular, the analysts noted that substantial efforts are underway to refine optoelectronic components used in both long-haul fiber optic systems and shorter systems such as local area networks and industrial process control systems. Continued research in these areas is of consequence because the industry is still undergoing rapid technological changes.

Market structure and technological innovation

In addition to reviewing aggregate data covering research and development expenditures, it is instructive also to review changes in the structure of the U.S. fiber optics industry that could have an impact on future research and

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1/ For example, in 1983 R&D expenditures for five of the major Japanese optoelectronics and telecommunications equipment manufacturers amounted to almost as much as the 1985 R&D expenditures reported by IBM and AT&T. Expenditures for Hitachi, Matsushita Electric, NEC, Toshiba, and Fujitsu amounted to roughly $5,400 million; expenditures for IBM and AT&T amounted to $5,666 million. NTIA Trade Report, p. 108. See Chapter 10 for additional information and data on West European and Far Eastern expenditures on research and devlopment.
2/ Although it is clear that revenues may have been lost, it is impossible to calculate the actual decrease in R&D that may have occurred.
3/ This may be more applicable to the various sectors of the optoelectronics industry than to the optical fiber industry.

development trends. 1/ The following section briefly reviews several hypotheses concerning the relationship between market structure and technological innovation. The discussion that follows examines whether or not these hypothoses help to explain developments in the fiber optics industry. Because of the lack of sufficient data, these hypotheses cannot be subjected to rigorous tests. Rather, only basic conclusions can be drawn. Much of the research concerning the relationship between technological innovation, market structure, and competitiveness has focused on two basic hypotheses. The first states that there is a positive relationship between innovation and monopoly power. The second states that large firms are proportionately more innovative than smaller firms. 2/

Two related hypotheses have also been tested by various researchers. The "technology-push" hypotheses suggests that a firm's R&D staff is the source of innovation because it can keep abreast of existing basic scientific research and develop new commercial applications. Firm's with larger research staffs are thought to have an advantage over their smaller counterparts. One example given of the technology-push hypothesis is the development of the application of lasers. Lasers were developed and built long before there was any specific commercial application for them. 3/ A similar product is optical fiber. As discussed earlier, optical fibers were developed before there was a clearly defined use for them in the telecommunications sector.

The second related hypothesis is known as the demand-pull hypothesis. It too implies that larger firms have an advantage over their smaller counterparts. The demand-pull hypothesis posits that the production and/or marketing staffs of a firm, in their work with the firm's customers, initiate the product innovation; the research staff simply solves the problems of the production/marketing staff. Innovation is, in effect, a response to increases in the firm's potential profit. One example of this process is the

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1/ To understand the nature of technological innovation and industrial development, researchers have examined the relationship between competitiveness, technological innovation, and industrial organization. Two contradictory scenarios may occur. Technological innovation in production processes and product development may affect the structure of the industry by increasing competition and entry into the market, and consequently leading to consolidation and exit. However, when existing firms undertake research and development, the resulting product innovation may prevent the entry of new firms into the market. Both phenomena may be taking place in different sectors of the fiber optics market.

2/ These hypotheses are associated primarily with the analysis of Joseph Schumpeter, set forth in Capitalism, Socialism, and Democracy. (New York: Harper & Row,) 1975. For a complete discussion of the relationship between Market (and industry) structure and technological innovation, see: Morton I. Kamien & Nancy L. Schwartz, Market Structure and Innovation (New York: Cambridge University Press), 1982 and William Baldwin and John T. Scott, Market Structure and Technological Change (New York: Harwood Academic Publishers), 1987.

3/ Kamien and Schwartz, p. 34.

development of transistors by researchers at Bell Laboratories; the product was developed to satisfy AT&T's need for more efficient switches. 1/

Other empirical research suggests that monopoly power and large size are not prerequisites for initial or continued success in terms of technological innovation. Research examining the relationship between firm size and technological innovation has not always conclusively resulted in a positive relationship between large firm size and proportionately greater R&D capabilities. Rather, a number of research studies indicate that medium-sized firms may be the most innovative. 2/

An alternative way of evaluating the evolution of the fiber optics market is in terms of a technology versus a marketing race. Theoretically, in the early stage of a product's life, the most important factors in establishing a dominant market share would be rapid product development and first entry into the market. During this phase, firms would be competing in a technology race. Hence, as noted above, medium-sized firms might have a competitive advantage in product innovation and would dominate a market in the initial stages of a product's life-cycle. Conceptually, these medium-sized firms could continue to dominate the market as long as their technological innovation was occurring rapidly and the resultant products were not easily and quickly copied.

As the product matures, standardizes, and is more easily imitated, i.e., as the rate of technology turn-over decreases or product innovation slows, the competitive edge in establishing market share would shift to those firms that are able to exploit it by offering the product for the lowest cost or by effective marketing, or other techniques. During this phase, firms would be competing in a marketing race rather than a technology race, and market share would appear to depend positively on economies of size. While perhaps not the most efficient scale of operation for product innovation, economies of scale would allow a firm to generate the large volumes corresponding to the lowest long-run average cost. In addition, economies of scale would allow large firms to descend the learning curve more rapidly than the medium-sized firms. Another possible outcome is for product differentiation to result in niche markets, with the dominant producer(s) sometimes leaving one or more niches to medium or smaller firms.

The fiber optics industry provides mixed evidence. On the one hand, optical fiber and cable producers appear to gain an advantage as they increase in size, become more diversified, and increase their market power. As noted above, examples of both the demand-pull and technology-push hypotheses can be found in the telecommunications industry. On the other hand, certain sectors of the optoelectronics industry are characterized by medium-sized firms. These firms have been quite innovative even though they are not large nor are they necessarily vertically integrated. In both instances, U.S. firms have held a competitive advantage in the international market. However, as the dominance of the U.S. industry is threatened by foreign producers, it is

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1/ Ibid., p. 35.

2/ See Kamien & Schwartz, p. 75-84, for a review of relevant studies on this issue.

instructive to review the U.S. industry's experience and to evaluate the implications for its future performance.

The competitiveness of U.S. optical fiber firms.--Since the late 1970s, the U.S. optical fiber industry has maintained the dominant market share of the U.S. and world markets. One firm in particular, Corning, has dominated the world market through patents, licensing agreements, and joint ventures with other firms. According to European and Asian industry repesentatives, Corning's aggressive patent litigation has strongly discouraged firms which do not have licensing agreements with Corning from entering the optical fiber market throughout much of the world.

Industry representatives also suggest that the long run strategy of most firms in the United States and abroad that do possess optical fiber capabilities is to allow Corning to maintain its dominant world position as an optical fiber producer. The reason these firms continue optical fiber operations is that optical fiber is an important factor of production for optoelectronic products and optical fiber systems. In general, the firms that do possess optical fiber operations are large, multi-product firms which produce both optical fiber and optoelectronic components. By producing optical fiber, these firms can retain their control over the necessary inputs for their final product, fiber optic systems. In some cases however, it seems clear that firms are also attempting to challenge Corning's technological control over the optical fiber market. 1/

The competitiveness of U.S. optoelectronics firms (telecommunications).--In the early 1980s, U.S. firms maintained a substantial share of the fiber optics market in the United States and Europe. In general, the U.S. firms which dominated the fiber optics markets in the early 1980's were medium-sized firms which were small relative to their counterparts in Europe and Japan. 2/

According to industry sources in the United States, the success of these U.S. firms was the result of their "being first" in the optoelectronic components market. The initial arrival in the market allowed the establishment of a market-share lead in both the U.S., Europe, and Asia (in certain instances). Indeed, a number of U.S. and European representatives of the optoelectronic industry confirmed that this description of the

1/ For example, Sumitomo Electric contended, unsuccessfully, that its processes and product differed from Corning's and therefore were not in violation of Corning's patents.

2/ Since the large market shares in the early 1980s appear tied to the U.S. firms' leads in innovations, much of the success of the U.S. firms in world markets during this period may have hinged on the medium-size of these firms. The U.S. laser industry offers the best example of this depiction of the market. As discussed above, a hypothesis tested and supported by many empirical studies is that medium-sized firms are more innovative than small and large firms. See Kamien and Schwartz.

optoelectronic market's evolution as a technology versus a marketing race conforms to actuality. 1/

Further confirming this characterization of the optoelectronics industry, an EC telecommunications expert also indicated that many optoelectronic products are entering the mature phase of the product life-cycle. He indicated that for some types of lasers, the major decreases in unit costs were the result of large volume production and that only very minor decreases in cost were the result of technological or process innovation.

Assuming that this general characterization of the optoelectronics industry is correct, i.e., that the evolution of different firms' market positions can be analyzed accurately in the context of a technology vs. marketing race, then determinate inferences can made about the present state of the market structure of the optoelectronics industry. First, in the early 1980's, market position in the optoelectronics market was determined by the ability to compete in a technology race. During this period, medium-sized U.S. firms were able to dominate portions of the market based on their ability to innovate quickly and to be the first to introduce these products into the market. Hence, in this early phase of the product's life, the medium-sized US firms appear to have won the technology race.

Second, as these products have matured and have become easier to imitate, success in the market is currently being determined by the ability to produce the large volumes necessary to bring unit total costs down rapidly and/or to exploit a stronger financial or marketing position. In this instance, large firms, (particularly those capable of sustaining long-term R&D projects related to process as well as product developments), have been the most successful and are currently taking U.S. and European market share from the established medium-sized U.S. firms. Hence, in this later phase of the product's life, larger, vertically integrated firms that can minimize the attendant risks of R&D activity more effectively, such as various Japanese firms, appear to have won the marketing race.

Finally, if this assessment is accurate, it is possible to infer the future market structure of the industry from parallel experiences in other maturing industries. As optoelectronics technology continues to mature, it appears that only those large firms capable of generating the volumes associated with low average cost will survive in the mainstream market. It appears that medium-sized firms will survive in the market only if they (1)

1/ For instance, a representative of a medium-sized foreign firm, indicated that, similar to other medium-sized U.S. firms, it viewed its competitive advantage in product innovation, i.e., the technology race, and not in the possession of marketing or production economies, i.e., the marketing race. The firm's representative indicated that the informal, underlying strategy of the firm was to concentrate on those products that were in the early stages of the product life-cyle and to sell those operations of the firm dealing in mature products. For this reason, the firm was concentrating its development and marketing efforts on data-communications optoelectronics, a relatively "new" technology, and selling its semiconductor operations, a relatively "mature" technology where it had lost its competitive advantage.

find special niches, such as supplying military consumers, (2) exploit their major strength in rapid product innovation and shift to those products which are at the early stages of the product life-cycle, (3) or merge with larger firms.

This analysis essentially focuses on the national market place. International differences complicate the conclusion, somehwat. At some point comparative advantages of foreign producers may outweigh the large volume benefits of larger U.S. producers. For example, in recent years, the medium-sized U.S. fiber optic producers have faced increased competition, especially from Japanese firms, in U.S. and European markets. Industry experts predict that these medium-sized U.S. firms will be unable to maintain the market-share lead established in the early 1980s and will either merge with larger firms or exit the market.

Even though the various hypotheses and concepts discussed above provide a plausible and useful framework for analyzing the evolution of market structure in the optoelectronics market, certain caveats should be kept in mind. First, and foremost, the preceding inferences are drawn from a large amount of anecdotal data and are not based on extensive information or empirical analysis.

Second, the inferences made about the current and future structure of the fiber optics (and particularly the optoelectronics) market are intended to give only a broad picture about the direction of the market. In some specific cases, these inferences may not be appropriate or may be oversimplified. For instance, it is true that some optoelectronics devices are in the latter stages of the product life-cycle. However, this statement does not apply to all telecommunication optoelectronic devices nor does it appear to apply to optoelectronic devices which are being developed for data communication and other specialized applications.

<u>Vertical integration and competitiveness</u>

In the long run most industry analysts expect the larger, vertically integrated fiber optics firms to enjoy the clearest market advantage. Size, but more importantly, the ability to produce, market, and service fiber optic systems is perceived as being the way to gain and maintain market share.

In addition, while some of these products are at a mature stage in their development, they do not appear to have reached the last stages of the product life-cycle. In contrast to optical fiber, telecom-optoelectronic devices are not yet considered a commodity. In addition, much of the optoelectronic technology is still considered to be sufficiently advanced that it is not easily duplicated by producers in many of the newly industrialized countries such as Korea and Taiwan.

Third, even though U.S. firms were characterized as possessing an advantage in product innovation over Japanese firms by a number of industry analysts, this may be an oversimplication. In actuality, it is not clear that US firms have the innovation advantage over Japanese firms across all optoelectronic products. 1/ In some cases, Japanese producers clearly have an advantage over U.S. producers. 2/ In fact, many U.S. firms have merged with or entered into joint ventures or similar relationships with Japanese and European firms. The following table 9-4 shows some of these relationships with Japanese firms. This trend is not just a phenomenon of the U.S. market. U.S. and foreign manufacturers have entered into various types of arrangements in foreign markets as well. This strategy not only allows firms to achieve some degree of vertical integration, but also to gain entry into foreign markets often as not protected by non-tariff barriers. At present it is difficult to determine how successful this strategy will be because the industry is undergoing rapid change and there is little available data. Nonetheless, as an increasing number of fiberoptics firms form joint ventures and other associations that result in greater degrees of vertical integration throughout the industry, it will be possible to evaluate the advantages of vertical integration in determining long-run competitiveness.

Short-run, exogenous factors

Finally, other short-term factors have also affected the competitiveness of the U.S. fiber optics industry both favorably and unfavorably. The decline in U.S. costs is one factor that has favorably affected the competitiveness of U.S. products. Perhaps the earlier development of U.S. fiber optic networks gave U.S. producers a learning curve lead and brought the initial pressure on producer prices in this country, in effect forcing further leadership in cost reductions. Much of the decrease in cost of U.S. fiber optic devices and systems appears due to learning curve effects. However, it is unclear whether the learning curve effects experienced by U.S. firms are larger than those of their competitors.

In addition, more recently the decline of the U.S. dollar has made U.S. products more attractive to consumers in U.S. and European markets relative to those of Japanese and European competitors. Between 1985 and 1986, exports of U.S. optical fiber and cable practically doubled while imports of optical fiber and cable to the United States decreased by 26 percent. No doubt, a significant portion of this favorable change in the balance of fiber optics trade was due to the dollar's decline. The current lack of international standards has also affected the industry negatively-both in terms of the supply-side and the demand-side. Finally, the single largest short-term factor unfavorably affecting US fiber optics products has been the slump in the demand caused by the completion of the long-distance optical fiber network in the United States.

Exchange rates.--Between 1982 and 1987, the U.S. dollar dramatically appreciated and then depreciated against all major currencies. In fact, between 1985 and 1987, the U.S. dollar depreciated by one third in real

1/ JTECH Report, p. 6-22. Also see figure 10-3 in Chapter 10.
2/ Ibid.

Table 9-4
U.S.-Japan joint activities in the telecommunications/data transmission sector

U.S. firm	Japanese firm(s)	Products (services)
AT&T	Ricoh, Matsui, KDD, Fujitsu, Toshiba	VANs, facsimile equip. computers, telecom. equipment, software
Alcoa	Fujikura, Hitachi	fiber optics, cables
Comsat	Shinwa	satellite earth stations
Contel (includes Executone)	Mitsubishi Elec.	telecom. equipment
DEC	Mitsubishi Elec.	semicondutors
Datapoint	Fujitsu	telecom. equipment
Digital Switch Co.	KDD	switiching equipment
GTE (includes Telenet)	Sumitomo Elec., Fujitsu, Marubeni	VANs, telecom. equip., PBXs
General Electric	NEC	telecom. equipment
General Motors (includes Hughes)	NTT, Mitsui, C. Itoh & Co.	satellites
Harris	Matsushita Elec.	transmission systems
IBM (includes Rolm Corp.)	NTT, Mitsubishi Elec., Tateishi Electric	VANs, PBXs
Motorola	NTT, Daini-Denden, Toshiba	semiconductors, radio equip.
Northern Telecom Inc.	Iwatsu, OKI, Mitsui	telecom. equip., PBXs
RCA & Ford	Sony, Mitsubishi, Marubeni, Nissho Iwai	satellites
United Technologies	NTT	"smart" buildings
United Telecom	Konematsu	VANs
Westinghouse	Toshiba	computer products
Westinghouse & GE	Mitsubishi Elec.	semiconductors

Source: U.S. Department of Commerce, NTIA Trade Report: Assessing the Effects of Changing the AT&T Antitrust Consent Decree, February, 1987., p. 114-115.

effective terms ("as measured by normalized unit labor costs"). 1/ While the U.S. dollar's appreciation should have adversely affected the competitiveness of fiber, cable, and optoelectronic products, it also coincided with a period when U.S. firms appeared, according to anectodal evidence, to have little competition from foreign firms. Therefore, it is unclear to what extent the dollar's appreciation adversely affected the world market share for U.S. goods. In contrast, the current period of the U.S. dollar's depreciation coincides with the period when U.S. firms began to receive increased competition from European and Japanese firms, especially in optoelectronic markets. Therefore, the depreciation of the dollar against all major currencies increased U.S. competitiveness vis-a-vis other major exporters. Indeed, according to representatives of one European optoelectronic's firm, "exchange rate movements along with learning curve effects" are currently important determinants of U.S. price competitiveness in foreign markets. 2/ Unfortunately, lack of data on world exports for the time period 1982 through 1987 does not allow this study to provide a rigorous analysis of the effect of exchange rates on the levels of exports and market shares of U.S. fiber, cable, and optoelectronics. 3/

Between 1982 and 1985, the U.S. dollar appreciated by over 30 percent in nominal terms averaged against all major currencies. 4/ This period coincided with the introduction of optical fiber cable and optoelectronics products into U.S. and foreign telecommunications markets. During this period, U.S. firms appear to have received little competition from foreign firms in either U.S. or foreign markets. The temporary market advantage of U.S. firms in both the domestic and foreign markets might be attributed to a number of factors: namely, patent protection (for fiber and cable firms), being first in product development and market entry (for some optoelectronic firms which sell lasers), and pre-existing marketing channels for established firms in the telecommunications market (for some optoelectronic firms which sell connectors and switching equipment and for firms which offer complete telecom systems).

Notwithstanding, the appreciation of the dollar against the currencies of major importers of U.S. fiber, cable, and optoelectronics, holding all other factors constant, would have decreased the level of U.S. exports to these markets. Between 1982 and 1985, the U.S. dollar appreciated in nominal terms by an average of 26.2 percent against the currencies of major importers France, the United Kingdom, West Germany, and Canada. In real terms during this period, the dollar appreciated by an average of 11.8 percent against these currencies. (Specifically, the nominal and real percentage changes of the dollar's appreciation against major importer's currencies were France, 37, 8; United Kingdom, 36, 19; West Germany, 21, 17; and Canada, 11, 3.)

1/ International Monetary Fund, World Economic Outlook, April 1987 (Washington, DC: IMF, 1987).
2/ From ITC staff interviews with representatives of Siemens in Munich, FRG in September 1987.
3/ Trade and industrial statistics do not have classification yet which permit compilation of data specifically applicable to optical fiber or to optoelectronic (as opposed to the myriad other types of electronic) devices.
4/ International Monetary Fund, World Economic Outlook.

Beginning in March 1985, the U.S. dollar began a general decline. Between March 1985 and February 1987, the dollar fell by 32 percent in nominal effective terms. 1/ As noted above, the dollar's decline coincides with the period when U.S. firms began to receive increased competition from European and Japanese firms. Hence, the depreciation of the dollar against <u>all</u> major currencies increased U.S. cost competitiveness vis-a-vis other major exporters. 2/ To the extent that the relative price of competing country exports reflect that shift, the dollar's depreciation has allowed U.S. exporters to bid away sales from foreign competitors in both domestic and foreign markets. In fact, between 1985 and 1986, the level of U.S. exports of fiber and cable increased by 97 percent while the level of U.S. imports of fiber and cable decreased by 26 percent. The U.S. dollar's depreciation in 1985 also coincides with the completion of U.S. long-distance networks. As a result, there was a large decrease in U.S. demand for fiber, cable, and optoelectronics. It should be noted that European and Asian telecommunication markets are still a few years behind the United States in completing their long-distance networks. Undoubtedly, these market conditions provided a powerful incentive for U.S. firms to look to foreign markets for increased sales. Therefore, both the dollar's depreciation and the decline in U.S. demand were important factors in explaining the increase in U.S. exports and the decrease in U.S. imports of fiber and cable between 1985 and 1986.

Table 9-5, which depicts nominal and real exchange rate indices for the U.S. dollar against currencies of major exporters of fiber, cable, and optoelectronic products, shows that the U.S. dollar depreciated in 1986 in real terms against the currencies of all major exporters. In nominal terms, the U.S. dollar depreciated by an average of 19.1 percent against the currencies of the eight major exporting countries. The nominal change in the dollar exchange rate per foreign currency ranged from a 29-percent depreciation against the Japanese yen to a 2-percent appreciation against the Canadian dollar. In real terms the U.S. dollar depreciated by an average of 19.7 percent against the eight currencies. The real change in the dollar exchange rate per foreign currency ranged from a 26-percent depreciation against the German deutsche mark and Dutch guilder to a 2-percent depreciation against the Canadian dollar.

1/ International Monetary Fund, <u>World Economic Outlook</u>.
2/ A dollar depreciation against an importer's currency affects U.S. exports differently than a dollar depreciation against all currencies. When the dollar depreciates against an importer's currency only, then by definition, other exporter's currencies also depreciate against the importer's curency. Therefore, the volume of trade for both the United States and all other exporters should increase. When the dollar depreciates against all currencies--both importers' and other exporters' currencies--the volume and market share of U.S. exports should increase. Krissoff and Morey, <u>The Dollar Turnaround</u>.

Table 9-5
Nominal and real exchange rate indices for U.S. dollar against currencies of major exporters of fiber, cable, and optoelectronics. Foreign currency per dollar, 1982=100

Country	1982	1983	1984	1985	1986	Percentage change, 1985-86
UNITED KINGDOM 1/						
Nominal.........	100	115.246	131.332	136.125	119.172	-12
Real 5/.........	100	110.692	121.636	118.955	96.6889	-19
GERMANY 2/						
Nominal.........	100	105.220	117.281	121.321	89.487	-26
Real 5/.........	100	104.980	116.399	117.231	86.4649	-26
ITALY 1/						
Nominal.........	100	112.299	129.904	141.178	110.225	-22
Real 5/.........	100	103.635	111.229	112.117	85.6856	-23
NETHERLANDS 2/						
Nominal.........	100	106.887	120.166	124.387	91.754	-26
Real 5/.........	100	106.314	117.430	119.290	87.9880	-26
JAPAN 2/						
Nominal.........	100	95.355	95.359	95.768	67.657	-29
Real 5/.........	100	98.755	101.326	102.542	77.5471	-24
FRANCE 3/						
Nominal.........	100	115.964	132.973	136.717	105.386	-23
Real............	100	105.758	109.604	107.889	4/	4/
SWEDEN 3/						
Nominal.........	100	122.037	131.662	136.948	113.386	-17
Real 5/.........	100	111.126	113.760	111.850	92.199	-18
CANADA 3/						
Nominal.........	100	99.894	104.972	110.679	112.626	+2
Real 5/.........	100	97.720	101.052	103.373	101.216	-2

1/ Exporter of Fiber and Cable.
2/ Exporter of both Fiber/Cable and Optoelectronic products.
3/ Exporter of Optoelectronic products.
4/ Not available.
5/ Deflated by multiplying the ratio of the foreign wholesale price index to the U.S. wholesale (producer) price index.

Source: International Monetary Fund, International Financial Statistics.

<u>Standards</u>.--The demand for optical fiber systems over the next ten years is contingent, in part, on the development of international standards. Currently, standards for fiber optics products vary from country to country. In the telecommunications sector, the various standards have not posed too many problems in that the different systems were compatible enough for analog transmissions. However, the switch from analog to digital transmissions and the increase in data rather than voice transmissions has resulted in an increasing problem of incompatibility between systems. Thus the need for international standards is becoming increasingly more urgent.

The lack of standards has a negative effect on both the supply and demand sides of the market. The lack of uniform standards has had the effect of splintering the market into many smaller markets. On the supply side, firms generally produce for one market. To produce for the various foreign markets requires considerably higher capital outlays for plant and equipment. Thus, production efficiencies are reduced.

The lack of standards has resulted in dampening the demand for certain types of fiber optic systems. Firms are reluctant to allocate sizeable portions of their capital budgets for systems which may be outdated or incompatible with associated systems as soon as they are installed. 1/

The development of ISDN seems to be providing the necessary impetus for the development and adoption of international standards. Unfortunately, the process is extremely slow. In the meantime, U.S., European, and Japanese producers are all developing components and systems that are ISDN compatible. 2/ Although it is difficult to measure the progress being made in other countries, various industry representatives have indicated that they believe that the Western Europeans, the Japanese, and the Australians are perhaps further along in the development of standards for various optoelectronic components. If these countries continue to make progress, the U.S. industry will be at a distinct disadvantage, there officials say.

1/ According to one expert:

> Rampant proliferation of cable types and proprietary designs now makes it nearly impossible to interconnect different vendor's fibers. Whats more, the type of fiber a user selects--from among the countless and subtly different varieties now available--can mean the diffence between a long installed life and widespread vendor support of a fiber network, or its overnight technological obsolescence.

"Brewing standards conflict blurs fiber optics' future," <u>Data Communications</u>, February, 1986.

2/ See chapter 5 for a more detailed discussion of the development of ISDN (integrated systems digital networks) standards.

<u>Changes in U.S. demand for fiber optics systems</u>.--The U.S. demand for optical fibers is in a slump, which has forced smaller firms to exit the market. The slump in demand is basically the result of the completion of long-distance ("trunkline") networks in the United States. During this current period of slack demand, it is expected that the larger firms will remain in the market; smaller fiber producers will be able to remain economically viable only if they are able to produce for specialty markets (such as the military market) or to maintain or expand their production of other products. What has made this substantial decrease in demand particularly difficult for optical fiber producers to handle is the fact that it coincided with the industry achievement of relative product maturity, with its attendant downward pressure on prices.

European and U.S. sources predict that the demand for optical fiber will increase once again when the local-loop networks are developed in Europe and the United States. Speculation on the part of these industry sources on when the local-loop demand will become strong range from two to ten years. When this development occurs, there will be an opportunity in the United States as well as the international market for the entry of new firms, as well as the expansion of existing producer capacity. 1/

1/ Commission staff interviews with U.S., European, and Japanese industry officials, August and September, 1987.

CHAPTER 10. PROFILES OF MAJOR FOREIGN PRODUCER COUNTRY MARKETS AND INDUSTRIES

Western Europe

In Western Europe, as in the United States, telecommunications has accounted for the largest portion of the Western European market for optical fiber, and related techology and equipment. However, there are some important differences between the development of the telecommunications sector of the European countries and that of the United States. In all but a few cases, each country has a similar institutional framework in which the telecommunications networks and services have been the responsibility of a public monopoly, the Post, Telegraph, and Telecommunications Agency (PTT), whereas the equipment used by the networks has been supplied by private enterprise. 1/ For both economic and political reasons, the PTTs generally have developed procurement policies that favor a limited number of suppliers in each country who share the major segement of the market between them. 2/

Officials of the various European PTTs, the European Community (EC), and major telecommunications and fiber optic equipment manufacturers also believe that the U.S. optical fiber producer, Corning Glassworks, has had an influence on the structure of the Western European optical fiber and cable industry in view of its licensing and joint venture relationships with various telecommunications cable manufacturers in the United Kingdom, France, West Germany, Italy, and the Netherlands. 3/

1/ Nguyen, Godefroy D., "Telecommunications: A Challenge to the Old Order," Europe and the New Technologies, Margaret Sharp, editor, (Cornell University Press, Ithaca, New York, 1985), p. 87. In the United States, AT&T acted in a manner similar to the various PTTs in Western Europe as a supplier of telecommunications services. However, its relationship with Western Electric (as the sole supplier of telecommunications equipment) was very different from the relationship the European PTTs had with their suppliers.
2/ Commission staff interviews with officials of West Germany's Federal Ministry of Post and Telecommunications on December 12, 1986, in Bonn, West Germany, and France's Direction General de Telecommunications, in Paris, France on December 22, 1986. Procurement policies are an extremely effective 'barrier to entry' allowing the 'inside' group to prosper and achieve special economies of scale (related to switching costs) while denying these advantages to the excluded outside group. The EEC Telecommunications Industry: Competition, Concentration & Competitiveness, (EEC, Brussels. Belguim, 1983), p. 12.
3/ Commission interviews with E.C. officials in Belgium in Dec. 1986 and Sept. 1987.

As a result of the protective policies of the PTTs, the European telecommunications markets are fragmented. Each country has pursued a policy that strongly favors domestic manufacturers of fiber optics and subdivides the Western European telecommunications market into 15 separate markets. 1/ In each market, concentration has tended to be high, with the top four firms usually accounting for at least three-quarters of sales. Up until recently, there have been very few pan-European firms, notable exceptions being subsidiaries of the U.S. firm ITT 2/, Philips of the Netherlands, and to a somewhat lesser degree, L.M. Ericsson of Sweden. European Commission (EC) officials attribute the segmentation of the European market to not only the procurement policies of the PTTs but also to the variations in technical standards developed by the PTTs.

According to some experts, the lack of competition engendered in the protected and guaranteed domestic telecommunications equipment markets of Western European countries has reduced competition and promoted inefficiency. In 1970, a French economist Ruges estimated that the French PTT paid at least 20 percent more than the average world price for its equipment. In 1983, the Organization for Economic Cooperation and Development (OECD) completed a study that showed that the price differential in telecommunications equipment between Western Europe and the United States was between 60 and 100 percent. 3/ Protected home markets have also prevented the development of a large, unified European common market in telecommunications that could help producers there achieve production efficiencies associated with large output volumes and become more successful in world markets. 4/ There has been evidence that the PTTs have tried to remedy the situation by encouraging more flexible procurement methods and internal competition among the national suppliers. 5/ But the major motivation for flexibility has been to promote innovation in electronics, including fiber optic transmission systems.

EC officials believe that the inevitable merger of telecommunications with information technologies that has been made possible by advances in microelectronics and optoelectronics will require even more drastic changes in the highly regulated and independent market structures of individual European nations if European industry is to keep abreast of other technologically advanced regions of the world, including the United States, and Japan. 6/ Accordingly, the EC has initiated several programs in the past few years to

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1/ Op. cit., Nguyen, Godefroy D., p. 87.
2/ ITT's worldwide telecommunications equipment division was merged in late 1986 with the equipment manufacturing division of France's Compagnie General de Electricite (CGE) to form Alcatel NV, with CGE maintaining a majority interest in the new company. Alcatel's assets make it the second largest telecommunications equipment manufacturer in the world after AT&T.
3/ The EEC Telecommunications Industry: Competition, Concentration, and Competitiveness, (EEC, Brussels, Belgium, 1983), p. 12.
4/ Commission interviews with officials of the Commission of the European Communities in Belgium during Dec. 1986, and Sept. 1987.
5/ Commission interviews with officials of the United Kingdom's Department of Trade and Industry in on Aug. 26, 1987 and the Netherlands Ministry of Economic Affairs Sept. 8, 1987.
6/ Commission interviews with officials of the Commission of the European Communities in Belgium during Dec. 1986, and Sept. 1987.

the past few years to promote joint research and development by industry, government, and university scientists and technologists in optoelectronics. The most generously funded of these, RACE, or Research in Advanced Communications in Europe, was launched in 1985 with the object of establishing a pan-European, integrated broadband communications network within 10 years. This program will stress the development of integrated optoelectronics and components, including fiber optics transmission devices and systems for high-data-rate broadband networks. Funding of $1.6 billion over the next 5 years was authorized for participants in the program. The European Strategic Plan for Research and Development in Information Technologies (ESPRIT), another important EC program directed at smaller and medium sized firms, is a 10-year program (1984-93) to provide the European information technology industry with the technology it needs to remain competitive in the international markets within the next decade. The program was designed to promote collaboration between countries in the EC and develop the basis for the development of European technical standards for all sectors of the industry. At the same time the program is to encourage R&D in areas such as advanced microelectronics, office systems, computer-integrated manufacturing, and advanced information processing. Fiber optic systems and technology figure prominently in the sectors to be funded. Aimed upstream at the technology from which a new generation of products and services will be derived, "ESPRIT is part of an economic strategy designed to ensure that the European information technology industry acquires the technology it needs in Europe for international competitiveness." 1/ Some 2000 man-years per year is planned for this program from 1986 onwards, and its budget is $1.5 billion for its first 5 years, 50 percent of it funded by the EC

Most industry experts believe that Western Europe will continue to be the second largest market after the United States for fiber optics in the next few years (fig. 10-1). One of the major U.S. marketing research firms in the fiber optics field reports that the European market will experience average annual growth of 30 percent over the next five years, rising from $300 million in 1985 to almost $1.5 billion by 1991. 2/ The largest part of this is initially expected to be accounted for by purchases of optical fiber and cable. However, optoelectronic equipment, including lasers, detectors, connectors, and other system components will increasingly take up larger proportions of total fiber optic expendistures as optical fiber is used more in local and subscriber network applications as is expected.

West Germany the United Kingdom, and France are the largest markets for optical fiber, cable, and related equipment in Europe. Other Western European countries representing less significant markets for fiber optics are Spain, the Benelux countries, Sweden, Denmark, and Norway.

European industry officials indicated to the Commission in December, 1986, that the European markets had not yet shown evidence of the slowdown in fiber sales experienced in the United States during 1986. This was because (1) long-haul fiber optic telecommunications networks were slower in

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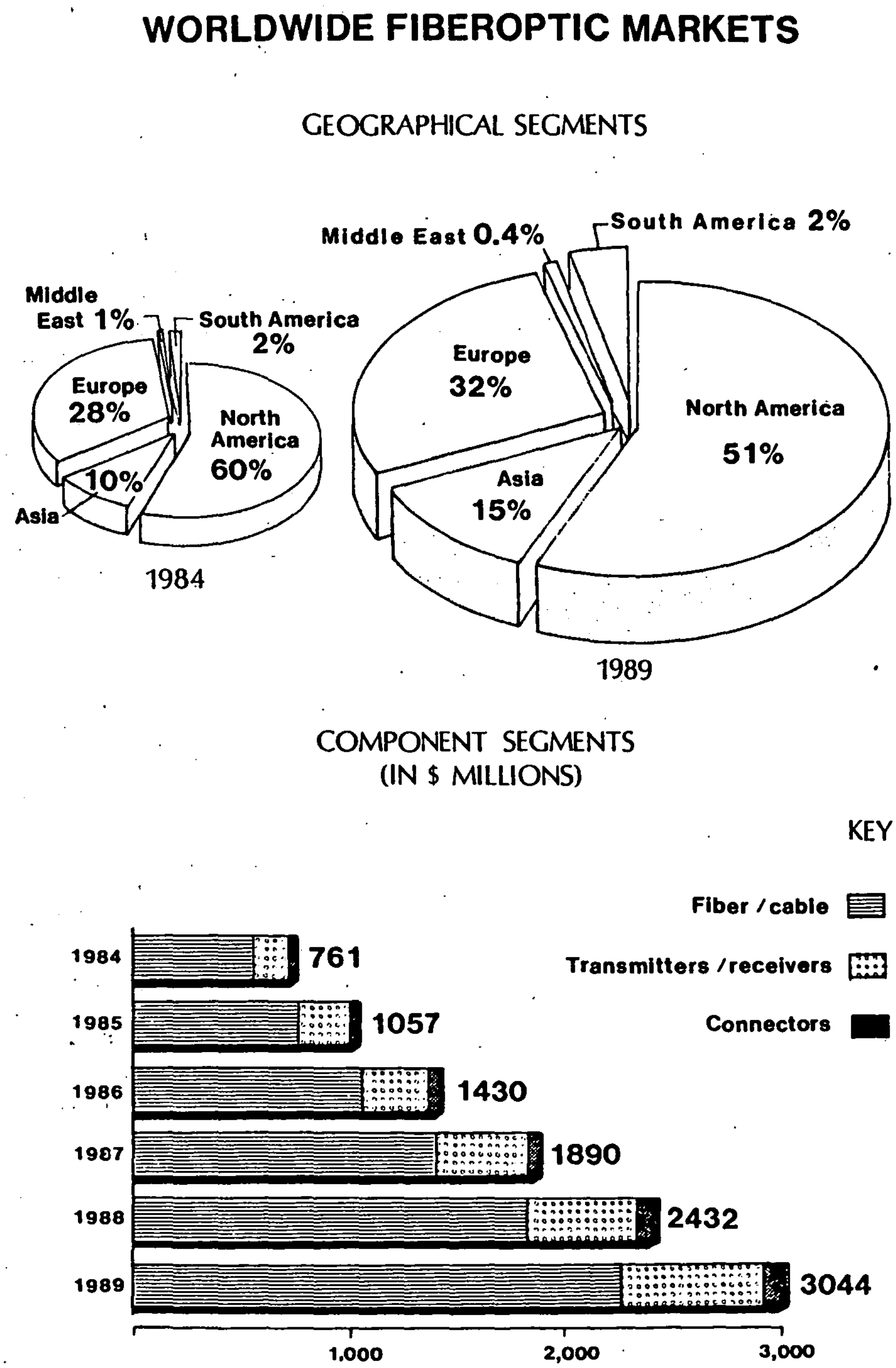
1/ ESPRIT, brochure of the Task Force of Information and Telecommunications Technologies, Commission of the European Communities, Brussels, Belgium.
2/ European Markets for Fiber Optics, Kessler Marketing Intelligence, 1986.

Figure 10-1
Growth in Western European fiber optic markets, 1984-1989



Source: Kessler Marketing Intelligence, 1986 developing in Europe than in the United States, (2) optical fiber had just recently begun replacing coaxial cable in the networks, and (3) the PTTs of the major European markets had made a conscious decision to emphasize initial development of fiber in local and data communication networks in major cities and regions before linking up these systems in nationwide long-distance networks. 1/ However, during a follow-up visit in August 1987, Commission staff learned that sales of optical fiber and cable had by then become sluggish there also. 2/

There are currently 17 producers of optical fiber in Western Europe (table 10-1). Although the telecommunications markets in Europe as a whole are generally controlled primarily by the government-owned PTTs in each country, the supply-side of the optical fiber sector of the Western Europe market has been dominated by Corning Glassworks. 3/ Since 1970, Corning has taken initiatives to protect the technology for manufacturing optical fiber by registering both process and product patents in most major countries of Europe, including all countries in Western Europe, except Ireland, Denmark, Luxembourg, Greece and Portugal. Corning has developed a number of joint venture and licensing agreements with major suppliers in most European markets. 4/ Because optical fibers are generally sold to cable makers who supply optical cables to users (PTTs), most of Corning's joint-venture partners in Europe are large cable makers.

Although Corning has a dominant position in the Western European markets as the result of its patents, its patent coverage varies from one country to another and several optical fiber producers operate without a Corning license. This is especially the case with respect to the Japanese firm Sumitomo which has granted licenses to Pirelli General in the United Kingdom and Wacker Chemitronic, GmbH in West Germany. According to EC officials, Corning did not believe the Danish Market was significant enough to warrant negotiating a licensing agreement with the Danish cabler NKT; accordingly, NKT has been able to manufacture optical fiber without one. 5/ Recently, however, AT&T established a relationship with NKT which some officials believe will enable AT&T to use as a springboard for sale of optical fiber into other European markets. Although Corning initiated patent infringement actions against Sumitomo in the United States and suceeded in having its fiber production shut down, the company has not initiated similar lawsuits in Europe.

1/ Commission interviews with officials of West Germany's Federal Ministry of Posts and Telecommunications on Dec. 12, 1986, and France's Direction General de Telecommunications in Paris, France on Dec. 22, 1986.
2/ Commission interviews with government and industry officials in Western Europe during Aug. 26 through Sept. 11, 1987.
3/ EC Decision of July 14, 1986, relating to a proceeding under Article 85 of the EEC Treaty (IV 30.320-optical fibers).
4/ Ibid.
5/ Commission interview with Dr. Spyros Konidaris and Svend Kraemer, Principal Administrator, Information Technology Task Force, Commission of the European Communities, in Brussels, Belgium on Dec. 9, 1986.

Table 10-1
Major producers of optical fiber in Western Europe, by estimated capacity and country, and by licensing agreement, 1986
(In km/year)

Item	Corning licensee	Estimated capacity
United Kingdom:		
Optical Fibres	Yes	250,000
STC	No	20,000
GEC	No	20,000
Pirelli General	No	25,000
France:		
CLTO(CGE)	Yes	25,000
Fiber Optiques Industries	Yes	55,000
West Germany:		
AEG	No	10,000
Standard Electric Lorenz	No	15,000
Philips Kommunication Industries	No	5,000
Siecor GmbH	Yes	80,000(1987)
Wacker/Sumitomo	No	100,000(1987)
Italy:		
Fib Ottiche Sud	Yes	75,000
Netherlands:		
Philips	Yes	60,000
Denmark:		
NKT	No	20,000
Sweden:		
L.M. Ericsson	No	15,000
Finland:		
Nokia	No	5,000
Switzerland:		
Cabloptic	No	4,000

Source: Official Journal of the European Communities, Aug., 22, 1986, pp. 43 and 44.

Since its introduction in European markets in January 1983, the price of single mode fiber in Europe, as in the United States, has fallen considerably. In part, as a result of the system of competitive tendering increasingly applied by European PTTs in the past year or so, there has also been a strong downward pressure on price levels for optical fiber cable through their increasing use of systems that promote competitive tendering. 1/ According to EC officials, this tendering system has led to downward pressure on the prices of optical fiber, which generally represents more than half the cable cost. 2/

EC officials, as well as various European industry representatives, contended that the key to success in the world market for fiber optics is the successful development of an advanced optoelectronics industry. 3/ Although the major firms in Western Europe have been preoccupied with supplying equipment for long-distance trunk transmission routes, most analysts believe that the demand for telecommunications grade optical fiber and cable is peaking, and that it will begin to decline in much the same way that U.S. demand began to decline in 1986. However, many European experts foresee a growth in the demand for optoelectronic components. 4/ According to EC officials, optoelectronic components development will be guided by a single, standard specification established by the EC Provisional standards that have already been adopted by an EC research committee on optoelectronic components, include the use of lasers rather than light emitting diodes (LEDs), 5/ and singlemode (or monomode) fiber as opposed to multimode fiber. 6/

1/ The price of optical fiber in Europe has been formed by the interplay of three forces. The suppliers of optical fiber, the optical cable makers, and the end users (usually the PTTs). The price of optical fiber is further determined by the price of traditional conductors such as copper wire, microwave and satellite transmissions with which they are in competition. The extent to which optical fiber is used is primarily a function of its cost effectiveness with respect to traditional copper cable and other mediums of communication. Official Journal of the European Communities, Aug. 22, 1986, p. 33.

2/ Commission staff interview with officials of the Commission of the European Communities in Brussels, Belgium on Dec. 8, 1986.

3/ This belief was also expressed by various industry and government representatives in North America as well as Japan, Australia, and other Asian countries.

4/ European companies known to be at work in this area include British Telecom, Plessey, and STC in the United Kingdom, Alcatel in France, Siemens and Standard Elektrik Lorenz (now part of the French-based Alcatel) in West Germany, Philips in the Netherlands and Ericsson in Sweden. "A New Look for European Communications", by Graham Finnie, Photonics Spectra, June 1987, p. 153.

5/ See app. F for the glossary of technical terms.

6/ Finnie, Graham, "A New Look for European Communications Photonics Spectra, June 1987, p. 153.

Currently, there are conflicts within the EC with respect to the funding of programs such as RACE and ESPRIT, as well as those of various countries such as West Germany's Broadband Integrated Fiber Optic Network (BIGFON) Program, and the United Kingdom's Joint Optoelectronics Research Scheme (JOERS). There appear to be major differences in views regarding the efficacy and fairness of programs at different trans-European and individual country levels. The PTTs tend to view EC programs as too abstract in concept, but company officials often look at their own country's PTT programs in much the same manner. The stonger firms are unwilling to have to share their advanced technology with newly energing firms. The larger firms believe that allowing new firms access to the results of their R&D without forcing them to bear any of the costs of the R&D was unfair.

Western European government and industry officials are in agreement that the two major keys to global competitiveness in global fiber optics and telecommunications markets are the development of better optoelectronic manufacturing techniques and integration of optical and electronic components on the same substrate. Accordingly, despite the reported disagreements over funding for the various programs, it is clear that many countries and firms will go ahead with their development programs anyway, and "the race is now on in company research laboratories to develop suitable components." 1/

The EC is also encouraging European researchers and their respective companies to collaborate on efforts to develop and refine optical switching. Whereas, some company officials expressed doubts regarding the short-term economic viability of optical switching for all but highly specialized applications, EC officials believe the search for materials and techniques that are suitable for switching signals in a purely optical domain is yielding advances that may prove useful in other applications, including new types of devices for image processing and amplification, holography, and switching.

West Germany

Market segments

Over 80 percent of the fiber optics market in West Germany is accounted for by telecommunications. Public telecommunications networks are planned, built, and operated by the West German PTT, the Deutsche Bundespost (DBP), and all products and equipment related to telecommunications, including optical fiber cable and other fiber optic equipment is produced in the private sector, which consists mostly of medium-sized and large firms. 2/ The DBP is the principal customer for telecommunications equipment in West Germany. Although it is not officially stated policy, the DBP has generally favored West German

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1/ Finnie, Graham "A New Look for European Communications", Photonics Spectra, June 1987, p. 153.
2/ Telecommunications Policies in Seventeen Countries: Prospects for Future Competitive Access. National Telecommunications and Information Administration; U.S. Department of Commerce, May 1983, p. 96.

manufacturers over the years. 1/ Because the DBP's procurement policies tend to favor a selected group of telecommunication firms, these firms have played an important role in planning, developing, and constructing major DBP telecommunication installations, including fiber optic systems. 2/

Although West Germany is a signatory to the GATT code on Government Procurement, it excluded telecommunications (but not other postal) equipment from the commodities with respect to which it adheres to the Code. As a result, foreign manufacturers have not been able to participate in the West German telecommunications market to any great extent. In light of this, U.S. Government officials have held four rounds of "fact finding" discussions during the past two years to develop more information concerning equipment procurement policies and regulations with respect to enhanced services, type approval procedures, product standards, and equipment attachment policies. 3/ Generally the DBP monopsony 4/ extends up to the point where its lines are connected to a home, office, or plant. Despite DBP policies, some U.S. optical fiber and cable firms (including Corning and Siecor) have enjoyed moderate success in the West Germany market because of their licensing and joint venture relationships with West German firms such as Siemens. U.S. optoelectronics firms have also been fairly successful in supplying the West German market with components such as long wavelength lasers.

In view of the increasing application of glass fiber technology in telecommunications, the cable market in West Germany is undergoing a fundamental structural change. According to industry forecasts that are based on the investment plans of the DBP, sales of copper cables will fall dramatically in a few years, to about 10 percent of 1985 sales. At the same time the forecasts predict that the demand for optical cables will increase substantially as these cables are substituted for copper. 5/ The Ministry has earmarked DM 2.5 billion ($1.4 billion U.S.) for the period 1985 through 1990 for the laying of optical cables (table 10-2). The switch from copper to optical cable is also expected to increase the demand for other fiber optic telecommunication equipment. Because the West German DBP is expected to continue its restrictive procurement policies and to retain its monopoly power with respect to telecommunications services, some U.S. officials have suggested that U.S. firms develop subcontracting arrangements with West German fiber optic equipment manufacturers and possibly license technology to them.

1/ Commission interviews with officials of the Duetsche Bundespost in Bonn, West Germany on Dec. 12, 1986.

2/ Op. cit., Telecommunications Policies in Seventeen Countries.

3/ Ibid.

4/ See app. F for the glossary of technical terms.

5/ Commission interview with officials in West Germany's Federal Ministry of Post and Telecommunications in Bonn, West Germany on Dec. 12, 1986, and West German company officials in December. 1986 and November 1987.

Table 10-2
Planned installation of optical fibers in West German trunk and local networks, by types, 1986-90
(In fiber km)

Year	Trunk network: Graded index (multimode) fiber	Trunk network: Single mode (monomode) fiber	Local network: Graded index (multimode) fiber	Local network: Single mode (monomode) fiber
1986......	50,000	20,000	15,000	0
1987......	10,000	46,000	0	40,000
1988......	0	56,000	0	75,000
1989......	0	54,000	0	150,000
1990......	0	45,000	0	260,000
Total...	60,000	221,000	15,000	525,000

Source: West German Federal Ministry of Post and Telecommunications.

West Germany is among the most advanced countries in the world in the employment of fiber optic technology in industrial and manufacturing applications. In addition, firms are investing substantially in the development of computer programmable, integrated machine tool and robotic systems in order to standardize and reduce costs of tasks such as soldering, welding, and cutting metal, glass, and other materials. 1/ Currently, optical fibers are utilized in such systems. However, the additional demand for data and nondata types of optical fiber that will be generated as computer integrated manufacturing becomes more economically and technically viable, is of considerable importance.

West Germany is a leading manufacturer of advanced fiber optic medical technology. 1/ Further developments in this area should increase the demand for all types of fibers, including advanced infrared (IR) fibers. West German industry sources expect that specialized data and nondata optical fibers will increase from the current level of about 2 percent of total German optical fiber production to about 5 percent by 1992. 2/

Finally, industry and Government officals state that military applications employing fiber optics and other advanced materials should continue to increase as Europeans begin to develop their own military programs. 3/ These officials state that the increased demand for data and nondata fiber, such as fiber optic gyros, sensors, and faceplates should create opportunities for both domestic and foreign manufacturers of advanced

1/ Commission interviews with various West German industry and government officials during December 1986 and August 1987 visits to West Germany.
2/ Examples of this equipment include laser powered surgical tools, imaging and sensing apparatus, and fiber optic endoscopes.
3/ Commission interviews with West German industry officials West Germany in September 1987.

fibers and fiber optic systems, especially West German and U.S. suppliers. Demand for optical fiber and cable in this sector of the West German market should increase from about 3 percent of total fiber demand in 1987 to 7-10 percent by 1995, according to the West German sources. 1/

Industry structure

The West German optical fiber and cable industries in West Germany are highly concentrated. Two of its five major optical fiber producers account for an estimated 85 percent of total fiber manufacturing capacity, while the three largest cable manufacturing firms account for over 80 percent of total optical cable manufacturing capacity. 2/ Optical fiber capacity for leading West German firms in 1986 is shown below (in km/yr):

Producer 3/	Estimated capacity
AEG	10,000
Standard Electronic Lorenz (SEL)	15,000
Philips Kommunication Industries (PKI)	5,000
Siecor GmBH (Siemens Corning)	80,000
Wacker/Sumitomo	100,000
Total	210,000

The West German firm Siemens is not only the largest supplier of optical fiber, cable, and optoelectronics equipment in West Germany, but also the largest telecommunications equipment producer in the EC. 4/ Apart from Siemens, the leading optical fiber and cable manufacturers include Philips Kommunications Industries, Standard Electrik Lorenz, and ANT Telecommunications, formerly AEG Telefunken. These three firms all began as copper cabling companies and continue to produce all types of optical fiber and copper cabling equipment and apparatus, including transmission, multiplexing, and connecting equipment for the West German market. Siecor, Siemens' joint venture with Corning Glassworks to produce optical fiber has a capacity of 80,000 fiber kilometers and is expected to increase its capacity to 200,000 fiber kilometers in 1989. Recently, Wacker Chemie, a West German chemicals manufacturer established a joint venture with Sumitomo to manufacture optical fiber; its optical fiber production capacity is expected to amount to 100,000 fiber kilometer by the end of 1987.

1/ Commission interviews with various West German industry and government officials during December 1986 and August 1987 visits to West Germany.
2/ Based on estimates contained in Official Journal of the European Communities, Aug. 22, 1986, pp. 43-44.
3/ Official Journal of the European Communities, Aug. 22, 1986, pp. 43-44.
4/ Siemens' total worldwide sales of $20 billion in 1986 made it the 14th largest company in the world in sales outside of the United States.

Future demand and competitiveness

Siemens, by virture of its joint venture and licensing relationships with Corning as well as its extensive experience in electronics and optoelectronics is especially well positioned in the global market as a total fiber optics system supplier. Siemens not only manufactures such basic fiber optic system equipment as lasers, detectors, and optical cable but also makes mulitiplexers and less exotic equipment like connectors, terminals, switching boxes, splicing equipment, and other components required to make an entire fiber optic system viable. 1/ Siemens' sales success over the past 5 years, 2/ which is supported by substantive research and development expenditures, is illustrated in the tabulation below (in billions of dollars) 3/:

Year 1/	Sales	Profit	R&D	Percent R&D/ sales
1986....	$25.4	$0.794	$2.92	11.5
1985....	29.5	0.827	2.59	8.8
1984....	24.8	0.578	2.05	8.2
1983....	21.4	0.434	1.89	9
1982....	21.7	0.399	1.84	8.5

1/ Fiscal year ended in September.

Siemens has achieved considerable success not only in the West German and other European markets but in the United States as well. Siemens' joint-venture with Corning (Siecor) in North Carlina serves as the U.S. representative for Siemens' West-German manufactured connectors, which have been utilized not only in Siecor installations of cable networks but by other cable manufacturers as well. Siemens also has supplied other important optoelectronic equipment, such as multiplexing equipment to the United States. Siemens is one of four major global suppliers of such multiplexing devices. While Siemens has been successful in the international market over the past few years, the firm reportedly is being challenged by new firms that have entered the market and have forced prices downward. 4/

1/ Interview by the Commission with officials of the West German company Siemens in Munich, West Germany, on Sept. 4, 1987.
2/ All figures converted at the mark's rate as of Feb. 9, 1987.
3/Wall Street Journal, Feb. 9, 1987.
4/ Commission interviews with West German industry officials September 1987. Siemens has mounted simultaneous sales efforts in the United States, France, Beligum, Taiwan, Italy, and Japan. It recently bought control of part of the telecommunications equipment business of a U.S. rival, GTE Corporation, which is a joint owner (with U.S. Telecom) of U.S. Sprint, the third largest telecommunications services company in the United States.

Research and development expenditures by West German firms in the electronics and advanced telecommunications sector involved in fiber optics are among the highest in the world and average almost 12 percent of total sales. Industry R&D expenditures are supplemented by extensive research efforts conducted by the Duetsche Bundespost in its Telecommunications Engineering Center (FTZ) located in Darmstadt, West Germany, just south of Frankfurt. From 1949 to April, 1987, the FTZ employment grew from 800 to 2,600, making it the largest medium level DBP authority. 1/ Tasks and main projects of the FTZ have included the following research projects: 2/

Networks	--digital transmission --use of optical fibers --broadcasting transmission and reception
Telephone services	--digital switching --digital transmission through fiber optics cables --itemization of bills
Text and data communications services	--Bildschirmtext (interactive) video text --Datex --teletex, telefax (facsimile)

The DBP has been especially supportive of the West German telecommunications and fiber optics industry in its procurement and R&D activities, according to both West German and U.S. industry sources.

In its efforts to accelerate development of West Germany as a leader in the telecommunications and information technology industries, the West German Government has allocated billions of dollars to devising the necessary standards and infrastructure to accomplish its goals. 3/ To that end, the West German government established a Commission on Telecommunications in April 1985. The Commission's goal is to develop ways to promote technical innovation, and to develop and comply with international standards as well as to enhance the West German industry's position in the telecommunications market. To develop the necessary infrastructure with which such broadband sevices as picture telephone, videoconferencing, datatext, and similar services can be efficiently transmitted over single optical fiber lines, the DBP has instituted an extensive program which will establish an Integrated Services Digital Network (ISDN).

In its BIGFON program initiated in 1980, the DBP was able to test the technology, logistics, and operational characteristics of a broadband integrated services local

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1/ Ibid.
2/ Peter Ziemons, Ruth Miles Henderson, Telecommunications and Radio/Television In the Federal Republic of Germany, Report by officials of the U.S. Embassy in Bonn, West Germany, 1987.
3/ Ibid.

network utilizing glass optical fiber technology. Different West German firms received contracts for building and operating the ten networks establishing regional islands around metropolitan areas (fig. 10-2). The result of the BIGFON program has been the development of a substantial market for optical fiber, cable, and related optoelectronics equipment, which for the most part has been supplied by West German producers. The next step for BIGFON will be to provide an overlay network for a long distance optical cable network to connect these islands into one vast network.

According to an announcement by the West German economics ministry at the end of 1986, 1/ the German Cartel Ministry approved a cooperative agreement between five smaller cable manufacturers to produce and distribute glass fibers for applications in telecommunications. The five firms are (1) Bayerische Kabelwerke AG, (2) Kabelwerke Ehlers GMBH, (3) Kerpenwerke GMBH & Co. KG, (4) Lynenwerke GMBH & Co. KG, and (5) Waskoenig Walter GMBH & Co. KG. These companies will form a new firm called Berliner GlasfusserKabel, GMBH, & Co. KG to produce glass fiber. This cooperative effort is expected to help these companies in the fast-growing German market against the major German manufacturers, including Siemens, SEL and ANT. 2/

United Kingdom

Market segments

The market structure of the fiber optics industry in the United Kingdom has been influenced primarily by the organizational structure of the telecommunications sector in that country, which has changed significantly over the past five years. Up until 1980, all telecommunications services were supplied primarily by the British Post Office (BPO). In that year, the telecommunications functions were separated from the BPO and vested in a specially created Government-owned company, British Telecom (BT). The British Telecommunications Act of 1981 granted BT, a public corporation, the power to provide telecommunications and data-processing services throughout the United Kingdom, as well as the responsibility for all day-to-day matters concerning the operation of these services. 3/ In 1981, another company, Mercury Communications, was licensed by the Secretary of State to provide intercity telecommunications service. Although Mercury initially got off to a "shaky start", because of problems in obtaining connections to British Telecom's local facilities, the threat of competition has had the effect of speeding up British Telecom's introduction of an "overlay" optical cable network to provide high-speed digital services. Mercury has provided this impetus

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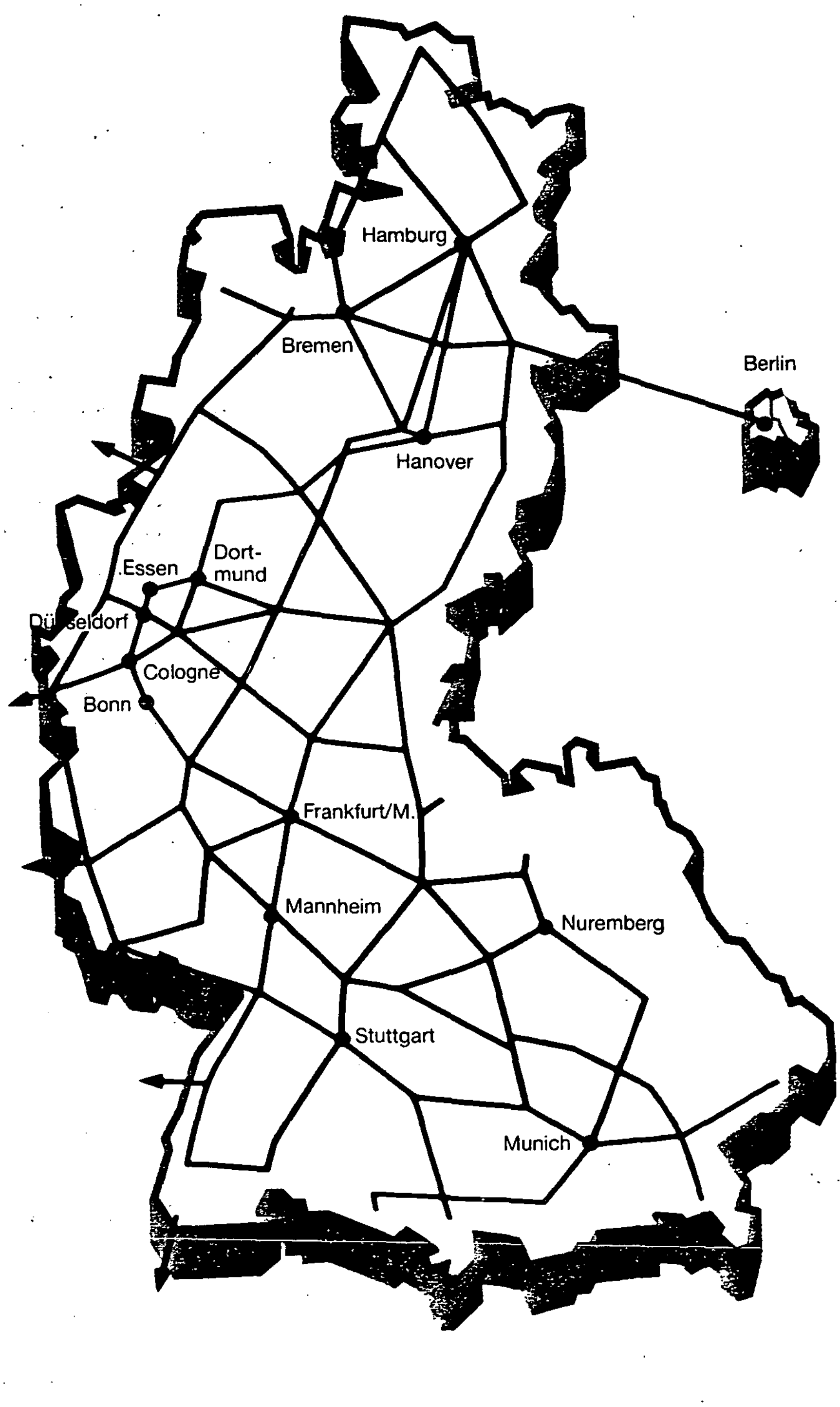
1/ Commission interview with officials in West Germany's Federal Ministry of Post and Telecommunications in Bonn, West Germany on Dec. 12, 1986.
2/ Report from the U.S. Embassy in Bonn, West Germany, dated Nov. 1, 1986.
3/ Telecommunication Polices in Seventeen Countries: Prospects for Future Competitive Access, National Telecommunications and Information Administration: U.S. Department of Commerce, May 1983, p. 203.

Figure 10-2
Deutsche Bundespost plans for development of an extensive fiber optic broadband network

Nationwide supra-regional optical fiber trunk network
Development until the end of 1990 (present plan)



largely as a result of its own efforts to establish a largely fiber optic telephone and data services network. 1/

The United Kingdom has the most extensive fiber optic telecommunication network in place outside of the United States and Japan, according to U.S. and Western European industry analysts. At the end of 1986, British industry and trade officials estimated market consumption of fiber optic cable in that country to be 200,000 fiber kilometers per year (table 10-3), compared with U.S. consumption in that year of approximately 1-2 million fiber kilometers. 2/ The British Telecom long distance trunkline alone represented 100,000 fiber

Table 10-3
Projected United Kingdom telecommunications fiber consumption, 1985-90
(In fiber kilometers)

1985	1986	1987	1988	1989	1990
150,000	200,000	190,000	170,000	160,000	250,000

Source: Interviews with officials of the United Kingdom Department of Trade and Industry and with officials of major United Kingdom producers.

kilometers of that amount. Mercury Communications' usage of fiber cable represented the bulk of the remaining portion of that amount. By the end of 1987, as major portions of British Telecom's trunkline were completed, purchases of fiber is expected to decline, following a pattern similar to that of the United States. 3/ As table 10-3 indicates, this downward trend is expected to continue until the beginning of the next decade when more extensive development of local networks and data transmission applications are expected to bring about a new wave of demand for optical fiber.

Despite the drop in demand for long distance fiber cable, British officials remain fairly optimistic about future prospects in local area and data communications markets in that country, which are expected to grow by more than 20 percent per year through the rest of this century. 4/ The military and defense industries also represent significant markets in the

1/ Commission interviews with officials of Cable and Wireless, in London, England on Dec. 19, 1986.
2/ Commission interviews with officials of the United Kingdom's Department of Trade and Industry and various industry officials in the United Kingdom during December 1986.
3/ Commission interview with the Department of Industry and Trade and United Kingdom industry officials at York Technologies, and Plessey Optronics during Aug. 27-29, 1987.
4/ Commission interview with British officials December 1986.

United Kingdom for fiber optic cable and specialized types of nondata fibers which are used in fiber optic gyros, sensors, and faceplates. Defense industry sources interviewed believe that this market presently may account for 5 to 10 percent of total fiber sales in the United Kingdom and should continue to grow in the future. 1/ However, industry officials complain that despite substantial research and development support given the industry by the Ministry of Defense, there is little diffusion into civilian markets, thus limiting the potential growth of this market segment 2/. Although this may be the case generally, technological developments in military aircraft systems incorporating lightweight fiber optic cable sensors and gyros are now being utilized in civilian avionics and represent a new market for these fiber optic products.

A current emphasis in the United Kingdom on modernizing industry through computer-integrated manufacturing, robotics, and other means of automation provide downstream potential for fiber optics because of its inherent ability to permit the transmission, processing, and control of large amounts of data and video information within extremely noisy and hostile industrial environments. British fiber optic industry sources concede, however, that despite the R&D in this area not enough emphasis has been given to developing markets for these systems in various British industries. 3/ The United Kingdom's medical equipment industry has represented an sizeable market for nondata type fibers for over a decade, and, with ongoing advances in technology, this sector is expected to continue to remain an important market for this type of fiber.

Industry structure

Four companies account for most (90 percent) of the United Kingdom's optical fiber production: Optical Fibres (a joint-venture of Corning Glassworks and BICC, a major British cabler) Standard Telephone and Cables (STC) (a British-based, multinational supplier of telecommunications cables, components, and systems, including optoelectronic and fiber optic transmission systems), Pirelli General (a subsidiary of the Italian and Swiss-based tire, telecommunication, and power cable manufacturer), and General Electric Company (a British integrated manufacturer of electronic and telecommunication systems).

Total British capacity for producing fiber was estimated to be about 350,000 fiber kilometers per year in 1986, 4/ and about 500,000 fiber kilometers per year by the middle of 1987. 5/ Almost four-fifths of this capacity is held by Optical Fibres Limited, the largest producer of

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1/ Commission interview with a procurement officer, Ministry of Defence, in London, England on Dec. 13, 1986.
2/ Commission interview with an official of Telephone Cables Limited (TCL) in London, England on Dec. 17, 1986.
3/ Commission interview with British industry officials December 1986.
4/ Official Journal of the European Communities, Aug. 22, 1986, p. 43.
5/ Commission interviews with British government and industry officials during Aug. 16-18, 1987.

optical fiber outside of the United States. The share of total capacity held by each of the major UK suppliers of optical fiber in 1986 is as follows (in km/yr) 1/:

Producer	Estimated capacity
Optical fibres	250,000
STC	20,000
GEC	20,000
Pirelli General	25,000
Total	315,000

Although total capacity exceeded the 200,000 fiber kilometer consumption in the United Kingdom market in 1986, a significant amount of optical fiber was exported in both fiber and cable forms to markets in East Asia, Australia, New Zealand, and the United States. British-made fiber also made its way into some undersea cable being installed under the Atlantic Ocean as part of the TAT-8 project (Chapter 4). By 1987, capacity utilization for optical fiber had dropped to less than 70 percent from 90 percent in the previous year, accordingly to government and industry representatives. This was a result of the continued expansion of fiber making capacity during 1986 and 1987 and the decline in demand beginning in the spring of 1987 as major British trunklines were completed.

BICC, is the largest supplier of optical cable in the United Kingdom, delivering about 120,000 fiber kilometers annually over the past 2 years; the company's production accounts for about 55 to 60 percent of the United Kingdom total. 2/ STC, Pirelli, and GEC, are also important suppliers of optical cable. STC, a vertically-integrated fiber optic producer also supplies a significant amount of cable to East Asian countries.

GEC supplies telecommunications cable, including fiber cable, to the United Kingdom and other markets through its Telephone Cables Limited (TCL) subsidiary. It has supplied much of the cable to the alternative Mercury telecommunications system in Great Britain. Pirelli, produces the bulk of the remaining long distance telecommunication cable in the British Isles, or about 5 percent. 3/

Pilkington Telecommunications Systems, is a major supplier of optical cable to the data communications, local area network, and computer interconnect market. The company has been successful in the United States as well as the United Kingdom market by specializing in IBM compatible systems as well as developing integrated manufacturing and control systems such as MAP

1/Source: Official Journal of the European Communities, Aug. 22, 1986, pp. 43-44.
2/ Commission interview with officials of the United Kingdom Department of Trade and Industries, and various British telecommunications companies during December 1986, and August 1987.
3/ Although Pirelli is licensed by Sumitomo to produce optical fiber in the United Kingdom it is licensed by Corning to make fiber in Italy.

(being pushed by General Motors) and TOP. A subsidiary of Pilkington's parent company manufactures nondata fiber optic devices such as night vision image intensifiers, fiber optic endoscopes, and fiber optic data multiplexers for use in data communication links.

York Technology, Ltd. is an important manufacturer in the nondata fiber market. Although much of its financial success has come from its fiber optic test equipment, its real interests are in developing advanced fibers for use in complex military and industrial control systems to minimize electromagnetic interferences and difficulties inherent in complex electronic systems. Although they have achieved some success in the United Kingdom and the United States, officials of the company believe it is essential that they develop partnerships with major defense contractors that could benefit from York's technology while helping York reach important military customers. Some of the fibers being worked on by the company include various types of sensors, fiber optic gyros, lightweight cables, and a combination of these components into operative systems. In addition to York Technology, there are number of other specialty producers of nondata type fiber, ribbons, cables and bundles for various medical and industrial apparatus, including advanced laser delivery systems.

The fiber optics industry in the United Kingdom is characterized by fairly high research and development expenditures; averaging 12 percent of total sales for several major firms in 1986. 1/ In addition, the British Post office as well as the more recently privatized British Telecom, have been leaders, along with AT&T, Corning, and various Japanese firms, in advanced optical fiber and optoelectronics research and development. For example, British Telecom's laboratories have conducted research in the following areas:

-Gigabit laser transmission trials in fiber optic networks
-All optical repeaters
-Bidirectional fiber optic links
-Corrugated optical fiber for rugged undersea cable

The United Kingdom is increasingly relying on private-sector initiatives for funding advanced research and development in the area of fiber optics. Nonetheless, British firms have received funds from government supported research and developement programs such as the Joint Optoelectronics Research Scheme (JOERS) and LINK. British Government officials believe that their country has important strengths in fiber optics, especially in the development of critical materials, lightwave optoelectronics devices and components, novel fibers, as well as having a large research and development base. However, given the British firms relatively small size compared with their U.S. and Japanese counterparts, the Government has determined that collective R&D efforts are needed to enable British industry to be successful in the international market. To consolidate the strengths of their advanced research in optoelectronics, the Department of Trade and Industry in the

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1/ Commission interviews with officials of the United Kingdom Department of Trade and industry and with officials of major British fiber optics firms during December 1986, and August 1987.

United Kingdom established JOERS a collaborative research program in December 1982. The program supports longterm collaborative research projects between industry and academic institutions in optoelec- tronics, including work on integrated optics, optical signal processing and storage, advanced fiber and technology, optical fiber sensors, and device fabrication processes and supporting technologies. 1/ Under the original $1.8 million phase of the program, 22 projects received support, including participation by 16 companies and 26 universities and technical schools. 2/

In December 1986, the British Government initiated another research program called LINK to aid their optoelectronics industry. This program is expected to fund up to 50 percent of the cost of joint academic-industry research programs through 1991; in addition to programs including advanced optoelectronic materials, and sensor technology, the program will fund research on undersea communications and digital optoelectronic processing as well as other programs involving fiber optics. Government officials emphasized to Commission staff that the program was not intended to replace JOUERS. 3/

British firms have also been highly involved in EC-wide programs such as RACE, and ESPRIT, with the largest participation of any country. Government and private-sector officials believe such participation is critical if European and British high-technology industry is to hold its own against its North American and Japanese counterparts, and even newly-industrialized countries such as South Korea. 4/

Future demand and competitiveness

Producers in the United Kingdom are becoming more active in the international market.The industry is in a good position to take advantage of expected developments in data communications and local area networks, given the experience it has gained in constructing extensive metropolitan area and

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1/ Department of Trade and Industry Press Notice No. 86/562, July 25, 1986.
2/ Each project in the program is required to involve at least two firms and one academic institution. In March 1986, an additional $17 million was made available to expand the total program support to $52 million in the years up to 1989. Some of the proposals accepted for funding included research on organic electro-optic and nonlinear optical materials, growth and characterization of III-V compounds on silicon substrates for optoelectronic components, integrated fiber-optic-device technology, multimode integrated optics for communications, and guided-wave optical devices based on organic crystals. Commission staff interview with officials of the United Kingdom Department of Trade and Industry in London, England on Aug. 26, 1987.
3/ Commission staff interview with officials of the United Kingdom Department of Trade and Industry in London England on Aug. 26, 1987.
4/ Commission interview of various United Kingdom government and industry officials in August 1987.

business premises fiber optic networks in cities such as London. In fact, the United Kingdom is a leader in data transmission applications of optical fiber. For example, Cable and Wireless has extensive plans through its Mercury venture, to link the world's major cities in a global network based principally on fiber optics. Beginning with its Mercury optical fiber based network in the United Kingdom, Cable and Wireless has plans to cross the Atlantic Ocean with its participation in the PTAT-8 undersea optical cable project, utilize leased lines across the United States continent, then continue with a planned project with the Japanese firm KDD to provide a second undersea fiber optic link from the United States to Japan, and to complete its network with an undersea cable project from Japan to Hong Kong and Korea, an area of the world Cable and Wireless has traditionally served. In the United States, Cable and Wireness has established a joint-venture with the Missouri-Kansas-Texas Railroads to install a fiber optic link between five major Texas cities.

France

Market segments

The structure of the fiber optics market in France is determined, for the most part by the country's PTT. Responsibility for French telecommunications policies resides in the Direction Generale des Telecommunications (DGT), the telecommunications unit of the French PTT (Postes, Telecommunications, and Telediffusion). 1/ The PTT operates the telephone network and buys its products from various suppliers. The policy has been and still is to have at least two suppliers of each type of equipment.

In the past 5 years, the French Government has focused on modernizing the country's telecommunications system. In 1983, French public telecommunications officials announced plans to develop a nationwide multiuser fiber optic network based on state-of-the-art technology. 2/ The network began with two links constructed in Paris and Montpellier, to integrate services already available on traditional copper and coaxial networks, (including telephone, telecopying, and videotext with televison) and provided commercial consumers and private subscribers throughout France with greater access to these various services. 3/ Expenditures have run between $4 and $5 billion (U.S.) per year (compared to $13 billion by AT&T annually on

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1/ Telecommunications Policies in Seventeen Countries: Prospects for Future Competitive Access, National Telecommunications and Information Administration: U.S. Department of Commerce, May 1983, p. 11.
2/ "France Greets Fiber Optics With Opens Arms". Photonics Spectra, June 1987, p. 156.
3/ Ibid.

average in the U.S. market). 1/ The French expect to attain complete digitization of the local networks by the early 1990s. 2/ The use of fiber has been growing steadily since the beginning of the network. From 1983 to 1984, the General Telecommunications Management of the DGT ordered more than 40,000 km of fiber, and in 1985 sought bids for 20,000 km for both short-and long-haul applications. 3/ Although DGT officials were less certain than West German and United Kingdom officials concerning future purchases of optical fiber in France's telecommunications networks, they estimated that it would peak at 65,000 fkm in 1986 then subside to 40,000 fkm in 1989, before increasing again in the next decade (table 10-4). With respect to nondata optical fiber, a number of French firms have put fiber to use in a variety of applications ranging from sensors and measuring devices to fiber optic gyroscopes for aviation. 4/

Table 10-4
French telecommunications fiber consumption, 1984-90
(In fiber kilometers)

1984	1985	1986	1987	1988	1989	1990
40,000	20,000	65,000	45,000	45,000	40,000	85,000

Source: Interviews by the Commission with officials of the French Government, 1986.

Industry structure

The French optical fiber and cable industries, like those of West Germany and the United Kingdom, are highly concentrated. There are two producers of telecommunications-grade optical fiber: Fibres Optiques Industries (FOI), a joint venture of Corning Glassworks and Alcatel 5/, with capacity of 55,000

1/ Telecommunications Policies in Seventeen Countries: Prospects for Future Competitive Access, National Telecommunication and Information Administration. U.S. Department of Commerce, May 1983, p. 11.
2/ Commission interview with officials of France's Direction General de Telecommunication in Paris, France on Dec. 22, 1986.
3/ "France Greets Fiber Optics with Open Arms" Photonics Spectra, June 1987, p. 156.
4/ Ibid., and Commission conversations with U.S. embassy and French industry officials in and around Paris, France in December 1986. For example, according to industry sources, Souriau has developed robotic devices for handling fragile objects in a production environment. Electricite de France (EDF) reportedly has developed a fiber optic interferometer to measure current in high voltage lines and has used fiber for safety reasons in very high-voltage situations, control and instrumentation as well as disconnected switches and circuit breakers.
5/ Formerly Compagine General d' Electricite, which in 1986 merged with the U.S.-based ITT's telecommunications business to form Alcatel, the second largest telecommunications equipment manufacturer in the world after AT&T.

fkm per year, and Compagnie Lyonnaise de Transmission Optique (CLTO) with capacity of 25,000 fkm per year. 1/

The two major optical cable producers for telecommunications purposes are Cable d' Lyon with an estimated 45 percent of French capacity, and Societe Anonyme de Telecommunication with 35 percent. Submarcon, which belongs to the Alcatel group, is a major global producer of submarine cable. Another cable producer is Fort Fiber Optics, a manufacturer of specialty cables for the local area and data communications markets. Fort is also a manufacturer of nondata, specialty fiber optic components for the medical, industrial, and military markets. Corning because of its technology lead and French patents was able to establish joint ventures with Alcatel to produce optical fiber. In addition, two U.S. optoelectronic component manufacturers were able to make sales of lightwave transmission and detection equipment for use in several French fiber optics projects.

AT&T recently attempted to enter the French market by developing a partnership with the larger Netherlands based electronics firm Philips to purchase Compagnie General de Construction Telphoniques, or CGCT, which has approximately 16 percent of the French government market for high technology telecommunications equipment. The sale was part of the French Government's effort to privatize various industries. The AT&T-Phillips venture had worked for two years to expand European sales of AT&T technology, and, in late 1986, seemed to have the deal all but wrapped up. However, Siemens, the large West German electronics firm, subsequently entered into the competition with the AT&T-Phillips venture for rights to CGCT. U.S. government officials, including those of the Federal Communications Commission, (FCC) then reportedly entered the picture by applying pressure on RBOCs with respect to foreign procurement policies. 2/

Ultimately, France accepted a bid by the much smaller Swedish telecommunications (and optical cable) producer Ericcson to purchase CGCT. Although French officials cited other factors as reasons for its selection of Ericcson over the West German and U.S.-Dutch companies, a staff report to the U.S. Congress concluded that among other things the U.S. Government's attempts to apply pressure on France turned out to be counterproductive. 3/

France also has an internationally oriented optoelectronics industry. In addition to Alcatel (the large integrated manufacturer of telecommunications and lightwave equipment), Societe Anonyme d' Telecommunication (SAT) is also strong in the optoelectronics as well as optical cable segments of the market, concentrating much of its research and development on local-area and subscriber networks. Finally, Thomson is a major global competitor of such firms as Siemens, NEC, STC, Rockwell, and AT&T in the optoelectronics segment in the market.

1/ Official Journal of the European Communities, Aug. 22, 1986, p. 42.
2/ Charles Mason " Congress: Gov't Efforts to Aid AT&T in France Backfired," Electronic News, Monday, Oct. 12, 1987.
3/ Ibid.

Global market and government policy

The French Government and telecommunications authorities have provided extensive support for the development of a modern telecommunications infrastructure and industry. The Government has allocated research and development funds for work on advanced digital, including fiber optic systems.

The French PTT has also created programs for the development and use of fiber optics in both long distance as well as local-area-network applications. In fact, France is ahead of the rest of the world in terms of providing subscriber networks to the home. A total integrated services digital network (ISDN) 1/ is scheduled for completion by 1990. This will provide the means for expanding a wide variety of broadband services to French subscribers, including improved reception of broadcast television from Switzerland, Luxemburg and Monaco, as well as from their own country, a larger selection of cable television channels with stereophonic sound and French subtitles for foreign broadcasts, as well as a selection of services such as videotex, remote surveillance and meter reading. 2/

Unlike other major producing countries, France not only has plans for the implementation of future subscriber networks, but actually has several networks established in cities such as Paris, Biarritz, and Montpellier. For example, the government has experimented with subscriber fiber optic networks in Biarritz and the government has already installed 5000 fkm of optical cable around Montpellier. In September, it began connecting homes and offices to the digital network. 3/

The Paris Metro established a closed-circuit television system called tube in its subway in 1987. Tube is broadcast via a fiber optic network installed along the subway tracks. The initial phase utilizes 400 fkm of multimode optical cables. If tubes are extended to the 40 plus Paris metro stations as well as bus stations, the amount of optical cable used will be substantial. 4/

These public-sector initiatives have important implications for the French companies that have secured thefiber optic system contracts. For example, the French cabler SAT supplying the optical cables for the Paris Metro network hopes to profit from its experience in overseas metropolitan markets. "Already, subway operating authorities in Marseilles, Barcelona, and Mexico City have begun investigating the Tube idea. 5/ Many of the French projects have been undertaken from a long range point of view, hoping that high costs incurred today will provide French society with a modern telecommunications infrastructure as well as advanced high technology industries. For example, the program for developing a fiber optic subscriber network in Montpellier may not return profits for over a decade, according to one industry source.

1/ See app. F for the glossary of technical terms.
2/ Commission interviews with French industry and government officials in December 1986. See also, Howard Rausch, "French City Will Soon Bask In a Fiber ISDN Limelight, "Lightwave," June, 1987, p. 22.
3/ Ibid., p. 22.
4/ Jonathan Weber "Fiber Carries, TV to Paris Metro Station," Lightwave, June 1987, p. 77.
5/ Ibid., p. 77.

> At 130 francs (about $25), per year from each customer, of which 44 francs are to be turned over to the Telecommunications Authority, it will take about 45,000 customers to make the system profitable.
> But early return on the investment does not appear to be the authorities top priority. More important is the prospect of serving France with a modern, upgradeable telecommunications system that will be able to meet expanding needs far into the 21st century. 1/

In addition, the French telecommunications and fibers optics industries appear to be early beneficiaries of such government sponsored programs. 2/

Although the French telecommunications market like other European markets has been relatively closed to penetration by foreign companies, some U.S. companies have achieved limited successes.

Late in 1986, Compagnie General d' Electricite (CGE), in an effort to increase its access to major global markets for telecommunications equipment (including advanced optical fiber and related equipment), merged its operations with the related components of ITT's worldwide operations. Included in the merger were ITT's Electro-Optics Division in Roanoke, Virginia, ITT Transmissions Systems in Raleigh, North Carolina, and Cable des Lyon's American cable manufacturing subsidiary. In another move to increase sales to the U.S. market, LiTel, a regional Midwest fiber optic network was provided a $10.3 million loan guaranteed by the French Government to purchase optoelectronics and other fiber optic equipment from the Societe Anonyme de Telecommunication. 3/

Submarcom, a part of Alcatel's optoelectronic and cablemaking operations that produces undersea cable, competes with other major submarine optical cable producers, STC (United Kingdom), Simplex (United States), and Ocean (Japan). Submarcom is involved in short-range unrepeatered systems as well as long-range undersea projects in North Africa, Asia, as well as the TAT-8 submarine project that will connect the United States and Europe with the first trans-Atlantic optical fiber system.

U.S. and other European industry officials point out that French fiber optics companies like Alcatel and Submarcom receive support from their government, particularly in third-world markets. French firms allegedly benefit from so called "soft loans" (which combine foreign aid with low-cost financing for purchases of their systems). These loans help the French producers win business from other foreign suppliers, including U.S. firms, for major telecommunications projects.

1/ Rausch, op. cit., p. 22.
2/ For example, Velec, which had sales of only $33 million last year, has immediately become competitive in the fiber optics market with its Montpellier experience, and expects to establish market in the international market as a result. Ibid., p. 22.
3/ <u>U.S. Long-Distance Fiber Optic Networks: Technology; Evolution; and Advanced Concepts</u>, Information Gatekeepers, Inc.; October 1986, p. 124.

Italy

Market segments

The structure of the fiber optics market in Italy is affected by a telecommunications sector that is a "truly unique conglomeration of government organizations and private or quasi-private concessionnaires". 1/ Services responsibility of the telecommunications network is divided between the Ministry, Posts and Telecommunications (PTT) and the STET Group (Societa Finanziaria Telefonica p.a.) of quasi-private companies. Overall policy and regulation, and supervisory control is exercised by the PTT.

Italy integrated optical cable into its long distance backbone networks more slowly than the other three major European powers because it had already completed extensive installation of coaxial cable in the late 1970s and early 1980s. However, it represents a growing market; one trade report estimates the Italian market for optical cable in Italy will grow by 268 percent between 1985-1989 to $39.7 million. 2/ Telecommunications authorities have developed plans to install a total of 150,000 fiber kilometers of fiber optic cable for long-haul and local telecommunications networks. By 1986, the Italian fiber optic industry had produced 20,000 fiber kilometers, primarily for use in Italy (table 10-5). By the early 1990s, Italy plans to connect 21 cities with 2,300 kilometers of cable.

Table 10-5
Italian telecommunications fiber consumption, 1985-90

(In fiber kilometers)

1985	1986	1987	1988	1989	1990
5,000	15,000	25,000	30,000	35,000	40,000

Source: U.S. Government estimated.

In 1985, Italy installed its first submarine cable to connect San Salvador, Venice, with the Lido resort area via San Giorgio Island. This 4.7 kilometer optical cable link is used for data and voice communications and has been demonstrated in use as a "telebrary" data bank access system.

Italy has also initiated several programs to develop metropolitan area networks incorporating optical cable. A $5.3 billion Milan network was completed for the Milan Fair to provide telecommunications and video services such as video telephone and videotex. Also, interactive services and plans have been developed for a similar network in Rome in 1980.

1/ Telecommunications Policies in Seventeen Countries: Prospects for Future Competitive Access, National Telecommunication and Information Administration. U.S. Department of Commerce, May 1983, p. 123.
2/ IMR Profile, "The Italian market for Fiber Optics Equipment and Systems," for the U.S. Department of Commerce, May, 1987.

The Italian telecommunications authorities, through various procurement and pricing schemes benefiting local producers, have effectively closed the relatively limited optical fiber and cable market to foreign suppliers. Opportunities do exist, however, for optoelectronic transmission equipment. Important suppliers in this segment of the market have included U.S. and West German manufacturers of lightwave lasers. The Italian government, however, is currently funding programs to promote the Italian optoelectronic systems industry. 1/

The Italian medical and industrial manufacturing sectors also represent important markets for both data and nondata types of optical fiber, including computer-interconnect cables, fiber optic sensors, faceplates, and coherent and non-coherent bundles for use in illumination and image transmission, for both industrial and medical purposes. This sector of the market is not regulated to the extent that telecommunications is, and imports of such products have been made from the United States, West Germany, and Japan.

Industry structure

The Italian optical fiber and cable industry is very highly concentrated, with only one manufacturer of telecommunications-grade optical fiber, and five producers of optical cable, though there are a number of manufacturers of other types of industrial and medical-use fibers.

Fiber Ottiche Sud (FOS), a joint venture of the Italian cable maker, Pirelli s.p.a, and the Italian firm, Sirti s.p.a., is licensed by Corning to manufacture optical fiber. The following tabulation indicates FOS's growth in production and sales over the past 5 years:

Year	Production (fiber km) 1/	Sales (U.S. dollars)
1982	5,000	420,000
1983	10,000	850,000
1984	10,000	850,000
1985	20,000	1,700,000
1986	30,000	1,700,000

1/ Italian industry officials indicated to the Commission that FOS's capacity had grown to 45,000-50,000 fiber km by 1987 from about 35,000 fiber km in each of the previous several years. These officials expect FOS to increase its capacity to 70-80,000 fiber km by the end of 1988.

The two largest manufacturers of optical cable are the multinational power and telecommunications cabler Pirelli of Milan, and Turin-based CEAT CAVI. Together these two firms have slightly less than two-thirds of the Italian market. The other three producers of optical cable are Teleco Cavi, 15, Manuli S.P.A., and Nuova Fulcurcavi S.P.A. There are no manufacturers of plastic, or non-data fibers in Italy.

1/ "Italy Moves Ahead in Fiber Optics," Optical Engineering Reports, August 1986, p. 17A.

Pirelli s.p.a. of Milan, the world's largest manufacturer of power cable and one of the largest producers of telecommunications cable, with total worldwide sales of $4.7 billion in 1986, 1/ dominates the Italian market for optical cable and has extensive overseas manufacturing facilities in 12 countries in Europe, North America (including the United States and Canada), South America, Australia, and Africa.

In addition to manufacturing optical cable for the Italian market, Pirelli also has several major optical cable contracts in the U.S. Regional Bell Operating Company (RBOC) market and claims that optical cable sales for the 1987 fiscal year will give the company 5 to 8 percent of the United States telecommunications cable market. 2/ Up until the present time, Pirelli has supplied most of its U.S. customers through exports from its Milan-based as well as Canadian cable-making facilities, but opened its first U.S.-based optical cable plant in Columbia, South Carolina, in 1986. In 1985 and 1986, Pirelli cable sales in the United States consisted of mostly long distance and feeder networks to such customers as U.S. West and Ameritech. However, in the spring of 1987, it signed its first RBOC contract with the Nynex Corporation to supply optical fiber cable products for subscriber loop applications. According to one Pirelli company official:

> ... the company is securing the RBOC business at the expense of competitors other than AT&T or Siecor," but he would not be more specific. He noted that, unlike AT&T and Siecor, Pirelli, "for a different flavor," is able to rely on cabling plants outside the U.S. from which to augment its 65,000 square-foot Lexington, SC, facility. 3/

Worldwide, Pirelli Cable Corp. has 11 fiber cabling plants, including a second North American facility in Surrey, B.C., Canada, which also supplies the U.S. market. Other important markets for Pirelli are the United Kingdom, and France. Through it has production facilities in the United Kingdom, it supplements its production there with imports of cable from its Milan facilities. It also manufactures optical fiber in that country under license from Sumitomo, thus making Pirelli the only global cabler with licensing relationships with both U.S. and Japanese fiber makers. In the difficult French market, Pirelli was able to qualify itself with French telecommunications authorities early on for installation of multimode fiber cables because "its cables were made better than French cables," according to the Italian industry sources. 4/

Pirelli also has important markets for optical cable in African countries and in South America where historical relationships were developed in the nineteenth century when Pirelli started in business as an owner of rubber plantations. Though Pirelli officials indicated that Argentina is developing as an important market for Pirelli exports, Brazilian government officials

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1/ "International Corporate Scoreboard," Business Week, July 20, 1987, p. 142.
2/ S. Scully, "Pirelli Scores Two RBOC Contracts, Claims 5% Share of U.S. Cable Market," Lightwave, Sept. 1987, p. 52.
3/ Ibid.
4/ Interviews by the Commission with Italian industry officials Milan, Italy, September 1987.

hope to develop that nation's own industrial capability in fiber optics. Accordingly, Pirelli has worked with Brazilian officials to develop turn-key manufacturing establishments for that country.

In the Italian market, in addition to supplying over 40 percent of that nations's long distance telephone cable needs, Pirelli has made significant sales to railroad companies which are establishing telecommunications systems for their own internal needs. It also has established contracts with power transmission authorities to produce over-power-ground-wire-cables. This is a natural business for Pirelli to be in because of its extensive experience as the world's largest power cable producer. It even contracted with the State Power Company of the Isle of Elba to produce a submarine power cable containing 12 optical fibers. Two of the 12 fibers are being leased by SIP, the Italian telecommunications services provides, for regular telecommunications purposes and the remaining ones are for the power authority network. 1/

Pirelli is also a partner in the FOS joint venture for manufacturing optical fibers under license from Corning Glassworks. Pirelli is the only European licensee of Corning not to have developed a joint venture with Corning itself. Pirelli also manufactures optical cable in Spain and Australia. (Pirelli is licensed by Sumitomo to produce optical fiber in the United Kingdom). In Mexico, Pirelli manufactures optical cable only, which it supplements with Italian made exports. Under the Corning licensing arrangement, FOS may not make direct sales of optical fibers to the United States, though Pirelli cables containing such fibers may be and are in fact exported there. FOS-manufactured fibers are sold directly into other European markets such as France, the United Kingdom, Canada, and to some South American and African markets.

FOS is also the supplier of optical fibers to the other four Italian producers of cable. The Italian government has a pricing and rebate scheme which allows cablers who purchase Italian-made (FOS) fiber to benefit from a premium over the average European price for fiber (using the United Kingdom producer Optical Fibres as the price-leader). Thus, although Italian cable producers are theoretically permitted to purchase fiber from foreign suppliers, it is not in their economic interest to do so. 2/

Pirelli has substantial financial resources behind its global operations. The group structure of the company is based on two holding companies and an investment company. 3/ Total research and development expenditures of the Italian optical fiber and cable producers amount to about 11 percent of sales. 4/ Government funding of fiber optics research is

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1/ Ibid.
2/ Ibid.
3/ The first two are Pirelli S.P.A., based in Milan, Italy, and Societe International Pirelli S.A. (SIP) of Basel, Switzerland. The Investment Company is Pirelli & C, also based in Milan, which owns about 18 percent of the two holding companies. Pirelli S.P.A. and SIP have equal shareholding interests in the various subsidiaries of the Group and in Pirelli Societe Generale S.A. of Basel, a company set up in 1982 and to which the management of Pirelli's worldwide industrial operation has been delegated.
4/ U.S. Embassy telegram, Rome, Italy.

conducted at the advanced research center for electronics and telecommunications of the STET group. In addition, Italian fiber optic companies are active in European cooperative advanced research and development programs such as RACE, ESPRIT, and EUREKA.

Global market and government policy

The Italian government would like to strengthen Italy's competitiveness in the optoelectronics sector of the fiber optics industry by integrating the activities of the relatively strong telecommunications optical cable segment and the weaker optoelectronics sector. The STET group of telecommunications companies includes two important firms with activities related to optoelectronics, these include Selenia SGS-ATES (semiconductors), and Italtel (telecom equipment). The group's telecommunications investments for the period of 1985-88 are programmed at 10,000 billion lire (approximately $11.4 billion (U.S.)). This investment is equivalent to the total amount invested during the previous 15 years.

The Italian telecommunications authorities and government are also advancing programs to develop new services such as teletex, video teleconferencing, and videotex to both modernize Italy's telecommunications infrastructure and also to help advance its telecommunications (including fiber optics) industry. The Italians are moving towards the integrated services digital network (ISDN).

> Their concept envisions a rather all-encompassing intelligent network. There are no plans to de-regulate the value-added portions of their network. 1/

Pirelli's activities to adjust to competitive pressures are related particularly to its overseas markets. Its officials indicate that it will continue to do whatever it has to do to develop its overseas market share, including increasing manufacturing capacity when necessary or desirable from an economic viewpoint. It will particularly emphasize, in addition to the large U.S. market, such developing markets as Africa and South America in which it already has established itself as a major telecommunications supplier. These markets represent tremendous future opportunities where development of planned telecommunications infrastructures will utilize enormous quantities of optical fiber and cable.

Pirelli officials also indicated that they also would like to reduce the dependence of its FOS fiber producing venture on Corning licenses. Pirelli officials stated that they will not necessarily continue their licensing agreement with Corning once its current term ends after the expiration of important Corning patents in two years. 2/ The officials point out that even if they do decide to renew a relationship with Corning, Pirelli will be in a much better negotiating position than they were before. Without the restrictions its FOS venture faces in exporting fiber to the important U.S

1/ Op. cit., Telecommunications Policies in Seventeen Countries, p. 133.
2/ Interviews by the Commission with officials of Pirelli, at the company's headquarters in an Milan, Italy on Sept. 7, 1987.

market, Pirelli would consider expanding its fiber manufacturing operations to become a supplier to that market as well as its well established position as a leading global supplier of optical cable.

Netherlands

Market segments

The Netherland Posterijen, Telegrafie, en Telefonie (PTT) is a "quasi-autonomous state body "responsible for the installation, maintenance, and management of an undivided public telecommunications infrastructure, providing telecommunications and postal services. 1/ According to Government officials, the PTT is in the process of opening up telecommunication equipment procurement procedures to more outside (including foreign) bidding in an attempt to stimulate competition for its traditional suppliers as well as to lower the costs of services to the public. 2/

Domestic demand for optical fiber and cable in the Netherlands long distance market is quite limited because of the fairly short distances between borders. Consequently consumption of optical cable has only amounted to from 1000 to 1500 kilmeters per year (table 10-6). Because of the density and above average prosperity of its population and industry, future demand in local area networks and subscriber links to the household should be significant, but not until after the beginning of the next decade. Support for fiber optic systems development is expected to come from the Government and the private sector.

Table 10-6
Netherlands telecommunications fiber demand: In fiber kilometers (fkm)
1985-1989

1985	1986	1987	1988	1989
1,000	1,000	2,000	5,000	4,000

Source: Netherland Postterijen, Telegrofie, on Telefonie (PTT).

In the past, the PTT procurement policy was directed toward Netherland's own electronic and cable companies, However, recently, U.S. suppliers of optical fiber and cable such as AT&T and Spectran have benefited from some PTT decisions to procure some fiber and cable from foreign suppliers, despite the fact that Philips is one of the worlds' largest manufacturers of optical fiber

1/ Telecommunications Policies in Ten Countries: Prospects for Future Competitive Access, National Telecommunication and Information Administration. U.S. Department of Commerce, March 1985, p. 111.
2/ Interview by the Commission with officials of the Netherlands Posterijen, Telegrofie, and Telefonie (PTT), and officials of the Department of Economic Affairs during September 1987.

and has sufficient optical fiber capacity of its own. 1/ PTT officials also indicated that for the sake of competition they would also be considering bids from U.S. and foreign suppliers of optical fiber as well as optoelectronic and other telecommunication transmissions equipment in the future.

Industry structure

The Netherlands optical fiber and cable industries, like those of the other major European producer countries, is highly concentrated. N. V. Philips is essentially the only manufacturer of optical fiber in the country. Its manufacturing capacity of 80,000 fiber kilometers in 1986, ranked it as the second largest in Western Europe at that time, though there are indications that the Corning-Siemens (Siecor) and Wacker-Chemie-Sumitomo joint ventures in West Germany may now in 1987 have capacity approaching or even exceeding that of Philips. 2/ Although there are several manufacturers of optical cable in the Netherlands, the bulk of the optical cable produced for the PTT's needs (approximately 80 percent) is manufactured by the largest Netherlands cable maker, NKF.

Philips, which is one of the largest electronics and electrical equipment manufacturing firms in the world, with 1986 sales of over $22 billion, is also a major producer of optoelectronic component systems used in fiber optic systems. 3/ In addition to long wavelength laser systems used for long distance telecommunications, Philips also produces small laser packages for compact disk systems that some industry experts believe may replace light emitting diodes in future local area network and loop applications.

Philips initiated research on optical fibers in the early 1970s. 4/ Rather than using Corning's OVD or AT&T's MCVD processes, the company developed their own plasma process (PCVD) that overcomes the problems of the others primarily in the energy exchange process in manufacturing the preform, that permits the heat used for the chemical vapor deposition process to be generated by a microwave reasonator rather than by flame (See Chapter 3). Philips scientisits believe this technology will eventually lend itself to continuous manufacturing processes for making optical fiber at substantially lower costs. Philips now has fiber making capacity that is among the highest in the world outside of the United States.

Philips believed its optical fiber and fiber manufacturing technique to be different enough from Corning's to permit it to sell its fiber in the United States without violating Corning's patents. However, Philips apparently decided it would not be worth the time and expense to fight Corning's challenges. Accordingly, they sold Philip's U.S. venture, Valtec,

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1/ Interviews by the Commission with U.S. and West European industry and government officials during fieldwork in 1986 and 1987.
2/ Based on estimates contained in Official Journal of the European Communities, Aug. 22, 1986.
3/ Philips' revenues make it the 11th largest sales leader in the world outside of the United States, "International Corporate Scoreboard, Business Week, July 20, 1987, p. 137.
4/ Interviews by the Commission with officials of N. V. Philips in Eindhoven, the Netherlands on Sept. 9, 1987.

to ITT, 1/ and thus settled their differences with Corning. Philips obtained a limited license in Europe from Corning, that has permitted Philips to develop partnerships with several major optical cable producers in Europe. Only passive sales of its fiber (that contained in cables manufactured by its partners) may be made to the United States under terms of the agreement.

Although Philips does not manufacture optical cable in the Netherlands, it does have a major interest in Philips Kommunication Industries, one of the largest copper as well as optical cable manufacturing companies in Western Europe (See previous section in this chapter on West Germany). Philips exports a substantial amount of its optical fiber to West Germany for this operation as well as supplying it to the Netherlands cable market.

Philips not any manufactures complete laser transmisson systems, but also produces components such as integrated circuits, and other active components in its discrete semiconductor group, as well as other passive components, many of which are used in fiber otic systems. About two-thirds of its $5 billion sales from this segment of the company are made to other system producers throughout the world, while one-third are made to Philips itself for various optoelectronic systems including fiber optic devices and systems.

The PTT is increasingly relying on private-sector initiatives to enhance the competitiveness of the Netherlands telecommunications and fiber optics industry, which consists largely of the activities of Philips.

Because Philips business was confined more to electronics, as opposed to telecommunications equipment and systems compared to other large players in the global market, it decided to develop a partnership with AT&T, to market telecommunications and other switching and transmission products for sales in Europe, Africa, South America, and Asia. By the end of 1986, the venture had received three major contracts to provide digital transmission and switching systems in the Netherlands, the United Kingdom, and Indonesia. 2/ Philips officials indicated that the new venture's entry into markets should benefit both AT&T's and Philips' fiber optic, as well as other segments of their telecommunications and electronic businesses, in short, making the Netherlands fiber optic industry more competitive in the international market.

Scandinavia

Due to the relatively small populations of the Scandinavian countries, the market for fiber optics is somewhat limited, though fiber optics is increasingly being given importance in the plans of the PTTs of Sweden, Norway, Denmark, and Finland. Denmark, in fact, had the highest per capita fiber optics expenditures in the world in 1986. 3/ In addition, Scandinavian

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1/ IT&T has since merged its optical fiber and cable operations, as well as its other telecommunications equipment business, with those of the French Compagnie General de Electricite to form a new telecommunications equipment concern named Alcatel. Alcatel is now the second largest telecommunications equipment firm in the world after AT&T.
2/ AT&T-Philips Venture Names a President," Lightwave, August 1986, p. 32.
3/ Kessler Marketing Intelligence Newsletter, December 1986.

PTTs tend to be more open to foreign suppliers than are those in other European countries such as West Germany and France. 1/

Fiber optic sales to the Swedish market will be about $25 million in 1987, of which approximately 60 percent will be accounted for by optical cable, according to estimates by U.S. embassy sources. 2/ The Swedish market for datacom cable will reach about $600,000 according to these sources. The Swedish PTT, Televerket, is the major customer for telecommunications cable, though private banks and firms are primarily responsible for purchases of optical fiber and cable for data communications purposes.

Norway is in the process of establishing an extensive fiber optic network, connecting 850 sites, that will be one of the world's largest private optical fiber networks. 3/ The Government Telecommunications Authority of Norway (Televerket) consumed about 2,800 fiber kilometers of optical cable, valued at $2 million, in 1985; and 3,300 fiber kilometers, valued at $2 million, in 1986. Purchases in 1987 are expected to drop in quantity and value by about 20 percent since major trunklines have been completed in Norway. Other domestic Norwegian customers of optical cable, primarily for datacom applications, include the Department of Defense, the State railways, and offshore petroleum companies.

The Scandinavian optical fiber and cable industry is limited to a handful of firms. In Sweden, Ericsson Fiber Optics, subsidiary of a major Swedish telecommunication equipment producer of the same name, is believed to account for 70 to 80 percent of Swedish domestic production of optical fiber and cable, including almost all long distance telecommunications optical cable. Two other manufacturers, Asea Optocom and Fiber Data AB, account for most of the remaining optical cable production, aimed primarily at the Swedish datacom market. Asea, along with Ericsson, is also an important manufacturer of lightwave optoelectronic devices, including lasers, LEDs, and detectors.

Ericsson, whose total company sales in 1986 were over $4.4 billion, has been an important telecommunications-equipment supplier to European and, now, the U.S. markets. In addition to its optical fiber and cable operations, Ericsson is involved in total fiber-optic-system production and development, including the manufacture of lasers, detectors, and connectors. Asea AB, though only a minor producer of optical cable, has also become involved in the manufacture of lightwave transmission equipment.

Norway has three manufacturers of optical cable: Standard Telefon OG Kabelfabrik, Norsk Fiberoplikk, and Norsk Elektrisk Kabeltubriek AS. There is no optical fiber production in Norway, however. Aggregate 1985 Norwegian output of optical cable in 1985 was 3,500 fiber kilometers valued at U.S. $2.4 million, of which glass single-mode cable accounted for 90 percent of total production. 4/ The United States and Japan supply the bulk of Norwegian imports of optical fiber, though fiber has also been supplied to the market from the United Kingdom, and the Netherlands, too.

1/ Interview by the Commission with officials of U.S. Embassy, Stockholm, Sweden, Sept. 1, 1987.
2/ Telegram dated Mar. 4, 1987 from U.S. Embassy, Stockholm, Sweden.
3/ Communications Week, Apr. 20, 1987.
4/ Telegram dated Mar. 19, 1987, from U.S. Embassy (Oslo, Norway).

Ericsson, Sweden's primary manufacturer of fiber optic systems depends primarily on Corning technology for the manufacture of its optical fiber. It has its own technology for producing optical cable. 1/ Sweden's Kabelmatik is a major world producer of telecommunications cable, including optical cable manufacturing equipment, and its equipment may be found not only in various foreign plants, but also in major U.S. cable manufacturing sites.

Although Finland, is a minor producer of optical fiber, the country traditionally has been an important manufacturer of cabling equipment. The country now manufactures optical-cable-production machinery for both European and U.S. markets. Nokia, a Finnish firm, with significant sales in the U.S. market, has recently created a total optical-fiber and cable-making system that includes preform-manufacturing equipment, fiber-drawing towers, fiber stranding and jacketing lines to form optical cables, and rewinding, and proof-testing lines. The modularly designed system permits a continuous process of manufacturing optical cable from preform to finished product. Nokia, recently (1986) purchased a majority of the shares of an Austrian cable machinery manufacturer, Rosendahl Maschinen GmBH to reinforce its lead in the global cable machinery market. In a related development, Nokia indicated it would merge with Mailleter SA of Ecablens, Switzerland, following approval by the Finnish and Swiss governments. More than 90 percent of the equipment of all three of these firms is exported. 2/

Other (including Eastern Europe and the Soviet Union)

Smaller markets in Western Europe rely almost entirely on imports of optical fiber, though limited optical cable production capacity exists in countries such as Austria, Switzerland, and Spain. These countries import their optical fiber primarily from Western Germany, and other Western European countries, though U.S. firms have also exported to these markets.

Although Corning Glassworks formed a joint venture, Telcor, with the Spanish Telefonica Nacional de Espana to manufacture up to 60,000 fiber kilometers of optical fiber per year by the last quarter of 1988, plans are reportedly on hold due to the global downturn in fiber demand during the past year. 3/ Nevertheless, the Spanish market for optical fiber, and cable is expected to experience good growth over the next several years as Spanish telecommunications authorities start to upgrade and expand Spain's telecommunication's infrastructure. Officials of another U.S. manufacturer, interviewed by Commission staff in London in December 1986, indicated that their company was planning to establish optical fiber production capacity in Spain; however, those plans are also reportedly on hold, according to West European industry officals.

Official Soviet data have been difficult to obtain. Industry analysts estimated in 1986 that the Soviet Union produces at most 200,000 kilometers of optical fiber annually. 4/

1/ Telegram dated Mar. 4, 1987, from U.S. Embassy, Stockholm, Sweden.
2/ Lightwave: The Journal of Fiber Optics, October 1987, p. 62.
3/ Telgram dated Feb. 27, 1987 from U.S. Embassy in Madrid, Spain and interviews by the Commission with West European industry officials during December, and August and September 1987.
4/ "Soviet Fiber Output Estimated at 200,000 fiber-km a year," Lightwave, March 1986, p. 1.

> Most of this is for military applications, with lightwave links in place in only a few cities, including Moscow, Leningrad and Grorki. Most manufacture uses modified chemical vapor deposition, the preform fabrication technique used by AT&T and others. But there's growing interest in the vapor-axial deposition process promoted in Japan. Manufacture is slow, fiber losses are high, production yields are low and quality control is poor by Western standards. 1/

In 1986, the Soviet Union disclosed plans to construct a 600 kilometer long distance communications network linking Leningrad with Moscow. 2/ The network was to be built using the railroad right of way for the rail line between those two cities. Although the system's completion date was not disclosed, officials did indicate that it was to be entirely digital. 3/ Unlike long distance networks built over the past several years in the United States, Western Europe, and Japan, the Soviet system will reportedly use graded-index multimode fiber. The system is expected to operate at much slower speeds than systems installed in the United States.

Poland is reportedly developing fiber optics technology of its own. However., given the political climate in Eastern Europe, it seems unlikely tjat a system for all of the Eastern European countries will be developed. 4/ Polands' fiber optic research is centered at the Technical University of Warsaw at the Institute of Electronics Fundamentals and Optronics, and at the Technical University of Lublin, 100 miles away. Two main Polish manufacturers are now operating fiber making plants. A factory in Lubin produces single mode fiber and experimental fibers. Glassworks of Bialystok also produces singlemode fiber. 5/

Canada

Market Segments

The Canadian telecommunications environment consists of a complex mixture of federal and provincial legislation, policies and regulation. Unlike the situation in many countries where there is a nationally controlled Post, Telephone and Telegraph (PTT) organization, the Canadian telecommunications services industry consists of a mixture of private, government, and joint private-governmental corporations and organizations. These are usually regulated by a single federal or provincial regulatory agency.

1/ Ibid., p. 1.
2/ "First Long Soviet Net Will Be Fully Digital On Multimode Fiber," Lightwave, June, 1986, p. 8.
3/ Ibid., p. 8.
4/ John Kreidl, "Poles Wait 15 Years for Phones But Look to Fiber Optic Future." Lightwave, December 1986, p. 21.
5/ Ibid., p. 21.

> This blend of private and public systems with centralized government planning is uniquely Canadian and has led to a rapid growth in the Canadian network to the point where Canada is second only to the United States in telephones per 100 population. 1/

In Canada, there are two national telecommunications systems: the TransCanada Telephone System (TCTS) and CNCP Telecommunications, which together account for 93 percent of the telecommunications carriage market. TCTS is an unincorporated association of the largest telephone company operating in each province plus Telesat Canada, the domestic satellite carrier. Bell Canada, which operates in Ontario and Quebec and is the largest member of TCTS, is owned by a large group of mainly Canadian shareholders and has significant direct and indirect equity interests in the principal telephone companies in each of the Atlantic provinces. The British Coumbia Telephone Company, the second largest telephone company in the country, with approximately 11 percent of the telephones, is indirectly owned by U.S.-based General Telephone and Electronics Corporation (GTE). Telesat is owned jointly by the federal government and by the major common carriers. 2/

Saskatchewan Telecommunications, which is owned by its provincial Government, developed and installed a 3,300 kilometer fiber optic network which links 52 communities in the province. In addition, it is adding 800 additional kilometers; this segment will be completed next year. The cable and optoelectronic equipment for this network was provided by the Canadian telecommunications equipment supplier, Northern Telecom. A $20 million link between Edmonton and Vancouver was completed by the other Canadian optical cable producer Canstar in 1987. Other major purchasers of optical fiber and cable in Canada are the two major railroads as well as Ontario Hydro and Manitoba Power which have purchased fiber optic turn key systems and local area networks from Canstar.

U.S. optical fiber and cable manufacturers as well as other telecommunications equipment manufacturers view Canada as a fairly closed market:

> The largest operating company, Bell Canada, owns a captive supplier that supplies the vast majority of Bell Canada's requirements. In addition through strategic placement of its facilities, [its supplier] Northern Telecom has been able to secure a substantial percentage of the provincial operating companies' procurement budgets. 3/

These views are supported by a decision of the Canadian Radio-television and Telecommunications Commission (CRTC), that the Canadian government actually sanctioned differential pricing between the domestic and foreign markets. "In

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1/ Telecommunication Policies In Seventeen Countries; Prospects for Future Competitive Access, U.S. Department of Commerce, NTIA Contract Report (NTIA; CR 83-24), May 1983, p. 71.
2/ Ibid.
3/ "Comments of Siecor Corporation on the Probable Economic Effect of the Proposed "United States-Canada Free Trade Negotiations" Before the U.S. International Trade Commission, Sept. 19, 1986.

essence, the CRTC permits the transfer price for telecommunications equipment between Northern Telecom and Bell Canada to be higher in Canada in order to encourage export sales." 1/

U.S. industry also alleges that the Canadian government has publicly encouraged the private sector to "Buy Canadian" in telecommunications equipment purchases. This fact was recognized by the office of United States Trade Representative (USTR) in its announcement in the Federal Register of the opportunity for public comment on the proposed U.S.-Canada Free Trade Area. USTR stated:

> Canada's Federal "buy national" policy discriminates against foreign suppliers in areas not covered by the Government Procurement Code. Canada's telecommunications and transportation agencies and utilities generally follow strict "buy national" policies. Products affected include telecommunications.
>
> Provincial government "buy local" practices are implemented through procurement, content, and origin regulations. 2/

Notwithstanding these practices, the U.S. optical fiber producer, Corning Glassworks has been able to develop a licensing relationship with Northern Telecom, to produce optical fiber. However, Northern Telecom is required under the license to purchase substantial amounts of optical fiber made by Corning in the United States, for incorporation into Canadian optical cable destined for the United States. Because much of the Canadian-manufactured optical cable supplied to the United States contains U.S.-made fiber, such cable exports also benefit from the provisions of section 807 of the Tariff Schedules of the United States, which exempt from duty the portion of the value of an imported item that is produced in the United States.

Industry Structure

The Canadian optical fiber and cable industry is highly concentrated. Northern Telecom is the only Canadian company with domestic optical fiber capability. Three major producers of optical cable, Northern Telecom, Canstar (owned by Canada Wire and Cable), and Pirelli Canada Inc., a subsidiary of the Italian-based multinational telecommunications equipment supplier, account for well over 90-percent of total Canadian production of cable.

Northern Telecom is considered a world leader in telecommunications and data equipment manufacturing. 3/ In 1985, the company had total sales of

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1/ Ibid.
2/ 51 Fed. Reg. 25, 157, 25, 140 (1986).
3/ Northern Telecom Ltd. was established in 1914 as a subsidiary of Western Electric Company and Bell Canada. In 1956, Western Electric and Bell Canada were separated under the terms of a consent decree arising out of anti-trust enforcement litigation between the United States Department of Justice and AT&T, a wholly-owned subsidiary of Bell Canada. As of January 3, 1986, Bell Canada Enterprises, Inc. held 52 percent of Northern Telecom's common stock. Bell Enterprises also owns Bell Canada which is a major customer of Northern Telecom.

$3.2 billion and profits of $225.4 million. 1/ In that year, the U.S. market accounted for well over 60 percent of Northern Telecom's total revenues. Though, Northern Telecom, through its U.S. subsidiary, has extensive telecommunications equipment manufacturing facilities throughout the United States, all optical cable sold by the company in the U.S. market is manufactured in Canada.

Northern Telecom is a fully-integrated supplier of telecommunications equipment, producing switches, multiplexers, as well as all types of optoelectronic transmission, receiving, and connecting equipment. It thus dominates the Canadian fiber optics market, "with a 75-percent overall market share," according to a recent industry analysis. 2/

Pirelli Canada, the subsidiary of the Italian-based multinational telecommunications and power company, was used as a conduit by Pirelli for exporting optical cable to the growing U.S. RBOC market after the 1982 AT&T breakup (see Chapter 5). However, the opening of a new optical cable manufacturing facility in Lexington, South Carolina should limit future sales of Canadian-made cable by Pirelli to that market.

Canstar has developed important contracts in the Canadian railroad and power company network market, and has achieved particular expertise in the data communications and local area network sector of the market. Canstar has also exported to the United States. Company officials indicate that they purchase the optical fiber for their cables from "Corning or licensees such as AT&T-whoever has the most competitive pricing." 3/

Global Market and Government Policy

Northern Telecom is expected to remain a major player in the U.S. telecommunications market. The share of its total revenues from sales to the United States rose from 41 percent of total revenues in 1981 to 67 percent of total revenues in 1986. 4/ The corporate structure of Bell includes, in addition to Northern Telecom, Bell Northern Research which receives an estimated 10 percent of total Bell Enterprise sales (Northern Telecom and Bell Canada) for extensive research and development of advanced telecommunications equipment, including fiber optic transmission and receiving equipment, as well as multiplexers, switches, and connecting equipment. Northern Telecom's strength in fiber optics is in its hold on an estimated 10 percent of the U.S. optical cable market, its extensive service facilities there, and its position as one of the world's largest integrated manufacturers of telecommunications equipment. Though sales of optical cable have fallen off considerably in the U.S. market during the first six months of 1987, Northern Telecom's increasing presence in the U.S. market, where it has extensive manufacturing and service facilities in almost each state, almost assures it of a significant portion of

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1/ "International Corporate Scoreboard," Business Week, July 20, 1987, p.52.
2/ Mike Edwards, "Fiber Optics Revolutionizing Telecoms", Electronic Times, August 1986, p. 17.
3/ Ibid., p. 17.
4/ Northern Telecom Limited, Securities and Exchange Commission Form 10-K (1985) at 1 (herein after "NTL 10 K").

future local area network and subscriber network markets, according to industry sources.

Canstar is also expected to benefit from the growth in local area network applications expected during in the next decade in Canada and the United States, with its experience in this area of the market. According to industry sources, there are 40 companies involved in fiber optics in Canada producing "everything from passive components and optical fiber splitters to gallium arsenide, ICs, and FO multiplex terminals". 1/

Canadian officials estimate that U.S. business accounts for about 80 percent of their fiber optics sales. 2/

> "Canada" says one photonics company executive "just does not have a strong high-tech consumer marketplace. That's not to say we have no market here. It just isn't very large; about 20 percent of sales. 3/

For this reason, the Canadian industry will continue to focus its marketing efforts on the U.S. market. Because of the Canadian industry's extensive dependence on the U.S. market for the bulk of its sales, the recent slowdown in this market has adversely affected the Canadian industry. Thus, industry officials believe that the largest growth market for fiber optics may be in the developing countries. Northern Telecom, with its extensive array of telecommunications products and services. is expected to enlarge its global presence. Various industry officials indicated that Northern Telecom had the potential to be a major competitor in the international market, given its ability to compete with other major integrated manufacturers of telecommunications equipment such as Sumitomo, AT&T, and Siemens. 4/

Japan, Asia, Australia

The Pacific Basin countries 5/ currently form the third largest market for fiber optic systems. Because of the rapid economic development underway in many of these countries and the strong economic growth projected for the developed countries in this group, these countries are expected to continue to constitute the third largest market for fiber optic systems and products over the next 5 years.

The development of the market for fiber optic products has followed a pattern similar to that found elsewhere in the world. The primary use of fiber optic systems has been for long-distance telecommunications; other applications include shorter, urban telecommunications links, military-tactical systems, LAN's, industrial control systems, sensors, and

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1/ Dudley R. Bahlonan "Photonics in Canada", Photonics Spectra, May 1986, p. 97.
2/ Ibid., p. 100.
3/ Ibid., p. 100.
4/ Interviews by the Commission with Western European industry officials in the United Kingdom, France, and West Germany, during December 1986.
5/ These countries include Australia, New Zealand, the Philippines, Malaysia, Indonesia, Singapore, Thailand, the Peoples Republic of China (China), Hong Kong, Taiwan, South Korea, and Japan.

medical equipment. In addition, the use of optical fiber in aircraft, automobiles, and trucks for data transmission as well as illumination is being examined. Of the countries included in this region, seven stand out either because of industry and/or market characteristics, and will be highlighted in the sections that follow. These include: Japan, Australia, New Zealand, China, Taiwan, Hong Kong, and South Korea.

The development of the Japanese market and industry is significantly ahead of that of other countries in the region. Thus, in the section that follows particular attention is paid to Japan. Areas that are evaluated include production, research and development, and recent changes in the structure of the Japanese market for fiber optics products. In addition, the role that the Japanese Government has played and continues to play in determining and sustaining the development of the fiber optic and optoelectronic industries is examined.

Early in the time period under evaluation, Japan had a technological lead in certain areas of the optoelectronics industry. As various researchers predicted, the country has continued its advanced research programs and has broadened its lead in optoelectronics and fiber optics. 1/ As Japan's optoelectronic and fiber optic industries are the primary challengers of those in the United States, Japan's continued progress in these fields is of particular importance in assessing the international competitiveness of the U.S. industry.

Korea and Taiwan are also examined in detail. Industry analysts have predicted that the fiber optic industry of both countries will follow the precedent set by the electronics and computing industries in each country, and develop much in the same way as the Japanese computer, electronics, and fiber optic industries. Whereas neither country is considered a major presence in the international market at present, both Korea and Taiwan have adopted policies designed to facilitate and promote the development of a fiber optic industry. 2/ Currently, both countries have companies that are producing at least minimal amounts of optical fiber and cable. What is of particular interest in both countries is not the size of the market for fiber optic systems over the next few years; rather, to the extent that productive capacity exceeds the size of the market, the planned development of export markets for these countries is of greater concern. Other areas that are evaluated below include how technology-transfer agreements and existing patents have limited the ability of these companies to participate in the international market, and what the result of the termination of these agreements and the expiration of important patents that are scheduled in the early 1990s will be with respect to the structure of the international market.

1/ The following reports have documented areas in which Japanese research and development efforts are ahead and/or are gaining ground: JTECH Panel Report on Opto- & Microlectronics, Science Applications International Corporation, La Jolla, CA, May 1985; JTECH (Japanese Technology Evaluation Program) Panel Report on Telecommunications Technology in Japan, Science Applications International Corp., La Jolla, CA, prepared for National Science Foundation, May 1986.

2/ Commission interviews with U.S. and Korean Government officials in korea and Japan, August 1987.

Another area of particular interest is the Australian-New Zealand market. In terms of size, Australia and New Zealand currently constitute the fourth largest market for fiber-optic telecommunications systems in the world. On the supply side, New Zealand is not a factor, as it does not have a fiber optics industry at present. The Australian Government, however, has made a concerted effort to promote the development of local industry, using direct and indirect methods. The result is an optical fiber and cable industry capable of meeting local demand and potentially of competing with other international suppliers in the global market. The Australian industry is also of interest in that the Australian Government, through Telecom Australia, has done much to foster the development of the fiber optic industry. Australia's harsh climate and geographic size makes it an obvious market for fiber optic systems; and, the government's policies to encourage industrial development and the country's research and development capabilities give it a potential edge in the development of an industry capable of competing in the international market. 1/ One example of the degree to which the Australian market for fiber optic systems has developed is Telecom's plan to introduce the first stage of ISDN, setting its own standards (in conjunction with existing international standards), and therefore influencing the telecommunications equipment industry that supplies the telecommunications authority. 2/

In addition, the market provides an example of why the U.S. industry has enjoyed mixed success competing with Japanese and European manufacturers in foreign markets. Australian industry officials contrasted the U.S. industry's unwillingness to manufacture products in compliance with Australian specifications with the Japanese industry's willingness to produce according to Australian standards. 3/

Other countries and territories in the region make up a growing and increasingly important market for fiber optic systems. Developments in Hong Kong Telephone's transformation of its telephone network to optical fiber from

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1/ Aside from government purchases of fiber optic systems (primarily through Telecom), there are other goverment "mechanisms" that help to further the development of the optical communications industry in Australia. The mechanisms include offset agreements and grants for research, development, and marketing. Other less direct aids include taxation concessions, tariffs or export incentives. E.R. Cawthorn and J. Felsinger, Optical Communications and Fiber Optics: Australian Capabilities and Opportunities, Volume 1 (Executive Summary and Principal Findings), Department of Industry, Technology, and Commerce, Government of Australia, October 1985, p. 14. The report also evaluates Australian research and development activities. Although, the report identifies a comprehensive R&D base in Australia, it notes that there are problems in this sector; in particular, the authors suggest that there is a need "to encourage greater collaboration between the private and public sectors in R&D and encourage greater industry participation in such activities. Telecom and OTC have a vital role to play here." p. 11.
2/ Collyn Rivers, "Australia First With Worldwide Network," Australian Business, Aug. 13, 1986, pp. 73-75.
3/ Commission interviews with various Australian industry officials, August 1987.

coaxial have formed the basis for similar transformations undertaken by HKT's owner, Cable and Wireless, in China. The Chinese Government's simultaneous emphasis on the development of a fiber optic industry and gradual development of a long-distance fiber-optic system may provide other developing countries with a useful model as they evaluate the benefits and costs of optical fiber versus microwave versus coaxial systems when developing plans to upgrade their telecommunications and information systems.

The discussion of various subregions of the Pacific Basin area follows the following format. The overall market for fiber optic systems is discussed with particular attention focused on the scope of demand for such systems both produced locally and imported and the identification of the primary purchasers of fiber optic systems. The structure of the local industry is examined with attention focused on certain economic indicators such as employment, production, exports, and research and development expenditures as the data are available.

In addition, the degree to which industry concentration is a factor is also examined. The fiber optics industry in all of these countries is characterized by considerable involvement of European, U.S., Canadian, and Japanese multinational corporations. In particular, we will examine the effect that various patents, licenses, and joint venture agreements have had on the industry in these countries.

The role of government is the next area addressed. Various governments have contributed heavily to the development of their respective local industries. This involvement, through direct and indirect subsidies, has affected the structure of the industry. Government also has affected the structure of the market through involvement in and regulation of public communication systems, local content requirements, and the development and institution of standards. Thus, government activity in the fiber optic and optoelectronic industry will be evaluated what the competitive consequences of its actions are. Expenditures on research and development are examined in terms of the long-term results of such efforts. The effectiveness of government-supported research consortia is also reviewed.

Japan

The development of the fiber optic industry in Japan followed a path similar to the development of its U.S. and Western European counterparts. In each case, initial research and development efforts were focused on telecommunications applications for optical fiber. As in Western Europe and the United States, the telecommunications industry in Japan has been regulated by the Government. The industry's development was facilitated by Government support in terms of funds, personnel, and facilities.

The telecommunications sector has typically been regulated for economic as well as national security reasons. In recent years, however, a shift towards a more deregulated telecommunications sector has occurred in a number of countries, including Japan. This shift has been, in part, a response tochanges in technology, which were thought to provide greater economic efficiency in a deregulated environment. 1/

Japan's actions have affected both the structure of the market and the structure of the industry. The structure of the industry, however, was established long before Japan focused its attention on the development of fiber optics. The organization of Japanese industry and the relationship between industry and government constitute two of the most important differences between the Japanese, European, and U.S. fiber optic industries. Industrial organization in Japan has had a lasting effect on the Japanese market in terms of competition, product development, price, and product availability. In fact, the organization of this industry has probably been a critical factor in its development: that is, in its ability to meet the demands of the Japanese market as well as to gain and retain its market share in the international market. 2/

Market segments

As with the United States and Europe, there was no significant commercial demand for fiber optic products until the early 1980s. Initially, the market for fiber optic systems and fiber optic components was dominated by the telecommunications sector, a sector controlled by two firms, Nippon Telephone and Telegraph (NTT) and Kokusai Telegraph and Telephone (KDD).

NTT was established in 1952 and was administered (until recently) by the Ministry of Posts and Telecommunications. NTT is responsible for the management of the domestic communications network. KDD was split off from NTT in 1953 and has been responsible for international communications services. Neither company is allowed to take part in manufacturing, thus maintaining the traditional split between domestic service industries and export-oriented producers.

In the early 1980s, fiber-optic telecommunications systems were first installed in Japan. At that time, NTT was the sole purchaser of such systems, and to date continues to be a major actor in the market. NTT was not only the

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1/ There was a general belief that the telecommunications industry is a natural monopoly characterized by decreasing long run average costs and that concomitant increases in operating size leads to economic efficiency when such an operation is regulated with rates set marginally above operating costs. Whether or not deregulation provides the economic benefits expected of it is not an issue to be discussed in this report. In some countries, however deregulation of telephone networks could lead to a situation where the new carriers would enter the market to capture business (data communication) customers. The former public communications concerns would no longer be in a position to subsidize rural customers (with high per capita or household costs) with the profits generated by business and residential customers in urban areas. Thus for noneconomic reasons, deregulation is unlikely in certain markets. Commission staff interviews with industry officials in Australia and Hong Kong, August 1987.
2/ See JTECH Report, pp. 2-1 through 2-31 for a more complete discussion of Japanese industrial organization in the telecommunications.

primary purchaser of telecommunications equipment but also was a guiding force in the development of fiber optic technology in Japan. NTT served and continues to serve as a conduit by which Government funds earmarked for fiber optic research would flow. NTT has provided the impetus for research and also, by default, has served as the developer of standards for the industry. 1/

For foreign producers, NTT's role in the market has been somewhat controversial. By setting design rather than performance standards which are unique to the Japanese market and by relying on close, priviledged working relationships with traditional suppliers, NTT has until quite recently effectively blocked the participation of foreign producers as well as other Japanese producers in the market. 2/ Over the past few years, this situation has begun to change, however. The change is, in part, a result of bilateral talks between the U.S. and Japan. 3/ During this period NTT has purchased increasing amounts of telecommunications equipment from U.S. suppliers. Table 10-7 illustrates that NTT's purchases from U.S. and other foreign

Deregulation of the Japanese market is beginning to have some effect on the strusture of the market. Revisions to the Public Telecommunications Law passed October 23, 1982, liberalized data-communications services and allowed

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1/ Although NTT had monopsony power in the domestic telecommunications market up until the mid 1980s, it seemed to not exercise its power as such. NTT's profitability (in terms of pretax return on equity and in terms of return on total assets) was lower than that of U.S. telecommunications companies. This situation was not unusual; Japanese companies generally exhibited lower profits than their U.S. counterparts for a number of reasons associated with the structure of the Japanese industrial system. There one notable exception, however. As one report notes:

> The communication equipment market generates the highest returns of any major Japanese industry, and it is the only business in which Japanese firms consistently earn higher returns than their U.S. counterparts. Over the 1979 to 1983 period, telecommunications equipment vendors earned an average return on assets of 6.9% in Japan and 5.71% in the United States.

JTECH Report, p. 2-9.

2/ The JTECH report states:

> The NTT procurement market offers very high returns to those fortunate enough to enjoy access to it. Unfortunately, this market has been virtually impermeable to imports. NTT's foreign procurement in the three-year period preceding the 1981 Telecommunications Treaty totaled less than $150 million out of total procurement during this period in excess of $5 billion. During that same period, NEC, Fujitsu, Oki and Hitachi accounted for almost two-thirds of all NTT purchases....(These vendors) and their affiliates control over 75% of the total Japanese telecommunications market.

JTECH Report, p. 2-10.

3/ The U.S.-Japan NTT, Trade Agreement of 1981 has been extended twice: once in 1984 and again in 1987 for an additional 3 years.

Table 10-7
Nippon Telephone and Telegraph purchases from foreign firms, 1980-86

(In billions of yen)

Amount from:	1980	1981	1982	1983	1984	1985	1986
U.S.	3.2	3.8	8.6	31.2	31.8	32.1	33.5
Total foreign...............	3.8	4.4	11.0	34.8	35.1	36.9	37.1

Source: NTT.

for the operation of value-added networks that compete with similar networks provided by NTT. 1/

The NTT company law, effective April 1, 1985, provided for the privatization of NTT. In terms of competition, NTT's status is similar to that of the Bell Operating Companies in the United States. In terms of ownership, NTT's situation is quite different. The Ministry of Finance took over the company's shares in 1985 and has been selling them off in blocks to domestic purchasers since that time. In addition, NTT continues to be supervised by MPT.

The Telecommunications Business law provides for the creation of two types of telecommunication companies. Class I companies are common carriers that are allowed to own and operate switching and transmission facilities. Class II firms lease switching and transmission services from the Class I companies. As of January 1986, five companies had been granted Class I status. 2/

In addition to the new common carriers, there have been a number of new companies established to provide data communications services to the business community. Many of these new, class II companies are joint ventures that involve U.S. and Japanese companies. 3/ At present, the major users of optical fiber and cable other than NTT are the "other common carriers" (OCCs). Japan Telecom and Telway Japan have both laid 500 km (12000 fkm) of cable. Daini Denden used fiber in inter-office networks or LANs in Osaka. the carrier did not use fiber in its long distance network, however; rather, it has installed a microwave long distance network. 4/

Table 10-8 shows projected changes in domestic consumption of various types of optical fiber used for telecommunications, data communications and other assorted uses such as medical or industrial. In addition to the

1/ VANs were allowed as "' a temporary measure'. VANs provide services such as financial transfers, inventory management support, and other specialized services over private communications networks." JTECH Report May 1986, p. 2-16.
2/ Of particular note, one of the new common carriers, Daini Den Den is managed, in part, by the Kyocera Corporation, an independent firm which is one of the major manufacturers of the ceramic material used in optical fiber connectors.
3/ JTECH Report, p. 2-18.
4/ George Faas, "In Japan, sales surge 24% but prices and profits drop," Lightwave, April 1987, p. 36.

Table 10-8
Japanese domestic consumption for optical fiber in Japan, by types, 1986-91

(In kilometers)

	1986	1991
	(km. core)	
Quartz type multimode Si fiber	5,400	1,900
Quartz-type multimode GI fiber	160,000	2,400,000
Quartz-type singlemode fiber	170,400	470,000
Multiple component multimode Si fiber	2,500	2,300
Plastic grade fiber	11,000	84,000
Drift fiber	42	200
Fiber bundles:		
Image fiber	120	250
Light guide	200	830

Source: OITDA.

telecommunications market, there is also a significant market for other types of optical fiber and various opto-electronic components. Current and potential users of optical fiber products include power companies, various heavy as well as light manufacturing concerns, computer, video, automotive, and aircraft manufacturers, as well as the manufacturers of medical and dental instruments.

Industry structure

Japan's optical fiber and cable industry is fairly concentrated in that 4 or 5 major fiber and cable producers account for most of the country's production. In addition, a number of these companies are vertically integrated. Table 10-9 lists the major producers of optical fiber and cable, including producers of plastic fiber. The table also shows the industry group with which each firm is associated. To understand the way in which the industry has evolved, it is necessary to review the way in which Japan's industrial sector as a whole has evolved.

Sixteen industrial groups account for roughly one-quarter of Japan's GNP and two-thirds of all exports. At the center of each group is a city bank and a trust bank. The groups consist of an "inner circle" of large industrial and trading companies, a second circle with a greater number of slightly smaller companies in a variety of industries and a third circle consisting of perhaps thousands of "smaller suppliers, distributors and affiliates." Since bank loans are a major source of capital for Japanese companies, the banks exert a substantial degree of influence over the group as a whole. Prior to the shift towards privatization in the telecommunications sector, three groups dominated the sector--Sumitomo (NEC and affiliates), Fuji (Oki and affiliates), and Dai-ichi Kangyo group (Fujitsu).

Table 10-9
Leading Japanese producers of all types of optical fiber and optical cable, by companies, by industry groups, and by sales, FY 85/86

(In millions of dollars)

Company	Estimated total sales	Industry group
Sumitomo Electronic Industries Ltd.......	3,884	Sumitomo
The Furukawa Electric Co., Ltd...........	3,633	Furukawa
Fujikara Ltd............................	1,062	Mitsui
Hitachi Cable, Ltd......................	1,425	Hitachi
Daninichi-Nippon Cables..................	715	Mitsubishi
Showa Electric Wire and Cable Co., Ltd...	754	Toshiba
Optec Dai-Ichi Denko Co., Ltd............	104	Mitsubishi Electric
Mitsubishi Rayon Co., Ltd................	1,833	Mitsubishi
Asahi Chemical Industry Co., Ltd.........	5,868	
Toray Industries........................	4,610	
Oki Electric Industry Co., Ltd...........	2,543	
Asahi Glass Co., Ltd.....................	4,583	Mitsubishi
Nippon Sheet Glass Co., Ltd..............	1,190	Sumitomo

Source: Japan Company Handbook: 1st half 1986 Oriental Economist, 1986.

Thus, the affiliates of these groups not only have been major players in the satellite communications programs but also have played a role as suppliers for the new common carriers. The two largest groups, Mitsubishi and Mitsui were absent in the past. 1/ However, more recently, Mitsubishi joined with

> "Mitsubishi has recently joined...with IBM Corporation and Ford Aerospace in two joint venture to provide communication services in competition with NTT. (Another new competitor)...is a recently formed consortium led by AT&T and the Mitsui Group. Mitsui also established a second joint venture with Hughes Communications in 1985 to provide telecommunications service in Japan. 2/

NTT and the Battelle Memorial Institute to form Photonics Integration Research Inc., a U.S.-based company that is working on commercial applications of optical circuit technology for the U.S. market. 3/

Japanese producers of fiber optics also develop and produce of fiber optic systems used for nontelecommunications applications. In addition to devoting considerable resources to the development of fiber and optoelectronic components to be used for VANs and other data communication applications, the major producers of fiber optics have developed products such as fiber optic sensors, and fiber optic components and links to be used in automotive and aviation systems, computers, and audio components. Japanese manufacturers

1/ JTECH Report, pp. 2-11 to 2-13.
2/ JTECH Report, p. 2-13. See pp. 2-17 to 2-18 for more information regarding affiliations of all five new common carriers.
3/ "NTT debuts video telephone; enters into optical IC venture," Telephony, July 20, 1987, pp. 14 and 18.

have also been active in the development of industrial-process-control systems for use by the petroleum, steel, and automotive industries. 1/

The demand for optical fiber and optoelectronics systems has increased rapidly over the past 5 years. The structure of the Japanese industry has contributed to this growth as has the Government's support for R&D in this industry. In addition to support on the supply and demand sides, the development of a fiber-optic long-haul network in Japan was facilitated by the simple fact that this technology represented an effective way of lowering the cost of information transmission, principally with the use of graded-index and subsequently single-mode fibers:

> ...to implement a broad band communication highway that traverses the high population density regions of Japan. This highway represents an integral part of the INS program....Japan is ideally suited to exploiting optical fibers in such a 'backbone' because its population is confined largely to a narrow corridor spanning the length of the country. 2/

As shown in table 10-10, total production for the Japanese optoelectronics industry and related industries has grown rapidly over the past few years. In 1985, total production was 864 billion yen, a 35 percent increase over 1984.

Table 10-10
Japanese optical industry output, by products, 1982-86

(In millions of yen)

Product	1982	1983	1984	1985	1986
Total optoelectronic components......	163,460	241,486	278,742	302,123	369,483
Light emitting elements............	88,972	118,521	121,826	134,719	159,293
Semiconductor lasers............	4,569	15,894	20,550	40,797	54,015
Gas lasers......................	2,382	4,999	6,658	8,027	8,887
Solid state lasers..............	827	1,282	3,883	3,635	2,935
LEDs............................	4,569	15,894	20,550	82,198	93,386
For telecom..................	1,516	4,202	4,545	5,075	16,034
Other........................	79,678	92,069	86,147	77,123	77,352
All other light sources..........	-	75	43	62	70
Detectors.........................	17,205	21,717	21,945	23,946	29,325
Hybrid optical devices............	29,091	40,190	39,289	32,463	39,186
Solar cells.......................	6,721	9,068	9,097	10,565	12,002
Optical fiber (includes cable).....	13,287	39,918	50,525	54,059	67,228
Silica..........................	12,641	37,609	48,265	51,771	64,665
Compound (includes plastic)......	646	2,309	2,260	2,288	2,563
Optical devices...................	8,184	12,072	36,060	46,371	62,449
Connectors......................	2,573	2,912	4,667	6,933	8,974
Other (switches, isolators, etc).	5,611	9,160	31,393	39,438	53,475

1/ Commission interviews with various Japanese industry officials, December 1986 and September 1987.
2/ JTECH Report, p. 6-17.

Table 10-10
Japanese optical industry output, by products, 1982-86--Continued

(In millions of yen)

Product	1982	1983	1984	1985	1986
Total optoelectronic equipment.......	84,619	156,847	283,314	446,677	543,196
Transmitters and receivers.........	9,328	21,995	31,859	28,234	36,456
Measuring instruments..............	2,949	5,223	16,698	20,717	26,753
Installation equipment.............	948	2,405	4,650	5,024	4,707
Sensors............................	3,751	5,375	8,362	9,395	13,366
Optical fiber....................				2,501	4,502
Laser............................				6,894	8,864
Optical disk equipment.............	13,056	46,818	114,817	249,653	300,075
Input and output equipment.........	25,318	43,109	53,802	75,943	102,440
Medical laser equipment............	4,412	4,567	4,311	4,833	5,920
Laser processing equipment.........	24,857	27,355	48,815	52,876	53,570
Optical systems: (Total)............	29,717	68,372	80,095	99,096	126,888
Public communication...............	14,354	40,077	39,713	53,154	65,627
Specific users communication.......	12,196	21,119	33,515	39,500	54,035
All other..........................	3,167	7,176	6,867	6,434	7,226
Total............................	277,796	466,705	642,151	847,896	1,039,567

Source: Optoelectronic Industry and Technology Development Association.

Employment in this industry is expected to increase also. Employment in 1986 was estimated at around 16,000; by 1990, it is expected to grow to 23,000. Approximately 50 percent of this increase is thought to be for research and development personnel. At present, the telecommunications and information equipment portion of the industry account for around 80 percent of total employment. This share will change as demand for these products shifts from long-haul telecommunications systems to other applications.

Although information regarding the scope of Japanese exports is not readily available, there is considerable evidence of the extent of the Japanese fiber optic industry's penetration of the international market. Not only do virtually all of the major producers participate in the international market, but also, their participation extends to Central and South America, the Middle East, Australia, South East Asia, and China as well as Western Europe and North America. In addition to a sales presence in all of these markets, Japanese producers have established subsidiaries, joint ventures, and/or technology-transfer agreements in countries in most of these regions.

Research and development

Most of the Japanese company officials surveyed by the Commission in interviews indicated that their companies spent a sizable percentage of sales revenues on fiber optic research and development, but they did not supply actual data. Thus, it is difficult to estimate R&D trends in the Japanese fiber optic industry, at least for that portion of Japanese R&D funded solely by the industry. Much of the research and development activities undertaken by Japanese researchers in the field of fiber optics has been and continues to be funded by the Government. The Japanese Government has financed a number of long-term research projects related to the development of the Japanese optoelectronics industry. Three such efforts include the photo-reactive materials project, the Joint Optoelectronics Research Lab (JOERL), and Exploratory Research for Advanced Technology (ERATO). 1/

Table 10-11 lists current national technology development projects. Support for these projects stems from multiple sources, one of which is MITI's research and development wing, AIST. The Japan Development Bank is another important source of funds for research and development. It has provided funds for technology development and, more importantly, for commercial activities. A third and perhaps most critical source of funds is the Ministry of Finance, which provides direct Government grants. 2/

Table 10-11
Japanese National Technology Development Projects, by duration and budget amounts, 1979-89

(In millions of dollars)

Project	Duration	Budget
Optoelectronic technologies	1979-85	160
Optical information processing	1979-85	70
Supercomputer development	1981-89	200
Next generation industrial technologies	1981-90	275
Satellite earth resource observation system	1985-90	105
Interoperable databases	1985-92	150
Fifth generation computers	1979-91	270
SIGMA (Automated Software Production)	1985-89	120

Source: JTECH Report, p. 2-14.

1/ The photo-reactive materials project of AIST is a 7-year project that commenced in 1985 with a reported budget of 7 billion yen from the Government and a comparable amount from the group of participating Japanese firms. The basic aim of the project is to study new organic superconductive materials as well as photo-reactive materials to be used in future generations of optoelectronics devices.

The ERATO program is sponsored by the Japan Research and Development Corporation, an organization within AIST. The program covers a few optoelectronics research efforts; one such effort known as the perfect crystal project concerns the use of thin-film technology, using molecular beam epitaxy on gallium arsenide (GaAS) substrates.

The JOERL, also sponsored by AIST, ended in March, 1987. The JOERL developed prototype components for an optical LAN that was built at a Japanese oil refinery. The JOERL, with 50 researchers from participating Japanese companies, focused on developments at the materials and components level of the fiber optic and optoelectronics systems. One of the lab's major projects was to develop ways to manufacture reliable, low-cost, mass-produced optoelectronics components. One example of its efforts was a low-cost method of growing indium free low-and no-defect gallium arsenide single crystals. Commission interviews with U.S. Government officals in Japan, December 1986 and August 1987.
2/ JTECH Report, p. 2-15.

Although the JOERL ended in March 1987, the nine participating companies have joined with four others under the auspices of the Japan Key Technology Center to continue research in these areas. The center was established to facilitate Japan's efforts to improve basic research capabilities. The Key Technology Center, which is financed by the Government largely from dividend cash flow from the Japan Tobacco Corporations and NTT stock 1/, supplies 70 percent of the funds for projects, with the participating companies supplying the remaining 30 percent. The center has initiated two projects since its inception. One project, the Optoelectronics Technology Research Corporation involves work on first, second, and third generation OEICs. Ultimately, a goal of this company is to develop mass-produced optoelectronics devices and other devices to be used for short distance optical communication applications. The other company formed by the key-tech center is the Optical Measurement Technology Development Company, which develops measuring equipment for the fiber optic industry--specifically that to be used in the development and production of coherent optical systems. Unlike the MITI large-scale projects, the Key Technology Center allows for considerably more private sector participation (that is, 30 percent of the financing). Yet, MITI and MPT still have retained an important controlling role, both directly and indirectly, through NTT.

In addition to direct, Government-sponsored research, corporate research is well developed and is expected to continue to grow. 2/ As discussed above, the Government-sponsored research tends to focus on basic research. Research undertaken by individual companies represents a sizeable share of corporate investment and, as a result, tends to be more oriented to product development. 3/ Table 10-12 shows projected trends in corporate research and development.

Industry organizations also have an influence on the direction research and development efforts take. The Japanese Government (MITI) and industry officials take an active part in the OITDA. OITDA recently allowed Corning and AT&T to participate. This is viewed by U.S. industry officials as being an important step not only because of the implications regarding R&D, but also because of the role industry organizations have with respect to developing standards. Traditionally NTT has established standards for the domestic market, and Japanese producers have manufactured different types of products for export in those instances (which happen to be most of the time) in which NTTs standards differ from those of the major export markets.

1/ The funds are estimated at 26 billion Yen per year from NTT and 5 billion Yen per year from Japan Tobacco Corporation.

2/ The industry is estimated to have spent 170 billion Yen directly on optoelectronics-related research and development. Industry sources indicate that these levels will increase dramatically over the next five years.

3/ Although industry responses varied, on average, Japanese companies reported that a fairly substantial percent of their total revenues went towards research and development in optoelectronics and optical fiber and cable, particularly considering the fact that the revenues generated by their fiber optics divisions do not constitute a significant portion of their total revenues. Commission interviews with various Japanese companies in December 1986 and August 1987.

Table 10-12
Projected Japanese corporate research and development by projects, 1985 and 1991

Item	1985	1991	Percent change
	--Million yen--		
Telecom components	5,600	15,100	169.6
O/A equipment components	11,100	21,300	91.9
Energy related components	3,400	7,200	111.8
Light receiving elements (for telecom)	5,400	14,600	170.4
Light receiving elements (for O/A equipment)	11,100	23,300	109.9
High-powered lasers	5,300	8,900	67.9
Solar energy	7,200	12,700	76.4
Optical fiber	4,400	9,500	115.9
Connectors	3,900	11,600	197.4
Circuit elements	7,600	18,800	147.4
Transmission equipment	8,800	23,300	164.8
Measuring instruments	7,600	10,900	43.4
Cable installation equipment	1,100	3,200	190.9
Optical sensors	6,000	25,300	321.7
CD-ROM discs	9,300	20,200	117.2
Compact discs	15,500	33,800	118.1
Worm disc equipment	13,900	34,800	150.4
Worm discs	12,900	29,600	129.5

Source: OITDA.

The privatization of NTT and changes in Government R & D policies have resulted in a changes in the way NTT's research activities are structured. It has not resulted in a decrease in either overall research and development expenditures or personnel, however. 1/ As table 10-13 shows, research and development expenditures have increased steadily over the past 5 years.

Table 10-13
Nippon Telephone and Telegraph research and development activities, 1983-87

	1983	1984	1985	1986	1987
R&D expenditures (billion yen)	94	127	170	187	220
R&D personnel	3,680	3,750	4,650	5,070	5,170

Source: NTT.

Much has been published regarding the ability of the Japanese Corporations to translate research and development efforts into commercially viable products, an ability that, on balance, surpasses that of U.S. and European producers. In the field of fiber optics, in particular, research and

1/ Commission interviews with NTT and Japanese Government officials, August 1987.

development efforts concerning telecommunications components, U.S. industry analysts have placed the Japanese ahead of the United States (table 10-14).

Table 10-14
Summary of Japanese v. U.S. R&D Efforts in Telecommunications, by components and by research area

Components	Area of research	Advantage
Semiconductor ICs:		
Memory	Japan	
	High-speed technology	Japan
	Voice band circuits	Efforts comparable
	Digital signal processing	Efforts comparable
Fiber optics:	Optical fibers	Efforts comparable
	Optoelectronic devices	Japan
	Transmit/receive electronics	Japan

Source: JTECH Report, p. 6-22.

This assessment has been supported by industry analysts as well as other U.S. Government analysts. As the JTECH report notes,

> ...both engineering design and manufacturing are regarded as research disciplines of considerable importance. This viewpoint helps explain the willingness in Japan to support a remarkable number of extensive, long-term engineering research programs without requiring some assurance of commercial viability....The Japanese also view research as a means of supporting manufacturing improvements and cost reductions for components already in production. Once a component is being manufactured, considerable effort is given understanding the basic scientific mechanisms on which both the operation and fabrication of that component depend. 1/

As the following chart illustrates (fig. 10-3), Japan's success does not extend to all areas within the fiber optic and optoelectronics industries. However, in terms of the components industries, the U.S. is not only behind, but is losing ground.

In the United States, and to a lesser extent, in Western Europe, more attention is focused on basic research. Engineering is viewed as being synonymous with the term, development. As such, engineering activities are more directly linked to the probability of success attached to their expected results. 2/ Industry officials have suggested that this approach may place U.S. firms at a competitive disadvantage as compared with their Japanese counterparts.

1/ JTECH Report, p. 6-23.
2/ JTECH Report, p. 6-23. This is also supported by interviews with various industry analysts in the United States and abroad.

Figure 10- 3
Japanese technology comparison by communications sector

表3.3.3　通信分野における日米技術比較

	Technology	Basic research in Japan			Advanced development in Japan			Product development in Japan		
		Behind	Equal	Ahead	Behind	Equal	Ahead	Behind	Equal	Ahead
Systems and networks	Networks	◄			●			►		
	Local-area networks	◄			●			►		
	Architecture, standards	●			●			◄		
	Basic services	●			●			●		
	Value-added networks	●			►			►		
	Metropolitan-area networks		●		●			►		
	Physical facilities		●				●	►		
	Network subsystems	●			►			►		
	Software	●			►			►		
	Hardware	●			►				►	
	Mobile radio systems			►		►			►	
	Trunked radio	◄			◄			◄		
	Mobile satellite systems	◄			◄			◄		
	Paging systems	●			●			●		
	Cellular radio	●			●				●	
	Future systems planning		►			►			►	
	Digitization			►			►			►
	Propagation			►	NA			NA		
	TDMA*			●	NA			NA		
Components	Integrated circuits			►			►			►
	Voiceband circuits		●			●			●	
	Digital signal processors		►			►			►	
	VLSI memories			►			►			►
	High-speed circuits			►			►			►
	Fiber optics			►			►			►
	Fibers		●			●			●	
	Devices			►			►			●
	Transceivers			►			►			►

*TDMA—time-division multichannel access　◄ Losing position　● Holding position　► Gaining position
NA—not applicable

(IEEE Spectrum, 6月, 1986)

Source: OITDA.

Future demand

As estimates for overall production and employment indicate, the Japanese industry is expected to grow quite rapidly over the next 5 years. There are a number of projects such as NTT's plans to install branch routes in conjunction with the trunk system, Japan Telecom's Shinkansen optical cable network following its major railroad routes, and the new fiber optic system being developed by Teleway Japan along the national toll roads that lead to the total value of fiber optic cable demanded amounting to 285 billion yen. Demand for optical fiber is expected to increase to 1,093,000 kilometers in 1990 from the 124,000 kilometers used in 1985, or by 780 percent. Domestic production of optical fiber is also projected to increase, with multimode fiber increasing more rapidly than single-mode or specialty fibers (table 10-15). Other applications expected to grow rapidly include fiber links in computers and audio equipment. Whereas current fiber use is not that significant, Japanese companies are focusing personnel and funds in those areas. For example, Japan has had a large share of the market for medical

Table 10-15
Future production of optical fiber in Japan, by types, 1986-91

	Domestic production (km. core)		Domestic production (Million yen)	
Type of fiber	1986	1991	1986	1991
Quartz multimode SI fiber.......	6,300	6,300	380	189
Quartz multimode GI fiber.......	240,000	3,500,000	21,000	160,000
Quartz type singlemode fiber....	340,000	1,200,000	41,000	70,000
Multiple component type multi-mode SI fiber.................	2,500	2,500	100	63
Fixed polarity fiber...........	70	330	140	230
Total......................	588,870	4,709,130	62,620	230,482

Source: OITDA, (table 2, 1, 2).

equipment utilizing optical fiber. In recent years, Japan has been a major source of imports of such goods to the United States.

Republic of Korea

Over the past few years, Korea has emerged as a producer of optical fiber and cable. Through the efforts of the Korean Government, the fiber optic industry has grown to the point where it can supply current as well as long-term Korean demand with considerable capacity remaining with which to supply an export market. The development of the optical fiber and cable industry is part of an overall plan on the part of the Government to promote the development of export-lead growth industries.

Market segments

The most important domestic customer is the government's Korea Telecommunications Authority (KTA). Other buyers include Pohang Iron and

Steel (private), Korea Electric Power Company (government), and the Korean Broadcasting System (government). KTA has a two-stage plan. The first stage is the development of the backbone network from Seoul in the north to Pusan at Korea's southern extremity. This stage is expected to be completed by the end of 1987. The second stage involves the development of lateral branches to smaller cities.

KTA has used its purchases in previous years to develop public telecommunications facilities for the 1986 Asian games and also for the upcoming Seoul Summer Olympics. Table 10-16 shows selected data on optical fiber and cable sales as well as projections for 1987-88. 1/

Table 10-16
Korean sales of optical fiber and cable: 1984-1988

(Quantity in fiber kilometers; value in millions of wan)

Product	1984	1985	1986	1987	1988
Fiber:					
Value......................	-	-	11,316	28,590	-
Cable:					
Value......................	-	-	22,399	90,152 e	-
Quantity...................	2,000	18,000	29,000	40,000 e	30,000 e
Total:					
Value..................	-	-	33,715	118,742 e	-

Source: Government of Korea, MTI.

Industry structure

There are five companies producing optical fiber and cable in Korea. All five companies operate under foreign technology agreements, which are described in table 10-17.

Just as production is expected to increase over the next year, so too is the workforce. Between 1984 and 1986, the total number of workers increased 48 percent to 370. In 1987, the workforce is expected to continue this growth with industry sources estimating that it will grow to 400. 2/

1/ KTA's fiber purchases are reported to amount to the following:

1985	1986	1987	1988
		(km)	
10,000	25,000	40,000 (e)	25,000 (e)

After 1990, KTA's demand for fiber is expected to increase again as it begins to install short-haul systems. George Faas, "Warning to fiber makers: Here come the Koreans," Lightwave, August 1987, p. 25.

2/ Other industry sources estimate that the 1987 workforce of production and research and development personnel amount to 340.

Table 10-17
The foreign technology agreements of the Korean fiber and cable producers, by companies, by products, and by years begun

Company	Products	Foreign technology agreement	Year begun
Samsung Semiconduct and Telecommunications.............	Fiber/cable	ITT (U.S.)	8/23/83
Daewoo Telecom Company Ltd....	Fiber/cable	Northern Telecom (Canada)	8/23/83
Goldstar Fiber Optics Company Ltd.......................	Fiber	AT&T (joint venture)	2/1/84
Goldstar Cable................	Cable	AT&T (tech. transfer)	12/31/84
Taihan Electric Wire Company Ltd.......................	Fiber/cable	Sumitomo (Japan)	12/31/83

Source: Government of Korea, MTI.

The market for exports of Korean cable has not been developed extensively by Korean producers of fiber optics (table 10-18). During the past year, the relatively soft international market combined with the reported lower quality of Korean optical fiber and cable contributed to the lack of demand for Korean products in the international market. 1/ In addition, Korean producers are restricted by the terms and conditions of foreign technical licensing and joint-venture contracts, as well as by patent-rights ownership. Most of Korean exports during 1986 reportedly went to joint-venture partners or foreign technology contractors.

Table 10-18
Korean exports of optical fiber and optical cable by destinations, 1986-87

(In thousands of dollars)

	1986			1987		
Product	U.S.	EC	Total	Mid East	Israel	East Asia
Optical fiber.........	3,280	35	3,315	3,000		
Fiber cable...........	947		947	1,500		
Total.............	4,227	35	4,262	4,500		

Source: Government of Korea, MTI (note, the figures for 1987 are for the second half only; during the first half the Government reported $79,000 for fiber and $21,000 for cable for a total of $100,000. No destination was identified for these exports.

Korean production capacity for both optical fiber and optical cable far exceeds the current demand for both products. Table 10-19 illustrates,

1/ Other industry sources estimate that the 1987 workforce of production and research and development personnel amount to 340.

Table 10-19
Korean production capacity and utilization, 1986-87

Product	1986 cap.	1986 act.prod.	1986 %util.	1987 (e) cap.	1987 (e) act.prod.	1987 (e) %util.
	Quantity in fkm					
Fiber...............	129,600	79,324	61	165,600	110,000	66
Cable...............	8,300	1,441	17	8,300	4,700	57

Source: Government of Korea, MTI.

capacity utilization for 1986 and 1987 is low. However, the expected utilization rates for 1987 are considerably more favorable for Korean producers. 1/ Since KTA's use of optical fiber cable is not expected to increase, but rather to decrease, it seems likely that the four manufacturers of optical fiber and/or cable and the other producer of optical fibers will seek to expand their fledgling export markets. 2/ Recent research indicates that there may be a market for Korean fiber and cable in certain Southeast Asian countries. 3/ During the 1984-86 period, there were minimal imports of optical fiber or cable into Korea. 4/

The Korean manufacturers depend on imports of many necessary raw materials as well as much of the optoelectronic components that are used in fiber optics systems. It has been estimated that 60 percent of these components come from Japan and the United States. At present, the import ratio from Japan and North American is estimated to be 50-50. 5/

Research and development

In 1977, the Korea Advanced Institute of Science and Technology supported a joint technology research development study with private industry. The effort did not succeed, however, in reducing the Korean industry's dependency on foreign technology. To date, Korean firms either use Modified Chemical

1/ A number of optical fiber purchasers have noted that while the price of Korean optical fiber and optical cable is less than the average price of European, U.S., or Japanese optical fiber and optical cable, the Korean producers have not been able to match the quality of their competitors' products and are hindered by their inability to market fiber optic systems.
2/ During ITC staff interviews with Korean government officials and industry officials, no official projections were discussed. However, the general consensus was that Korean demand would decrease by approximately __ percent in the next few years.
3/ One analyst speculated that "Korea's first export push will probably be" ... in the form of transmission systems with the fiber built in. All four producers have received many inquiries from newly-industrializing countries of southeast Asia." George Faas, Lightwave August 1987, p. 23.
4/ Pohang Iron & Steel installed a high-speed optical network manufactured by Sumitomo Electric that used a total of 27 kilometers of cable. Lightwave, January 1986.
5/ Op. cit., p. 23.

Vapor Deposition (MCVD) or Vapor Axial Deposition (VAD) under the licenses mentioned in table 10-18.

For the most part, the Korean manufacturers concentrate on product development, rather than basic research. In general, industry sources estimate that product development activities amount to around 5 percent of company revenues.

Future demand and developments

At present, of the export efforts the producers of fiber optics are restricted by the technology transfer agreements as well as Corning's patents. This limitation on exports is of consequence to the four producers since Korean fiber and cable capacity greatly exceeds the expected domestic demand for fiber and cable. This situation will not be mitigated by the development of a data-communications market or the expansion of KTA's system to go beyond the backbone network and short branches off of the backbone network. Thus, to fully take advantage of their current production capabilities and achieve economies of scale, Korean producers will have to expand their collective share of the international market for fiber optic products. According to industry sources, some of the manufacturers are in the process of developing technological abilities to produce optoelectronics devices that would allow them to market optical fiber systems. This would improve their ability to compete in the international market when the technology transfer agreements expire in 1990-1991, and when Corning's patents similarly expire.

Australia

Market segments and demand

The Government of Australia has a definite economic interest in promoting the development of its optoelectronics and communications industry. The telecommunications market is divided between Telecom Australia, a semi-Government authority that controls the domestic market for telecommunications services, and the Overseas Telecommunications Commission, which controls telecommunications links between Australia and other countries, ships, and external territories.

Telecom Australia has net fixed assets of approximately A$10 billion and employs a labor force of around 88,500. Telecom exercises a great deal of authority over the provision of domestic telecommunications services and over what can be attached to the network. To prevent Telecom from taking advantage of its monopoly power as the sole domestic provider of domestic telecommunications services, public control and ownership was established. Nonetheless, the authority has considerable power both as a monopoly provider of services and as a monopsonistic buyer of optical fiber products. 1/

The Australian market is expected to grow considerably over the next 5 years. Most of this growth is a function of an increase in demand by Telecom Australia. In 1984/85, Telecom purchased around 7,000 fkm. In 1985/86, Telecom's usage more than quadrupled, rising to 32,000 fkm. By 1986/87, usage

1/ Commission staff interviews with Australian industry officials, August 1987.

had risen to 50,000 fkm. Telecom's demand for optical cable for telecommunications purposes is expected to amount to 60,000 fkm in 1987 for high capacity interexchange and long-distance routes. 1/ Projected usage for optical fiber used for telecommunications purposes is illustrated in table 10-20. In addition, submarine cable demand will amount to 10,000-15,000 fkm. for the Tasman-2 cable between Australia and New Zealand, with production scheduled to begin in 1988. Two other phases of the project are also being planned with international involvement as shown in table 10-21.

Table 10-20
Projected Australian telecom fiber usage in fiber kilometers (fkm) 1987-1991 1/

1987/88	1988/89	1989/90	1990/91	1991/92
60,000	85-90,000	85-90,000	85-90,000	70-75,000

1/ These projections are based on the assumption that optical fiber will be used to replace conventional telecommunications cable up to the local exchanges and in some instances up to the neighborhood junctions.

Source: Telecom Australia.

Another area of the market being developed in Australia involves local area networks (LANs). Telecom Australia is in the process of installing two experimental systems: one in Melbourne, the other in Sydney. In addition, LANs have been installed by various institutions both nongovernmental and Governmental. Industry sources have indicated that the demand for optical fiber used for data communications systems is expected to remain at 5,000-10,000 fkm per year over the next few years, barring any significant changes in technology that would affect the cost of such systems. Power authorities are also beginning to use optical fiber systems both to transmit data and voice information and to monitor the temperature of high-voltage conductors. There are also a growing number of transport systems employing optical fiber systems. The most extensive of such systems in Australia is that installed by the Queensland Rail as a part of the Railroad's coalfield mainline electrification project. Scientific research is another growing market for fiber optics in Australia. The Australian Telescope and the Endeavor project are two examples of fiber's usefulness in scientific research. Other uses include industrial control-applications, manufacturing-process control, and other uses as sensors.

1/ Telecom estimates that 30-35,000 fkm will be used for the long-distance trunklines and the remainder will go for junction usage, short trunklines, and some usage through to local exchanges and out to neighborhood exchange boxes (pillars).

Table 10-21
Expected demand for submarine cable for the Pac Rim project

Item	Completion date	Length	Projected cost
		Kilometers	Million dollars
Project:			
Pac Rim East (New Zealand-Hawaii)...	1996	8600	216
Pac Rim West (Australia-Guam).......	1993	7400	216
	Investment share		
	Percent		
Investors:			
Overseas Telecommunications Commission (Australia)............	72.5		
AT&T (U.S.)........................	13.6		
Telecommunications Commission of New Zealand......................	8.3		
KDD (Japan)........................	5.6		

Source: "KDD will join Pacific Cable Project," Lightwave, November 1987, p. 11.

Industry structure

During the past few years, there has been a slow shift towards the establishment of worldwide standards for optical fiber and optical cable. The trend towards greater homogeneity of products makes it difficult for countries to establish such industries on their own. Australia, like other countries, has protected its industry through Telecom Australia's market-supply policies. Because of the scale of its operation, Telecom Australia's technical standards have been adopted by the Australian industry as industry standards much in the same way as Bell Research Lab's (AT&T) standards have become the U.S. industry's standards and European standards have become de facto standards in various Western European countries. Telecom's standards do not always coincide with the standards of other countries; the net result, therefore, of its purchasing policies is that telecommunications products in Australia are designed and produced to meet these standards. In addition, the establishment of separate standards has resulted in many companies not vying for Australian projects because they are not capable of rapidly accommodating their production processes to produce products according to Telecom's specifications, and they have no inventory on which to fall back.

In addition to standards, the Australian Government has recently instituted changes in tariffs applied to products in the fiber optic market. Sources expect that the increase in tariffs coupled with the actual and projected increase in local production capabilities will result in a heavy reliance on Australian suppliers. Nonetheless, given the expected continued increase in demand for fiber optic products over the next 5 years, there will be an opportunity for foreign suppliers to retain some portion of the Australian market (particularly for optoelectronics components).

The scale of production in Australia is considerably smaller than that of the United States, Japan, or the EC. Nonetheless, the number of optical fiber and optical cable producers has grown over the past few years. There are currently two major producers of optical fiber and three producers of optical fiber cable. Table 10-22 delineates the relationships between the Australian producers and various multinational concerns.

Table 10-22
Ownership and supplier relationships in optical fiber production in Australia, by companies, 1986

Company	Ownership (country) Percent	Technology source	Supplier relationship
Fiber:			
OPTIX Australia...	Pirelli 15 (Italy)		
	Sumitomo 34 (Japan)	Sumitomo	Sell to: Olex Cables Pirelli Cable
	Olex 51 (Australia)		
Optical Waveguides Australia........	Corning 50 (U.S.)	Corning	Sell to: Austral Standard Cable
	AWA 20 (Australia)		
	Metal Manufacturers 30 (UK)		
Optical Cable:			
Olex Cables.......	Affiliated with Pacific Dunlop		
Pirelli Cables....	Subsidiary of Pirelli (Italy)		
Austral Standard..	Metal Manufacturers (Australia)		

Source: Various Australian Manufacturers.

Australian production capacity is considerably greater than current production levels. However, industry sources stated that they expected production levels to increase; consequently capacity utilization rates should improve over the next year or so. Currently, optical-fiber production capacity is estimated at 200,000 fkm per year. Optical cable capacity amounts to well over 350,000 fkm per year. Capacity utilization rates vary, ranging from 40 to 60 percent.

The two producers of optical fibers did not begin production until 1986. Prior to that time, the only producer of optical fibers in Australia was AWA. Since AWA's production was limited, some of Telecom Australia's demand for optical fiber and cable was met by imports. Import data for years prior to

1985/86 are not available. Nonetheless, table 10-19 shows the shift in imports and the major suppliers to the Australian market over the past 2 years or so.

As table 10-23 illustrates, major suppliers to Australia include Japan, the United States, and the United Kingdom. The decline in imports between 1985/86 and 1986/87 coincided with the completion of Australia's optical fiber production facilities and Telecom Australia's subsequent shift from relying on imports to purchasing Australian optical fiber cable.

Table 10-23
Optical Fiber and Cable (Tariff Item No. 70.18.100): Australian imports, by sources, June 1985-86 and June-May 1986-87

(In Asustralian dollars)

Country	1985/86 June-June	1986/87 June-May
Austria	-	7,642
Canada	-	341
Finland	4,269	11,415
France	485	878
West Germany	8,017	12,236
Israel	1,719	
Italy	1,164	93
Japan	4,209,943	1,311,368
Netherlands	-	549
Sweden	-	179
Taiwan	147	-
United Kingdom	2,694	45,023
United States	8,420,719	2,470,884
Total	12,649,156	3,860,609

Source: Government of Australia

Australian producers to date have focused mostly on the domestic market and have not developed an extensive export market. There have been exceptions, including exports of optical terminal and link equipment to the United States, exports of stabilized laser instruments and fiber visual aids to the United States, exports of optical cable to New Zealand and the United States, and exports of optical fiber and cable to Southeast Asia. One of the major constraints to increasing exports cited by Australian industry officials is the cost of shipping, particularly for optical fiber cable. One official estimated that freight costs amounted to 8 to 10 percent of the costs of Australian optical fiber cable. Another factor that contributes to the difficulty Australian manufacturers face in selling to the international market is the fact that the cost of imported materials used to produce optical fiber and cable tends, on average, to be higher because of the tariff rates imposed by the Government. The Australian government has announced plans to increase Australia's export of communications equipment from A$40 million to A$600 million over the next 10 years. To achieve this increase, the government plans to work with Telecom and the Overseas Telecommunications Commission. Australian industry sources indicated that likely markets will continue to be the United States, Southeast Asia, and New Zealand--at least for the next 5 years.

Research and development

There is a significant amount of research and development being sponsored by the Government, industry, and higher education facilities. The research and development activities range from basic research to applied research on production processes and product development. The Government is a major sponsor of research and development projects and programs designed to foster the development of the industry in general, both directly and indirectly. Direct initiatives include a research-grants program administered by the Department of Science to foster research and development in the field of optical communications. The Government's Department of Industry, Technology, and Commerce administers the Australian industrial research and development incentives scheme: a program which has disbursed over A$320,000 for projects concerning optical communications, especially optical fiber cables. In addition, the Department of Defense sponsors research and development in fiber optic applications. 1/

Indirect incentives include tax incentives for research and development; the Government gives a tax credit of 150 percent for certain types of research and development activities. Whereas much of the research activity is reportedly fragmented and in need of a greater degree of coordination, it has yielded positive results. According to industry sources, Australia has made significant contributions in three areas: production methods, cable design, and construction methods. 2/ Telecom Australia continues to give out contracts for developmental work, in addition to the work it conducts in its own research facilities. To date, it has concentrated more so on optical fiber than on optoelectronic components, focusing on flouride glasses and plastic. Work is also being conducted concerning hydrogen ingress in optical fibers. According to officials, this balance will shift in the future. For example, Telecom Australia is reported to be developing fiber optic devices

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1/ Commission staff interviews with Australian industry officials and U.S. Government officials, August 1987.

2/ Optical fiber production technology has been enhanced by independent Australian innovations incorporated in the newly constructed Optical Waveguides plant. Within the plant is an inner building (all of which is a clean air zone reducing the possibility of dust damage to the fiber). In the outer building, the company has built a three-story drawing tower that rests on a separate foundation, independent from the building's foundation. This insulates the tower from vibrations coming from other parts of the plant.

A second innovation is the development and use of nonmetallic cable in the country's long-distance network. Telecom Australia developed plastic reinforcements for its cable in order to prevent lightening and electromagnetic interference affecting the functioning of the cable. To add additional strength, Telecom Australia has combined fibers with kevlar or glass-reinforced plastic strength members.

A third innovation is a type of tractor that reduces tension on the cable during the process of installation. This facilitates faster installation and has resulted in Australia's project being built faster than originally planned.

based on II-VI compounds. Telecom Australia is also in the process of developing fiber optic reference standards as a part of its LAN project in Melbourne. The researchers will measure optical power, optical attenuation, wavelength, and optical spectra. The standards Telecom develops will "be traceable to Australian national standards and thence to international standards." 1/

Future demand

According to Australian industry officials, domestic demand for fiber optic systems is expected to grow steadily over the next 5 to 10 years. As noted above, much of this growth comes from the telecommunications sector. Unlike the U.S. market, the Australian market for optical-fiber telecommunications applications is not expected to decline sharply upon completion of the long distance routes. According to industry officials, the Australian practice of using duct systems in urban areas facilitates the switch from copper (coaxial) to optical fiber systems since the cable does not have to be dug up in order to be replaced. 2/ After 1991-92, Telecom is scheduled to begin some second phase projects. Instead of putting in new ducts, Telecom may decide to replace old cable with fiber optic cable, thereby increasing capacity while minimizing costs.

Although the majority of industry sources indicated that it was unlikely, the possibility of Telecom or some other entity developing a subscriber-loop system and laying fiber cable to the home does exist in Australia. If subscriber-loop systems become a reality in the early 1990s, industry sources estimate that consumption of optical fiber will exceed 300,000 fkm.

New Zealand

Market segments

The market for fiber optic products in New Zealand is limited mostly to telecommunications. At present, there is only one manufacturer of optical fiber cable, Austral Standard Cables Pty. Ltd. which is a subsidiary of Austral Standard Cable, Australia. Austral Standard's primary purchaser is the New Zealand Post Office, the Government authority responsible for telecommunications services throughout New Zealand. Fiber usage in New Zealand is currently estimated at 20,000 fkm per year. Austral Standard has a production capacity of around 60,000 fkm per year. To date, Austral Standard has not exported its products, in part because it has only been producing for around 3 years and has not fully developed its production capacity, and in part because it would then be in direct competition with its parent firm. 3/ Given its current excess capacity, the importance of export market development is growing.

1/ Review of Activities 1985-86, Telecom Australia, pp. 42-44.
2/ Commission staff interview with Australian industry representatives in August, 1987.
3/ Commission staff interview with Australian industry officials, August 1987.

Although only fairly limited amounts of fiber have been laid in New Zealand, a larger market is developing for submarine cable, specifically for the TASMAN-2 project, which is to connect Australia with New Zealand. Current usage of satellite and cable links is at or near capacity. TASMAN 2 will be jointly owned by the New Zealand Post Office and the Australian Overseas Telecommunications Commission. The project is the first phase of the proposed 25,000 km network, which is expected to link New Zealand and Australia with North America and Asia by 1995. Fiber cable for this project is expected to be supplied from a producer in Australia. 1/

Because the use of optical fiber in New Zealand is quite recent, the New Zealand government began to collect data on imports only after since July 1, 1986. For the latter half of 1986, the United Kingdom was the largest supplier, followed by Australia, Denmark, Japan, and the United States.

Hong Kong

There are no companies involved in the production of optical fiber or optical cable. Existing COCOM restrictions serve to inhibit the development of such an industry in Hong Kong. Despite the lack of local production of optical fiber and cable, the market for these products is well-developed.

Market segments

There are two users of fiber optics systems in Hong Kong: Cable and Wireless (HK) Ltd. and the Hong Kong Telephone company. Both of these companies use glass single mode and multimode optical cables for the transmission of voice, data, and video information in each of their networks. The Government of Hong Kong has granted an exclusive franchise to Cable and Wireless for external communications for the Territory and to Hong Kong Telephone for communications within the Territory. Both companies are part of the Cable & Wireless Group.

The Government of Hong Kong owns 20 percent of Cable & Wireless (HK) Ltd; Cable & Wireless PLC owns the remaining 80 percent. In addition, Cable & Wireless PLC owns almost 80 percent of the Hong Kong Telephone Company. Since 1983, the Hong Kong Government has moved to deregulate the market somewhat. Hong Kong Telephone asked the Government to deregulate certain telecommunications products and services to allow consumers to buy telephones and other related products from Hong Kong Telephone's subsidiaries as well as other manufacturers. Subsequent to this request, the Government granted licenses to three cellular phone companies. The Government also allowed other companies to use the domestic telephone network for data-processing services. In August 1986, the Hong Kong government solicited bids for Hong Kong's first cable franchise. This last action reportedly intensified the pressure on the Government to deregulate the telecommunications sector. 2/

1/ Currently there are no submarine cable production facilities in Australia; given the government's local content requirements, a submarine cable facility will be developed as a part of the TASMAN-2 project.

2/ Commission staff interviews with Hong Kong industry officials and U.S. Government officials, August 1987.

<u>Domestic consumption</u>.--The Hong Kong Telephone Company first installed glass multimode optical fiber cable in 1981 for its junction network. Since the initial installation, the company has installed an average of 100 km of multimode cable per year for a total of 17,000 fkm in its overall network (approximately 600 kilometers of cable according to HKT). The Hong Kong Telephone Company's network covers all of the Territory and is, according to some reports, one of the largest urban, fiber-optic networks in the world. Over 50 percent of the 68 exchanges and 12 radio stations in the Territory are presently linked with multimode optical cable. In addition, sources report that Hong Kong Telephone laid an additional 12,000 fkms of single-mode cable during the fiscal year, beginning April 1, 1986.

Cable and Wireless (HK) Ltd. provides Hong Kong with various international telecommunication services. 1/ The company also installed its first optical fiber cable in 1981, when it linked its Kowloon branch with its headquarters in Hong Kong. This initial project used around 15 fkm of cable. In 1986, the company installed a second line between its headquarters and a satellite station in the southern part of the Territory using cable imported from GEC Telecommunications Ltd. Table 10-24 shows the extent of optical fiber cable used by Hong Kong Telephone during the 1981-86 period.

Cable and Wireless (HK) Ltd. has two new projects underway. One is a joint venture with the Guangdong Posts and Telecommunications Administration Bureau (GPTB) to develop an optical fiber system to link Hong Kong with Guangzhou. To date, Cable & Wireless (HK) has contracted with GEC Telecommunications to provide and install approximately HK $15.4 million worth of equipment. This system totalled around 90 to 100 kilometers and to have a

Table 10-24
Optical fiber cables installed by Hong Kong Telephone, by types, January 1981-October 1986

Description	Type of cable Metallic	Non Metallic 1/	Total
Number of cables	73	8	81
Total length (km)	460	32	492
Total fiber (million meters)	10.97	0.25	11.22
Number of splices	14,354	296	14,650
Number of closures	606	51	657

1/ Used in lightning-prone areas.

Source: Hong Kong Telephone Company.

1/ These services include telegram, telex, telephone, television-program transmission and reception, ship-to-shore, and air to ground communications.

capacity of 46,080 telephone circuits. It was initially equipped to handle telex, telephone, and tv transmissions between Hong Kong and Guangdong.

Another project (scheduled for startup in 1990) involves the development of a submarine digital optical cable system connecting Japan, Korea, and Hong Kong. Participants in the project include KDD of Japan, the Korean Telecommunications Authority, AT&T, and the Telecommunications Authority of Singapore. Cable & Wireless (HK) reportedly will finance 30 percent of the project. The total project is expected to cost $200 million. 1/

Although all of the fiber and cable used for these projects has been supplied by foreign manufacturers, import data are only available for 1986. 2/ Hong Kong's imports for 1986 are shown in table 10-25.

The primary supplier is Furukawa Cable Company of Japan. The company has supplied all of the 12,000 fkm of multimode cable per year used by Hong Kong Telephone between 1981 and 1986 and will supply the 12,000 fkm of single mode

Table 10-25
Optical fiber cable: Hong Kong imports, by sources

Source	Quantity (meters)	Value (US dollars)	Percentage distribution of total imports
Japan	149,599	1,259,044	99
United Kingdom	900	10,287	0.8
New Zealand	1,000	2,042	0.16
West Germany	50	782	0.04
Total	151,549	1,272,155	100

1/ SITC 773119.

Source: Government of Hong Kong, Census and Statistics Department.

cable that Hong Kong Telephone is planning to lay in 1987. Two other suppliers of much smaller amounts are BICC (UK) in 1981 and Pirelli General (UK) in 1986.

Future demand

Demand for optical fiber systems is expected to continue to be strong in Hong Kong. Hong Kong Telephone has already developed plans for a second phase of its optical-fiber replacement program. During phase two, the company plans

1/ According to industry sources, the link from Hong Kong to Okinawa will contain 5,000 fiber kilometers, the link from Okinawa to the Japan mainland will contain 5,000 fiber kilometers; the link from Okinawa to Korea will contain 1,400 fiber kilometers. Thus, the entire system will use around 11,400 fkm of optical fiber.
2/ Prior to this year, optical fiber and optical cable were included in a larger, basket category.

to complete the ring system that will link the internal Hong Kong territories. In addition, the demand for LANs from the business community is expected to continue to grow. Since Hong Kong is a major financial and business center, the data communication needs of the companies in the colony continue to escalate. As a result, there is a need for the continued development of fiber optic systems. In addition, it is likely that there will be continued financial involvement on the part of Cable and Wireless in the further development of fiber optic systems in China. Thus, Hong Kong will likely serve as a base of operations for various producers of fiber optics attempting to enter the Chinese market. 1/

Taiwan

Taiwan's fiber optic industry is currently emerging from the developmental stage. Production is limited in terms of quantity and is also limited to telecommunications applications. Taiwan's market for fiber optic products is more advanced than its industry, however. Conditions in Taiwan have lead some industry analysts to speculate that Taiwan along with Korea will emerge as strong competitors in the international market. One analyst familiar with conditions within the Taiwan optical fiber industry pointed out that whereas production was not fully underway, the Taiwanese producers have up-to-date equipment and technology and, as a result, will be able to produce products of a quality comparable with that of other major manufacturers.

Market segments

Taiwan began to use optical fiber and cable on a experimental basis in its telephone system about 3 years ago. Imports during this trial period were the sole source of the optical fiber cable used in the system. The level of imports was minimal, however, amounting to 44 kilometers in 1985 and 34 kilometers in 1986. The major suppliers of this fiber and cable were Japan and the United States.

During the 3-year trial period, four interoffice trunk systems for telephone lines were installed. Eventually the telecommunications authorities plan to replace all existing telephone lines with fiber optic components and cable. U.S. Government sources estimate that demand for optical cable will amount to around 5,000 fkm annually.

The Government of Taiwan is actively promoting the development of a local industry to satisfy the expected demand. The Government currently offers a 5-year tax holiday for a new plant or a 4-year tax holiday for an expansion project. In addition, imports of new machinery used for this industry are exempt from import duty. The state-owned Bank of Communications currently offers low-interest loans to manufacturers of fiber optics. And, at present, local users are required to purchase locally produced fiber and cable if it is manufactured locally. In the future, the use of locally produced fiber and cable is expected to increase as Taiwan authorities direct users of fiber and cable who file import applications to local suppliers. 2/

1/ Commission staff interviews with Hong Kong industry officials, August 1987.
2/ Commission staff interviews with U.S. government officials, August 1987.

China

There currently is little or no commercial production of optical fiber or cable in China. The fiber optic facilities that do exist are state-owned and, to date, have limited their operations to research projects. However, the country has been active in basic research and has made advances in theoretical optics research from the mid-1960s through the 1980s. According to industry sources, China has 10 research departments. Much of the research and development as well as manufacturing activities in this area are supervised by the Ministry of Posts and Telecommunications (MPT).

Market segments

Shanghai is considered by some to be the center for fiber optics in China. State and municipal authorities support local investment projects through the use of preferential taxes, labor assignments, and financing programs. The second important area is Wuhan, where the MPT has located its Research Institute of Posts and Telecommunications Science.

Although the MPT controls much of the manufacturing and research and development as well as the development of projects that use fiber optic systems, a number of other ministries and Government organizations are involved in the development of a fiber optics industry. 1/ MPT does not have total control over manufacturing and equipment procurement and it does not manage local telephone service. Thus, the market for fiber optic systems in China is not completely centralized. The potential demand for fiber optic telecommunications systems is considerable, according to industry sources. Much of the existing equipment is dated, and at present private telephone service does not exist. 2/

Projects that involve the development of fiber optic systems are currently underway in China. All of the projects are infrastructure projects and are detailed in China's national plan. The projects can be grouped according to four basic applications:

(1) Longhaul trunking systems;
(2) Links between digital central office switches;
(3) Internal networks for various Government ministries;
(4) Research organizations and universities that are working on domestic design. 3/

1/ For example, the Ministry of Machine Building is reportedly the largest producer of coaxial and copper cable; in addition it has developed some fiber production capability. The Ministry of Light Industry is considering the possibility of component and subassembly technology transfer. The People's Liberation Army is working on designs for telecommunications networks and local area networks. Ken Zita, Lightwave, May 1987, p. 29.
2/ One account states, "Transmission facilities consist predominantly of open steel wires; many switching centers are equipped with foreign technology dating to the 1920s, and private telephone service is unknown." Ken Zita, p. 28.
3/ Lightwave, June 87, p. 45.

The seventh 5-year national plan (1986-1990) specifies that approximately $1.35 billion be allocated to improvements in the telecommunications sectors; this amount represents a 6-percent increase over that which was allocated during the sixth 5-year plan. Some of the projects open to foreign participation include MPT's proposed line from Chongging to Wuhan to Nanjing, which is currently under construction. Other projects that have been announced are the line along the Datong-Qinghuangao railway route, and a high-speed hookup between Guangzhou and Hong Kong. Although Phillips and NEC reportedly have been fairly successful in negotiating such projects, many industry representatives indicated that it is difficult for small firms to operate profitably in the Chinese market, because both fixed and marketing costs tend to be quite high. 1/

Regardless of the high costs and changes in the political climate, it appears that the Chinese Government has placed a high priority on the development of the telecommunications system outlined in the national plan. 2/ According to one source, the growth in telecommunications traffic between Hong Kong and China is expected to be between 30 and 40 percent per year.

It is often difficult for companies to identify to whom to sell. Along with MPT and the provincial and municipal bureaus, four other industrial ministries (coal, rail, water and power, and petroleum) and the army have been allowed to develop and construct their own national telecommunications systems. To date, the only ministry (other than MPT) that is investing significantly in fiber optics is the railway. The Ministry of Railway's network consists of 250,000 subscriber lines that account for 5-12 percent of total active local circuits in China. The army is also attempting to develop an optical-fiber telecommunications network; its efforts, however, have been hampered to some extent by export restrictions imposed by supplier countries. 3/

Industry structure

China's manufacturing capacity is limited; it supplies a small portion of current consumption and is not expected to account for a large fraction of consumption over the next few years. Industry sources state that production of optical cable amounted to 2,500 km in 1984, 4,000 km in 1985, and approximately 8,000 km in 1986. Joint manufacturing ventures have been signed with Furukawa (Japan) to produce 20,000 fkm per year and Elk Corporation (United States) to produce optical cable. N.V. Philips (Netherlands) has licensed production of its optical couplers.

The Chinese Government has encouraged cooperative manufacturing arrangements and other types of agreements that would increase the amount of technology transferred into China and would facilitate the development of a

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1/ Commission staff interviews with U.S. and Australian industry officials during August and September 1987.
2/ The problems encountered by U.S. and Australian firms seem to be similar. One Australian industry official cited labor quotas as being an obstacle as well as they further exacerbate the problem of high fixed costs of production.
3/ Lightwave, June 1987, p. 46.

fiber optics industry in China. 1/ Table 10-26 delineates the extent to which various manufacturers of fiber optics have entered the Chinese market. Industry sources indicate that despite the efforts of the Chinese Government, entry into the Chinese market is somewhat formidable for many foreign manufacturers; those companies that have historical ties to the Government through proximity or economic relationships have the distinct advantage.

1/ See Lightwave, June 1987, p. 45-46 for more details.

Table 10-26
Activities of U.S. and foreign fiber optic companies in China, by companies, by countries, and by scope of projects

Company	Country	Scope of project(s)
Alcatel	France	o 170 km fiber with 100 terminals o fiber links in AT&T's installation in Wuhan
AT&T	United States	o inter office switches for 51,000 line switching installation in Beijing o 23-km fiber in Zhuhai
BICC	United Kingdom	o 190-km optical cable in Guanxi, Yunnan and Guangdong o Network feasibility studies in Peari and Yangtzee River delta and Zhejian and Jiangsu provinces o Fiber network design in Guangdong
NEC	Japan	o Fiber for the Ministry of Posts and Telecommunications Nanjing-Wuhan-Chongging long-haul route east section
Nokia	Finland	o Fiber for Datong-Beijing-Quinghuandao
Elk	United States	o $5 million joint venture for fiber and cable in Hunan
Furukawa	Japan	o $6 million joint venture for fiber and cable in Xian
GEC	United Kingdom	o 140 Mbits/sec terminals to Shenzhen
ITT/SEL	Germany	o 25-km fiber links for ITT S1240 nodes in Shanghai o Fiber for Datong-Beijing-Quinghuandao rail line
LM Ericsson	Sweden	o Short fiber hops to connect nodes in switches
NTT	Japan	o Consulting contract for rail fiber projects
Phillips	Netherlands	o 100-km fiber for Sophox private net work in Beijing
Phillips/APT	Netherlands	o Contribute to 2400km route linking Wuhan and Nanjing; built by NKF Waddinzveen o Advanced joint venture negotiations in Wuhan o Licensing agreement for optical couplers MEI
Pirella/Telletra	Italy	o Cables in Fushou, Xiamen, Nampeing, Fukian, Changsha, Dalian and Shenyang o Cables in Guangzhou-Hong Kong link o Submarine cables in Guangdong and Liaoning
Plessy	United Kingdom	o Advanced joint venture negotiations for optical devices in Shanghai o Fiber sales in Hunan
STC	United Kingdom	o 143-km fiber with 34-Mbit/sec terminals to Shenzhen o 140-Mbit/sec terminals in Guangdong o Advanced joint venture negotiations for PCM in Shanghai

Source: Lightwave, June 1987, p. 46.

CHAPTER 11. GLOBAL COMPETITION FOR OPTICAL FIBERS AND CABLES: PRESENT AND FUTURE TRENDS OF THE U.S. INDUSTRY

This chapter delineates some of the key factors that affect and are likely to continue to affect the competitiveness of the U.S. fiber optics industry. The chapter will highlight the concerns and problems identified by the respondents to the Commission's questionnaire and by other industry officials in various interviews with the Commission staff. In addition, issues raised by industry analysts and other knowledgeable sources will be evaluated. The following discussion not only identifies these factors but also examines the implications of current trends in the world fiber optics industry for the U.S. industry's future growth.

The Industry's Assessment of U.S. Competitiveness

Tables 11-1 and 11-2 show the U.S. optical fiber and cable producers' assessment of the overall health of their industry in the U.S. market as well

Table 11-1
Competitive assessment of the U.S. optical fiber industry in the U.S. market

	Source of competitive advantage: Overall assessment	Source of competitive advantage: Price advantage 1/	Selected factors (percent foreign advantage)	
	Percent	Percent		
No advantage 2/	7	7	Labor cost	52
Domestic	73	66	Materials cost	26
Foreign:			Capital cost	18
Japan	3	3	Other costs	17
France	1	3		
United Kingdom	1			
Taiwan	1			
Korea	1			
All other	15	18		

Source: U.S. producers of optical fiber and cable.

1/ May not equal 100 percent because of non-responses.
2/ Firms indicated equal advantages for U.S. and foreign producers.

as in the international market. Table 11-3 shows the competitive assessment of the U.S. optical fiber and cable industry in the international market as viewed by U.S. purchasers of these products. The domestic producers' assessment of U.S. competitiveness mirrors that of various industry analysts; whereas the U.S. industry is currently competitive, foreign producers in general, and Japan in particular, have the lead in certain sectors of the market. In interviews with the Commission, a number of industry officials in Asia and Australia as well as in the, United States noted that the U.S. industry lacks the ability to offer the kind of engineering and technical assistance that Japanese producers provide. In fact, these officials generally thought that the issue is neither the quality of the U.S.-produced

Table 11-2
Competitive assessment of the U.S. optical fiber industry in the international market

	Source of competitive advantage		Selected factors (percent foreign advantage)	
	Overall assessment	Price advantage 1/		
	------------Percent------------			
No advantage 2/...	-	8	Labor cost	48
Domestic..........	38	38	Materials cost	30
Foreign:			Capital cost	27
Japan...........	19	6	Other costs	31
France..........	6		Transportation	44
United Kingdom..	6		Engineering/	
West Germany....	4		technical assist	46
All other.......	27	38	Availability	41
			Other	70

Source: U.S. producers of optical fiber and cable

1/ May not equal 100 percent because of non-responses
2/ Firms indicated equal advantage for U.S. and foreign producers.

Table 11-3
Competitive assessment of the U.S. optical fiber industry in the U.S. market

	Source of competitive advantage		Selected factors (percent foreign advantage)	
	Overall assessment	Price advantage 1/		
	------------Percent------------			
No advantage 2/.......	8	9	Labor cost	39
Domestic..............	73	79	Materials cost	15
Foreign:			Capital cost	16
Japan...............	7	2	Product design/	
			quality	15
France..............	1		Engineering/	
Canada..............	2	1	technical asst	11
All other...........	8	9		

Source: U.S. purchasers of optical fiber and cable.

1/ May not equal 100 percent because of non-responses
2/ Firms indicated equal advantage for U.S. and foreign producers.

optical fiber and cable, nor the price of these U.S. products, which is most often in line with the prices of comparable products offered by European and Japanese producers. Rather, the problems with the competitiveness of U.S. fiber optics products frequently cited have to do with the lack of international standards, marketing and technical assistance support, lack of favorable financing, and delays, uncertainties, and other problems generated by U.S. export control policy.

These tables clearly show that the firms responding to the questionnaire consider the U.S. industry to be competitive in the U.S. market. However, in a related question (not shown in previous tables), 60 percent of the U.S. producers indicated that foreign producers have an advantage in the international market.

Because demand for optical fiber and cable has declined somewhat in the past year and a half, the competitive position of the U.S. producers in the international market is of some concern to the industry as a whole. U.S. producers have indicated that they are focusing on reducing costs and working to increase the efficacy of their marketing, as well as their research and development. In related questions on the, Commission questionnaire, industry respondents focused on the following issues.

Lack of Market Information

In the 1984 Competitive Assessment of the U.S. Fiber Optics Industry, the Department of Commerce recommended that the industry develop an association that would serve to monitor developments in the industry and collect market and industry data. Such a trade association would also serve to educate potential consumers of fiber optic systems about the potential uses of the systems.

This dual need for information on the part of the industry and on the part of the industry's potential customers was recognized by a number of respondents. Not only did they point to the need for more data, but they also indicated that more attention needed to be directed towards the education of consumers about the technical and economic viability of fiber systems. 1/

Industry Standards

The development and adoption of international standards is a major concern of many within the fiber optics industry. On the one hand, the lack of standards divides the international market for fiber optic systems by creating constraints to trade; the capital costs required to produce differentiated products to comply with the various standards that do exist are often prohibitive or are high enough to discourage U.S. companies from developing products for these markets. This is true, in particular, for optoelectronic components and optical cable. There is less of an effect (if any) on optical fiber.

The lack of standards also puts a damper on demand for fiber optic systems. Prospective purchasers are reluctant to buy systems because the adoption of standards might render the existing systems obsolete. In addition, by keeping markets somewhat fragmented, the lack of standards tends to keep the price of fiber optic systems somewhat higher than it would be if the various components of the systems could be mass produced. Thus, standardization should ultimately result in an increase in the quantity of fiber optic systems demanded, to the extent that it results in a decrease in the price of these systems. Efforts are underway in the United States, Japan, and Western Europe to develop standards, in particular those associated with

1/ For example, OITDA in Japan has amassed a great deal of data covering the Japanese and the international market.

ISDN. 1/ It seems, however, that the U.S. efforts generally are being made on an ad hoc basis. European and Japanese efforts have been more comprehensive. 2/ The companies and countries that have the greatest input in the standards debate are likely to emerge with the greatest control in the international market. Thus, to the extent that active participation in the various standards conferences would give U.S. companies more control over the development of standards, it is probably in their collective interest to do so.

For selected U.S. companies that have established niche markets, the development of international standards may hamper their competitive position by making it more viable for larger, multinational corporations to compete in these markets. Just as other countries such as Japan and Australia have developed unique standards that have served to protect their respective home industries, smaller, emerging U.S. companies have similarly benefited from the current lack of standards. On balance, however, it seems that the net result of the U.S. leadership in development of international standards will be positive for the U.S. industry.

U.S. Patents

The patent position of the U.S. optical fiber industry has been the concern of a number of industry officials. Corning's patents have clearly helped them to expand and retain and expand their market share in the United States and in the world market. 3/ This has in turn influenced the development of the U. S. fiber optics market. Moreover, its patent position has given Corning and its licensees the ability to achieve cost economies related to learning effects.

Given the strength of the U.S. optical fiber industry in the international market, various industry analysts wonder what will happen when key patents run out. In the medium term (that is, over the next 5 years), U.S. demand for fiber optic systems is not expected to increase substantially because industry sources do not expect subscriber loop systems to be developed until the mid-1990s or beyond. As a result, the entrance of foreign producers into the U.S. market could constitute a serious threat to marginal U.S. firms. Thus, a related area of concern to U.S. producers is the current openness of the U.S. market contrasted with the lack of access to the more economically developed foreign markets.

Research and Development

A critical determinant of the competitiveness of the fiber optics industry has to do with the industry's technological innovation. Thus, it is not surprising that industry representatives would express concern over the state of research and development in the U.S. fiber optics industry. They raised three general areas of concern: the scope of government funding of

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1/ See app. F for the glossary of technical terms.

2/ Commission interviews with U.S. and Western European industry and government officials and analysts during 1986 and 1987.

3/ As discussed in earlier chapters, Corning has filed patents in most major markets for fiber and cable, requring companies to enter into licensing arrangements or face the potential cost of litigation.

research and development, the lack of commercial applications for much of the government funded research and development, and the short-term focus of many of the firms in the U.S. fiber optics industry.

As data reported by the U.S. industry in the Commission's questionnaire show, most of the R&D activities undertaken by U.S. industry are funded internally. In fact, according to respondents to the Commission's questionnaire, little research and development is funded by the U.S. Government. This is in contrast with the EC countries and Japan where the respective governments take a more active role in funding and organizing R&D projects. Furthermore, U.S. Government R&D funding in this area is predominantly for military applications. Although there is some limited overlap between research done for military programs and that for the commercial sector, a great deal is not transferable either because the results are classified or because there simply are no commercial applications in the short run. 1/ In fact, given the requisite paperwork and security for most military research and the inability to transform the basic research into subsequent commercial applications, some U.S. companies indicated that it was not in the firm's best interest to pursue government-sponsored R&D programs.

The conclusion that can be drawn from industry comments is that U.S. Government R&D deserves more attention as a key factor in the competitive future of the industry. A subject for future study would be to examine the efficacy of joint R&D programs supported by the Japanese Government. What needs to be determined is (1) how successful these programs are compared with the R&D undertaken by individual U.S. firms, and (2) whether such a government- sponsored industry consortium would be successful in the United States. The joint Sematech project promoted by the U.S. semiconductor industry suggests that many in a closely related industry believe that it is not only worth the effort but may be crucial. 2/

Openness of the U.S. Market

A number of industry analysts and representatives cited the U.S. Government's policy of allowing foreign competition in the U.S. market as being a concern. As one company noted, the openness of the U.S. market and the resulting foreign competition is not really a problem; the real problem for U.S. firms is that many of the major foreign markets are closed to U.S. companies. This is the case even when these U.S. companies gear their production and marketing for the specific foreign markets. The companies indicated that U.S. Government efforts 3/ to encourage the opening of various

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1/ In interviews with various U.S. optoelectronic component manufacturers, the Commission inquired about the possibility of transferring technology developed for various military programs to applications in the commercial sector. In most instances, the officials indicated that the research had little practical applicabilty over the next 5 years.

2/ In interviews with the Commission, various optoelectronics industry officials stated that they thought that the joint arrangements would produce results that would enhance the competitiveness of the U.S. industry; however, they did not believe that the major U.S. firms would participate in this type of venture.

3/ For example, U.S.--Japanese bilateral talks were cited by questionnaire respondents as generating useful changes in the Japanese Government's policies that govern the accessability of the Japanese market.

foreign markets had been useful, and therefore should be continued. The companies noted that protectionist U.S. trade policies might ultimately prove to be counterproductive.

According to the companies, one problem associated with the erection of barriers to foreign competition in the U.S. market has to do with the growing internationalization of U.S. corporations in the fiber optics industry. This report has discussed the international and interrelated nature of the optical fiber and cable producers in preceding chapters. Many of the U.S. companies have facilities in other countries or have entered into joint ventures with firms in other countries. An increase in U.S. nontariff and tariff barriers might actually make it more difficult for the U.S. industry to compete in the international market because the barriers would potentially increase the price of intermediate goods and component parts, many of which must be imported. 1/

The U.S. industry is far from being perfectly competitive. Opening up the world market will not necessarily reduce the degree of concentration in the U.S. industry. In certain instances such as the submarine cable sector of the industry, the existing degree of concentration in the industry and the nature of demand for the product make truly competitive conditions unlikely in the next 5 to 10 years, say industry analysts. In the submarine cable sector, for example, it is unlikely that the number of producers in the international market will increase by more than a few. 2/ Since most of the projects are financed and controlled by consortia of telecommunications operations, which (with the exception of the U.S. concerns) are mostly affiliated with their respective national governments, contract awards are not made solely on the basis of competitive bids. For example, whereas foreign companies are allowed to land their cable on the U.S. shore, the U.S. company does not have a similar right in European countries. Industry officials have suggested that the U.S. Government should place similar constraints on foreign manufacturers in order to make the playing field even.

Industry Targeting

A related issue is industry targeting. A number of respondents as well as industry officials interviewed indicated that the U.S. industry was at a disadvantage with respect to the Japanese industry because of government support for the export activities of the Japanese fiber optics industry. It is clear that such practices have generated positive results for Japan's firms in the targeted industries, although some research suggests that Japan's policy of protecting its high-tech industries may generate some macroeconomic costs. 3/ Nonetheless, Japan's practice of selectively supporting certain export sectors clearly has given many of its leading-edge industries a competitive advantage in the international market.

1/ A number of U.S. producers indicated in responses to the Commission questionnaire that it was necessary to import production equipment and materials because of lack of quality and/or availability in the U.S. market.
2/ At present, there are reportedly four producers and a fifth is expected to be established in Australia in 1988.
3/ See Baldwin and Krugman for an analysis of the benefits and costs of Japan's protection of the semiconcductor industry.

Financing

A critical factor affecting the competitiveness of the fiber optics industry is related to the U.S. industry's ability to offer favorable financing to prospective consumers of fiber optic systems. One advantage that various industry officials attribute to Japanese companies is their ability to offer attractive financing for large-scale fiber optics projects. This clearly constitutes an advantage in the international market. Much of the current and future demand for telecommunications systems comes from and is expected to come from the newly industrialized countries and some of the less-developed countries. The ability to offer flexible financing may significantly affect the U.S. industry's ability to win contracts in these countries.

In addition, the U.S. industry is faced with capital costs that are significantly higher than those faced by the Japanese industry. 1/ Given the capital-intensiveness of the fiber optics industry and the U.S. industry's reliance on internal funds for research and development, the relatively higher capital costs faced by the U.S. industry currently place it at a disadvantage with some of its major competitors.

U.S. Marketing Practices

In interviews with foreign purchasers of optical fiber and cable, a frequently cited factor that affects the competitiveness of U.S. fiber and cable industry in the international market is the U.S. producer's unwillingness to gear their production to the specifications of their potential customers in other markets. 2/ This problem was cited for optical fiber and cable producers as well as optoelectronic components producers. Another problem identified by various foreign industry officials in Asia and Australia concerned the U.S. industry's lack of knowledge of the international market; not only did U.S. manufacturers show an unwillingness to produce according to other countries' standards, but at times the manufacturers also displayed a total lack of understanding of the foreign markets. In other words, many U.S. producers would fare better in the international market if they focused more effort on intelligence gathering, as well as on product design and marketing tailored specifically to the requirements of prospective foreign markets.

Export Controls

One of the principal complaints of U.S. manufacturers and foreign purchasers of optical fiber, cable, and optoelectronic components concerns export controls. The various industry officials who expressed their opinions regarding U.S. export controls generally recognized the need for export controls. Their complaints centered on (1) the scope of the controls, (2) the delays associated with the administration of the controls, and (3) the paperwork burden these controls represent for U.S. producers and their foreign affiliates and customers.

1/ Albert Ando and Alan Auerbach, NBER Working Paper No. 2286.

2/ In one instance, a U.S. manufacturer that used optical fiber as an input for another product, indicated that the major U.S. optical fiber producers were not willing to produce the type of fiber that the manufacturer needed. As a result, this U.S. manufacturer has to rely on a Japanese producer for the fiber input.

Disputes over the controls focus on a chronic issue concerning what fiber optic products are widely available in the international market. Efforts are being made by U.S. Government officials at the Department of Commerce to update the list and eliminate many of the low tech items. 1/ In addition, officials are taking steps to reduce the length of the waiting period for a license to as short as 14 days. 2/ Other changes that have been suggested either by Government officials or as a part of potential legislaton include limiting DODs oversight responsibility and increasing the size and strengthening the technical expertise of the Commerce Department staff responsible for administration of the program. The rationale behind all of these suggested changes is quite clear: the U.S. industry is at an unfair disadvantage.

> Between unilateral restrictions placed on U.S. domestic products and bureaucratic indecision in Washington, foreign companies are moving away from purchasing current U.S. parts or designing U.S. components into future products. I have seen letters written by CEOs of major foreign companies instructing their managers to "design out" U.S. parts from their product. This is being done to eliminate the problem of these companies being bound by the U.S. re-export regulations and other unilateral restrictions that accompany our products throughout the world. 3/

There is a growing awareness that export regulations need to be brought more in line with the regulations followed by the CoCom countries. Fiber optics industry officials in the United States and foreign countries made it quite clear to the Commission staff that the situation described in the passage above is not a disappearing phenomenum. Whatever changes have been made to the U.S. export regulations, the industry would like to see many more. 4/

Conclusions

The Medium Range Demand Outlook for Fiber Optics Systems

At present, most of the developed country long-line networks have been completed (or are scheduled to be completed within the next few years). Industry analysts expect a resurgence in demand to occur in the early 1990s, as submarine cable projects and additional long-distance networks are developed or retrofitted in the newly industrialized and less-developed

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1/ Hunter Alexander, "Baldrige Fights De-Americanization," Washington Technology, Mar. 5, 1987, p. 9.
2/ Ibid.
3/ Malcolm Baldrige, quoted in Ibid.
4/ The Commission interviewed various U.S. producers of optical fiber and cable and optoelectronic components manufacturers in the Untied States between August 1986 and September 1987. In addition, the Commission interviewed similar producers in Western Europe, Australia, Japan, and Korea. The majority of these officials (both representatives of U.S. and foreign fiber optics firms) indicated that the export regulations needed to be revised to some extent.

countries. In the medium term (over the next 5 years), potential demand is less likely to provide a basis for expansion, than to permit existing producers to use existing production capability more fully. The probability of this outcome is increased by technology trends which have expanded capabilities of existing fiber optic systems considerably.

In the 1990s, industry experts expect the demand for intermediate and local lines, LANs, and subscriber loop links to the home to develop rapidly. Already, the market for local area networks for campus systems as well as within buildings has begun to develop. Ultimately, when the market for subscriber loop systems to the home fully develops, the resultant increases in demand will be sufficient to support additional optical fiber and cable producers. Industry analysts have been understandably reluctant to predict when this might occur.

Competitive Scenarios for the Longer Term

As discussed in previous chapters, optical fiber is apporaching the mature stage and has begun to acquire the characteristics of a commodity item. Vernon's product life cycle theory suggests that at this stage, costs advantages should shift production to the newly industrialized countries, such as Taiwan and Korea. However, despite the fact that Korea has developed its own optical fiber and cable industry, the advantage has not shifted away from the major producers in Japan, North America, and Western Europe. In fact, it seems possible that some analysts have been too quick to characterize fiber strictly as a commodity item; it seems just as likely that not all of the major technological breakthroughs have been achieved. This probability appears to have three consequences at present. First, competitors expect that Corning may be on the verge of introducing new technological innovations and filing new patents; as their key patents are about to expire, this action would help Corning to maintain its dominance in the U.S. and international markets. Second, wheraas some competitors may be prepared to cede the field, assuming that optical fiber is at the commodity stage, at least one firm (Sumitomo Electric) appears intent on challenging Corning in terms of developing its own new technology, thereby gaining the competitive edge. Third, even if optical fiber matures as a commodity without further technological breakthroughs, some in the industry believe that the road to future success depends on the development, production, and supply of the optoelectronic components used in the fiber optic systems; that is, the companies that will have a clear advantage will be those that can develop a lead in optoelectronics around which the systems are designed and then manufacture and supply the entire fiber optic system to the final consumer.

Following this third scenario, optical fiber production will inevitably become more standardized; more firms, especially in the newly industrialized countries, will enter the market and profit margins will become increasingly narrow. The smaller the fiber optic system, the greater the importance of optoelectronic components, because smaller systems tend to be more component intensive. Thus, as the market moves progressively toward LANs, intrabuilding, and other more confined systems, improvements in optoelectronic component technology are likely to affect the demand for the systems (and consequently the fiber contained in the system), and are likely to result in substantial profits for the firms that develop the application of new technology. The optoelectronic components producers that expand into systems development may either produce or purchase optical fiber, and as more firms enter the optical fiber market, there will be greater supply resulting in lower prices and potentially lower profit margins. From the optical fiber producer's viewpoint, the best way to assure the use of the firm's product is to integrate optoelectronics production and systems development.

According to this scenario, firms such as AT&T and Corning can maintain position best by integrating vertically to acquire or develop greater optoelectronics and systems capabilities, and thus assure that these systems will use their optical fiber. If others are quicker to develop the lead in major optoelectronic devices and systems, their ability to choose from a variety of optical fiber suppliers based on terms of offer would tend to undermine the lead of the now-dominant suppliers.

It may be several years before it can be discerned which of the three scenarios will prove to be true. Meanwhile there is evidence of effort in all three directions: Corning's continued defense of its patent rights suggests that it will do everything it can to strengthen and maintain technology leadership in the optical fiber market; but, it has also gained a growing optoelectronics capability through acquisitions of small optoelectronics firms over the past few years. Similarly, reports of Sumitomo Electric's efforts to achieve technological breakthroughs in optical fiber production and product technology continue to circulate. However, through interviews worldwide, the Commission found instances of optical fiber producers content to maintain current optical fiber capability, whereas others were prepared to leave the field and concentrate on optoelectronics and systems development.

From available indications, it matters significantly for U.S. global competitiveness which of the three scenarios comes to dominate. Clearly under scenario 1, the continued dominance of firms like Corning and AT&T leave the United States in a favored competitive position globally; scenario 2 could result in a major shift of advantage to Japan; and scenario 3 has equivocal potential.

As we have seen, the present U.S. optoelectronics industry is not particularly concentrated, not unlike the U.S. semiconductor industry at its same stage of development. Although a few producers are diversified electronics suppliers and can afford to carry the development work for new lines using the income derived from their established markets, many of these firms are not large compared with potential contenders in the field. Main Japanese contenders in this field are presently the major diversified firms that now dominate electronics in Japan; in the United States only AT&T seems to have comparable resources and versatility, unless IBM or other major U.S. computer/electronics firms should become late entrants into the field. On balance, if this scenario proves to have the edge in the 1990's, Japanese or other East Asian firms, or some of the broadly integrated European firms such as Philips, and Siemens, may establish the kind of competitive challenge that has eroded U.S. leadership in electronics in the past decade.

The uncertainties of outlook are not extraordinary for this early stage in a newly emerging industry, of which the future shape is only vaguely discernible. However, if we narrow the focus to the near-term outlook for the U.S. fiber optics industry, factors determining competitiveness are easier to delineate. Since ultimately the outcome of the contending scenarios could swamp many of these near-term factors, observers of the industry will want to keep an eye on future indications of which scenario(s) most accurately describe developments.

It is clear that the U.S. optical fiber and cable industry and, indeed, the overall U.S. fiber optics industry currently is competitive in the U.S. and in the international market. It is not clear, however, whether the U.S. fiber optics industry will remain competitive. Perhaps the most important factors affecting the future competitiveness of the U.S. industry include access to foreign markets, 1/ U.S. export controls, the ability of the industry to develop new technology, and international standards. Most U.S. industry officials believe that without any action on the part of the U.S. industry and the U.S. Government, it seems likely that some of the critical foreign markets will remain closed, or access will be quite limited. In addition, they believe that if export control procedures are not streamlined and if the export control list is not revised periodically to reflect changes in foreign availability of new technology, U.S. industry efforts to compete internationally will continue to be hampered. Faced with limited access to foreign markets and increased competition in the U.S. market as certain key U.S. patents expire, U.S. industry representatives state that they find their companies losing the competitive edge. Industry analysts believe that a continuation on the part of the U.S. Government to favor military-related research and development and a continuation on the part of the U.S. industry to favor short-term R & D projects that suit its profit objectives will result potentially in further deterioration of the U.S. industry's relative position in the international market. 2/ Such deterioration will be exacerbated if European and Japanese Governments continue their efforts to develop comprehensive, commercially oriented R&D programs. Finally, if the U.S. industry continues its ad hoc approach to the development of standards, industry analysts believe it will lose ground to more aggressive Japanese and European efforts in this area as well.

Interviews with various U.S. and foreign industry officials as well as discussions with other industry analysts and U.S. Government officials have provided the Commission with various suggestions as to how to mitigate these negative medium-term prospects. According to these officials, the U.S. Government needs to continue to improve U.S. industry access to foreign markets, particularly Japan and the EC. Once these efforts are underway, the U.S. industry needs to intensify its own efforts on two levels; first, to improve its information-gathering efforts and to increase its marketing programs, and second, to adapt its products to meet foreign standards, until international standards are fully developed and accepted.

From the industry's point of view, gaining access to portions of the international market will be inconsequential, however, if the U.S. Government does not continue its efforts to keep the foreign availability assessments of its export control list more up-to-date and compliance requirements for U.S. export control regulations more in line with the CoCom regulations followed by the U.S. industry's major competitors. 3/ Closer cooperation and more effective communication between the U.S. Government and the U.S. industry in this area is being sought.

1/ Including the extent and effectiveness of U.S. Government efforts to help the U.S. industry to increase its access to particular markets.
2/ Interviews by the Commission with optical fiver and optoelectronics industry officials and analysts during fieldwork in 1986 and 1987.
3/ Efforts to gain greater cocom conformance have continued to have major discrepancies in practice to the disadvantage of U.S. producers.

In addition, the U.S. industry (with the support of the U.S. government) might consider taking a more active role in the development of international standards, say U.S. and foreign industry analysts. Active participation in this process may be one way to ensure that the U.S. industry will be able to influence the final outcome and minimize the changes that the U.S. industry will have to face.

Efforts to broaden the scope and improve the effectiveness of U.S. R&D would be beneficial to the U.S. industry, say industry experts. On the industry's part, it may help to shift the balance of R&D programs from the short-run toward the long-run. 1/ The type of research conducted globally in the fiber optics industry tends to be medium to long-term in nature. Thus, placing short-term profit constraints on R&D programs may be consistant with corporate profit objectives in the shortrun, but is believed by industry participants to be counterproductive in the longrun. On the U.S. Government's part, some U.S. industry officials indicate that it may be necessary to examine direct incentives such as military development programs. As various industry experts pointed out, a shift toward funding research programs with commercial objectives might create a greater return for the funds allocated and might help give the U.S. industry more of a competitive edge relative to its Japanese and European counterparts. Industry officials also suggested that the U.S. Government examine the efficacy of indirect incentives such as R&D tax credits and various macroeconomic policies that could be used to help increase industry R&D efforts. To do this, they suggested that the government examine Japanese Government efforts, to determine whether it would be feasible to follow a strategy similar to that of Japan.

The U.S. industry can also work towards increasing the demand for fiber optic systems say industry and government analysts. As Department of Commerce officials and various industry representatives have noted, the establishment of a trade association not only would help the industry in its intelligence-gathering in the U.S. and international markets, but also would serve as a means to heighten consumer awareness of the economic and technological advantages of fiber optic systems over alternative systems and government awareness of the industry's concerns on issues such as Government R&D policy and export controls.

The U.S. industry's reliance on imported materials and production equipment is viewed as a liability by some analysts in and out of the industry. According to industry officials this reliance is due, in part, to a lack of skilled machinists and design engineers as much as it is due to a lack of natural resources. 2/ Appropriate changes in U.S. education or technical training may be necessary to alleviate the U.S. dependence on foreign production inputs, they say.

The future development and competitiveness of the U.S. fiber optics industry will affect not only the associated high-tech industries, such as the computer industry, but also many basic manufacturing industries. For example, its importance to the future of the United States in the next generation of

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1/ Interviews by the Commission with industry analysts in the fiber optics field at various times during 1986 and 1987.

2/ Various representatives of U.S. fiber optics firms discussed their inability to hire competent machinists and design engineers. They pointed out that as a result, they were forced to rely on equipment designed and manufactured in Japan and/or certain Western European countries. Responses to the Commission's questionnaire supported this assertion.

major computer developments, in manufacturing technology, and national defense may well be pivotal. Thus, the issues highlighted above need to be addressed more fully and intensively than they have been to date. Hopefully this report will provide some insight into how these basic issues can be evaluated and resolved.

Appendix A

Request letter from the Senate Committee on Finance

United States Senate

COMMITTEE ON FINANCE
WASHINGTON, DC 20510

CHAIRWOMAN USITC
86 FEB 13 P5:01

February 12, 1986

The Honorable Paula Stern
Chairwoman
U.S. International Trade Commission
701 E Street, N.W.
Washington, D.C. 20436

Dear Madam Chairwoman:

The Committee on Finance requests that the United States International Trade Commission conduct a series of investigations under section 332 of the Tariff Act of 1930, on the international competitiveness of selected major United States industries.

The 99th Congress faces important decisions regarding a wide range of trade issues, including Administration efforts to launch a new round of multilateral trade negotiations aimed at reducing international barriers to trade in goods, services, and investment flows. To guide Congress in decisions about the future of the international trading system, the Committee needs to understand the competitive strengths and viability of key U.S. industries, the extent and nature of competition facing these industries in foreign and domestic markets, and the extent to which any current trade problems result from special situations such as the strong dollar, debt and interest rate problems, or from more fundamental competitive problems.

Several witnesses appearing before this Committee have stressed that U.S. competitiveness and industrial viability must be gauged in terms of performance in international as well as domestic markets. It is important for these studies to examine the viability of these industries and U.S. trade negotiation objectives from the vantage point of the global nature of competition and the internationalization of production and ownership.

For each of these industry studies the Committee requests coverage of:

The Honorable Paula Stern
Page 2
February 12, 1986

1. Measures of the current competitiveness of the U.S. industry in domestic and foreign markets;

2. Comparative strengths of U.S. and major foreign competitors in these markets;

3. Nature of the main competitive problems facing the U.S. industry;

4. Sources of main competitive problems; to what extent from:

   a. special transitory or reversible situations such as exchange and interest rate problems, as opposed to

   b. fundamental or structural problems;

5. Competitive strategies; how important are foreign and U.S. markets to future competitiveness, in terms of economies of scale, growth rates, and pre-empting of market advantages.

The Committee decided not to identify specific industries or numbers of studies, but envisages up to seven studies. The Committee has instructed its staff to work out with ITC staff the specific industry selection and production schedule, depending on availability of appropriate staff to conduct them within the requested time. However, it requests that all studies be completed within 18 months and submitted to the Committee individually as completed.

The industries to be studied should be pivotal to overall U.S. industrial and technological strength, by virtue of being (a) either pathbreaking in the development of leading edge technologies that will shape future competitiveness of other U.S. industries, or (b) supplying critical equipment or materiel used in other important industries. The selection should be diverse enough that the range of their impact should reach broadly across the entire spectrum of U.S. industrial strength, represented by the seven tariff schedules. Examples would be key industrial agricultural commodities, selected synthetic organic chemicals, and textile fabrics, along with the equipment producing industries associated with each.

The Honorable Paula Stern
Page 3
February 12, 1986

The Committee recognizes that much of the information and data desired may not be available from secondary sources and that primary data gathering may prove essential to understanding global industry competition. It requests that in meeting the objectives of these studies the Commission develop new sources of information outside the United States through both interviews and questionnaires where possible, to assure effective assessment of the strengths and weaknesses of foreign competitors, and of the terms of competition in key foreign markets.

Sincerely,

Bob Packwood

BOB PACKWOOD

United States Senate

COMMITTEE ON FINANCE
WASHINGTON, DC 20510

April 2, 1986

Dr. Paula Stern
Chairwoman
United States International
Trade Commission
701 E Street, N.W.
Washington, D.C. 20436

Dear Chairwoman Stern:

Pursuant to my February 12th letter to you requesting a series of investigations on U.S. international trade competitiveness under section 332 of the Tariff Act of 1930, this is to confirm that the following specific sector studies are requested within that general heading:

Auto parts and equipment
Optical fibers and associated technology and equipment
Steel sheet and strip and associated equipment
Textile mills and associated equipment
Building-block petrochemicals: Competitive implications for construction, cars, and other major consuming industries

The Committee still has under consideration additional requests within the overall survey, and will relay those to you shortly.

The Committee understands that the International Trade Commission cannot begin and complete all the studies simultaneously, but requests that it begin them as soon as staff resources are available so the Committee will have results available as soon as possible for its consideration of the future of the trade agreements program.

Sincerely,

Bob Packwood

BOB PACKWOOD
Chairman

Appendix B

Notice of Institution of Investigation No. 332-233
in the Federal Register

concerning the building-block petrochemical industry on such end-user industries as the automotive and construction industries.

Public Hearing

The Commission will hold a public hearing on this investigation as well as the four others in this series (Inv. Nos. 332-229 through 332-233) at the United States International Trade Commission Building, 701 E Street NW Washington, DC, beginning at 10:00 a.m. on February 24, 1987.

All persons shall have the right to appear in person or by counsel, to present information and to be heard. Persons wishing to appear at the public hearing should file requests to appear and should file prehearing briefs (original and 14 copies) with the Secretary, U.S. International Trade Commission, 701 E Street NW., Washington, DC 20436, not later than noon, February 2, 1987. If the Commission decides to hold one or more hearings outside of Washington, DC, it will issue a supplemental notice of hearing by January 6, 1987.

Written Submission

Interested persons are invited to submit written statements concerning the investigation. Written statements should be received by the close of business on November 21, 1986. Commercial or financial information which a submitter desires the Commission to treat as confidential must be submitted on separate sheets of paper, each clearly marked "Confidential Business Information" at the top. All submissions requesting confidential treatment must conform with the requirements of § 201.6 of the Commission's *Rules of Practice and Procedure* (19 CFR 201.6). All written submissions, except for confidential business information, will be made available for inspection by interested persons. All submissions should be addressed to the Secretary, United States International Trade Commission, 701 E Street NW., Washington, DC 20436. Hearing-impaired individuals are advised that information on this matter can be obtained by contacting our TDD terminal on (202) 724-0002.

Issued: July 22, 1986.

By order of the Commission.

Kenneth R. Mason,

Secretary.

[FR Doc. 86-17102 Filed 7-29-86; 8:45 am]

BILLING CODE 7020-02-M

[332-233]

U.S. Global Competitiveness: Optical Fibers, Technology and Equipment

AGENCY: United States International Trade Commission.

ACTION: Institution of investigation.

EFFECTIVE DATE: July 9, 1986.

FOR FURTHER INFORMATION CONTACT: Mr. Christopher Johnson or Ms. Linda Linkins, General Manufactures Division, Office of Industries, U.S. International Trade Commission, Washington, DC 20436 (telephone 202-724-1730 or 202-724-1745, respectively).

Background and Scope of Investigation

The Commission on July 9, 1986, approved the institution of investigation No. 332-233, following receipt of letters on February 13, 1986 and April 2, 1986, from the Chairman of the Committee on Finance, United States Senate, requesting that the Commission conduct a series of investigations under section 332(b) of the Tariff Act of 1930 (19 U.S.C. 1332(b)) concerning the international competitiveness of a broad range of selected major United States industries. Institution of this study is scheduled for September 10, 1986.

The Commission investigation will examine the U.S. optical fiber industry, and its major foreign competitors, to determine the impact of global competition on the industry, and to assess how the industry is responding to these dynamic forces. As requested by the Committee, the Commission's report will analyze and address: (1) Measures of the current competitiveness of the U.S. industry in domestic and foreign markets; (2) comparative strengths of U.S. and major foreign competitors in these markets; (3) the nature of major competitive problems facing the U.S. industry; (4) the sources of these problems, including the extent to which they arise from special transitory or reversible situations or are the result of more fundamental or structural problems; and (5) the importance of U.S. and foreign markets to the future competitiveness of U.S. and foreign producers, in terms of economies of scale, growth rates, and pre-empting of market advantages.

Public Hearing

The Commission will hold a public hearing on this investigation as well as the four others in this series (Inv. Nos. 332-229 through 332-233) at the United States International Trade Commission Building, 701 E Street, NW., Washington, DC, beginning at 10:00 a.m. on February 24, 1987. All persons shall have the right to appear in person or be represented by counsel, to present information and to be heard. Persons wishing to appear at the public hearing should file requests to appear and should file prehearing briefs (original and 14 copies) with the Secretary, U.S. International Trade Commission, 701 E Street, NW., Washington, DC 20436, not later than noon, February 2, 1987. If the Commission decides to hold one or more hearings outside of Washington DC, it will issue a supplemental notice of hearing by January 16, 1987.

Written Submissions

Interested persons are invited to submit written statements concerning the investigation. Written statements should be received by the close of business on March 12, 1987. Commercial or financial information which a submitter desires the Commission to treat as confidential must be submitted on separate sheets of paper, each clearly marked "Confidential Business Information" at the top. All submissions requesting confidential treatment must conform with the requirements of § 201.6 of the Commission's *Rules of Practice and Procedure)* 19 CFR 201.6). All written submissions, except for confidential business information, will be made available for inspection by interested persons. All submissions should be addressed to the Secretary, United States International Trade Commission, 701 E Street NW., Washington, DC 20436. Hearing-impaired individuals are advised that information on this matter can be obtained by contacting our TDD terminal on (202) 724-0002.

Issued: July 22, 1986.

By order of the Commission

Kenneth R. Mason,

Secretary.

[FR Doc. 86-17103 Filed 7-29-86; 8:45 am]

BILLING CODE 7020-02-M

[332-231]

U.S. Global Competitiveness: Steel Sheet and Strip Industry

AGENCY: United States International Trade Commission.

ACTION: Institution of investigation.

EFFECTIVE DATE: July 9, 1986.

FOR FURTHER INFORMATION CONTACT: Ms. Nancy Flecher, Minerals and Metals Division, Office of Industries, U.S. International Trade Commission, Washington, D.C. 20436 (telephone 202-523-0341).

Appendix C

Official Transcript of Proceedings before the U.S. International Trade Commission in the matter of U.S. Global Competitiveness: Optical Fibers, Technology and Equipment, Investigation No. 332-233

C-2

Please return to Edward H.

[O]FFICIAL TRANSCRIPT
[P]ROCEEDINGS BEFORE

THE U.S. INTERNATIONAL TRADE COMMISSION

MEETING OF THE COMMISSION

DATE: February 24, 1987

TIME: 9:38 a. m. - 7:10 p. m. (AFTERNOON & EVENING SESSIONS)

PAGES: 138 thru 361

In the Matter of:

U.S. GLOBAL COMPETITIVENESS

INVESTIGATION NO. 332-229 THROUGH 332-233

FEB 26 1987

ALDERSON REPORTING

(202) 628-9300

20 F STREET, N.W.

MR. AVERY: Thank you.

COMMISSIONER LODWICK: Again, thank you very much, Mr. Ellwein. It was helpful testimony.

Mr. Secretary?

MR. MASON: Mr. Chairman, the next witness is Mr. Paul Polishuk, please.

TESTIMONY OF PAUL POLISHUK, PRESIDENT, IGI CONSULTING, INC., BOSTON, MASSACHUSETTS.

(Having been first duly sworn by Secretary Mason.)

COMMISSIONER LODWICK: Please proceed.

MR. POLISHUK: Evening, gentlemen, Mr. Chairman, members of the Commission:

Thank you very much for inviting me to come here this evening. I know it's been a long day, and I'll try not take much of your time.

I feel somewhat like a fish out of water in that I don't represent an industry or a company, but I represent a publisher, my publishing company.

My name of Paul Polishuk, I represent and I'm president of Information Gatekeeprs, Incorporated. We publish essentially in the fiber optics field.

I've been associated with the fiber optics field since 1971 when I was first a member of the U.S. government as a member of the Office of

Telecommunications. And then I left to form my business in 1977.

Since the founding of our company, Information Gatekeepers, Incorporated, we've been actively involved in tracking this field of fiber optics from its development worldwide.

As a publisher in the field, I've observed that -- we believe in free and fair trade. It's our opinion that trade in these two fields are not free and fair, and many barriers still exist today.

The rules of the game are presently being played differently for various major market sectors.

Let me state at the outset that fiber optics is critical to the U.S. industry. And although our leadership in this has been eroded due to a number of factors including our own government ineptness, the competitive nature of the world market, and to a certain degree, the lack of aggressive promotion by our own industry, still, fiber optics is in its infancy, and much of the future lies ahead of us.

The U.S. can still regain and maintain its competitive edge, but only if government and industry work effectively together toward the same goal.

I've tried in this testimony to outline the reasons in as much detail as possible for the present situation and possible U.S. action.

They represent only my viewpoint, and I'm sure during the course of the hearings and your staff investigations, you'll have lots of other points of view.

And as I point out, I do not represent the fiber optics industry; I represent my own personal views.

But I would like to make it clear that the limited resources of our small company are available to your staff.

Rather than bore you with my background, you can read it in the prepared text, I'd like to quickly review the reasons for the present U.S. competitive situation in the field of fiber optics. It will differ somewhat from the standpoint of what you've heard in previous testimony.

But what I'd like to do is highlight those pieces and those parts that deal directly with government interventions and possible government actions in this field.

As I pointed out earlier, or have tried to earlier, the issue that you are addressing is not a new one.

As early as 1971, there was express concern by certain government employees and members of the industry concerning the competitive position of the U.S. industry in fiber optics.

It was obvious to those observes that certain countries saw fiber optics technology and markets as a key to their economic growth, and were planning to invest heavily in not only the development of the technology, but also experimental trials of large enough size to determine the economic feasibility of technology, and put their industries far down on the learning curve.

It was clear that the main target would be the large, open and lucrative U.S. market. It was, then, as it is now, that most markets were closed to U.S. manufacturers in telecommunications, and especially with regard to fiber optics, to protect their infant industries, until they became of a size to compete in the international marketplace.

Now, I'd like to just discuss a number of factors, the first of which is lack of attention to the early warning signals by government.

Although it was recognized as early as the early seventies that the Japanese and Europeans were recognizing themselves that fiber optics was an important future technology, and that develoment of this technology would lead to large market opportunities, U.S. government officials, usually political appointees in major decision making position, disregarded the signs or paid little attention to them.

Studies and recommendations by government organizations and employees went unheeded.

This is perhaps endemic in a system where priority is put on near term problems, and the long range problems get short shrift.

Signals continued to be transmitted to the government, but no attention was paid to these signals. Even a report of competitive assessment prepared by the Commerce Department as early as two years ago does not seem to receive any attention.

Why put the resources into competitive assessments unless some action is taken? So that's one of the problems I present before you.

Another problem is the lack of aggressive overseas marketing by U.S. firms. From our following of the trade in fiber optics around the world, a number of U.S. firms both large and small actively promoting fiber optics overseas is rather small.

Japanese and European fiber optics firms, however, are actively promoting sales overseas, and especially to Third World countries.

Part of this is due to the rapid growth that existed in the U.S. telephone market, occupying the interests of U.S. manufacturers, getting fat and happy with the U.S. market.

Now that this market has slowed somewhat, there's now an interest being showed by our manufacturers in these foreign markets. And they're now starting to shift their efforts.

However, market positions have already been estalished by our competitors.

Next point is competitive assessment capability and resources are lacking within the U.S. government. You're planning on a rather ambitious competitive assessment of this technology, but the U.S. government, who is the main organization that has been involved in this, and the Commerce Department, should be performing competitive analysis on key technologies such as fiber optics on an ongoing basis.

We've already pointed out that the fiber optics competitive assessment is being updated at the Commerce Department. But despite valiant efforts by the staff, I fear it will not provide a comprehensive and realistic view of the U.S. industry market position.

This is due to a number of factors, the most important of which is the inability for even limited resources to visit U.S. manufacturers, to collect critical, unbiased information.

Travel funds are usually not available, and as a result, the staff has to rely on manufacturers to provide the information, often from the local offices where it's a phone call away.

Another factor is that lack of technical expertise to evaluate major developments and relate them to market opportunities and competitive strategies of foreign companies and manufacturers.

In a high technology such as fiber optics, it's critical that your marketing assessments understand the technology involved.

Often the technical expertise resides in the government, but it's hardly ever called upon for fear of treading on someone else's turf, while possibly not knowing where the expertise resides in the Federal government.

Next is the lack of a centralized data base and memory. There is no central data collection capability concerning industry statistics on fiber optics component systems within the government today.

So if you perform a competitive assessment, you're going to compare it to what? There presently are no statistics collected, not only in the U.S. It's not available in the U.S. What do you think about obtaining data on other countries? The situation is even worse.

We know of only one country, and that is Japan, that has an association -- called the Opto-electronics Industry Technical Development Association -- formed by the largest fiber optics manufacturers at the urging of MIDI, a government organization.

This association collects and publishes production statistics and market forecasts of fiber optics markets in Japan and around the world.

With the shifting of people within government, as we know, there has to be some sort of long term commitment to track -- commitment and memory -- to track and retrieve data on important trends, rather than trying to reinvent the wheel whenever people change jobs.

C-11

Next, the data collection capability within the U.S. government. The Department of Commerce must rely on its foreign posts to collect data on fiber optics development in the major developed countries of the world, commercial officers are often not familiar with telecommunications and know less about the fiber optics industry. Besides not being experts, they are often overburdened since they must support many industry groups and requirements.

The excellent questionaire, I think, prepared by your staff to major U.S. embassies around the world was well done. I dare say that the commercial officer has little inkling of how and where to get the information requested and to assess its relevance and value, although I have been somewhat surprised in talking to your staff that the returns are not so bad.

Often at foreign posts we have found, at least in our travels around talking to people at various posts there are the necessary resources to collect and analyze the in-country data, but often these elements do not communicate with each other. For example, at the embassy in Tokyo technical expertise exists within the scientific attache, the military attache, other government technical representatives that are located around the embassy as well as the Naval Research

Laboratory. But the resources do not communicate as there is no formal mechanism for them to communicate, and hence there is no information exchanged.

Since there is no association there is no central industry focus for fiber optics presently. I am sorry to say you have got one industry representative, but where are your other representatives to the industry? And I think that is indicative of the young age of the fiber optics industry in that there is no central focus association of trade groups at the present that represent the majority of U.S. fiber optics companies.

Many of the fiber optics companies in the U.S. are small, high technology firms. There are the larger firms, and you have heard from them, I am sure. In Japan, MITI finds it useful to encourage the formation of trade associations in new and emerging technologies as a way to focus the industry's interest and to funnel government resources to the industry.

COMMISSIONER LODWICK: Dr. Polishuk, I am very sorry to interrupt but your time has expired, and if you wish we would be happy to include the rest of your testimony in the record.

DR. POLISHUK: Fine. It is all there, and I am free to answer questions if you have them.

COMMISSIONER LODWICK: Please.

Commissioner Rohr.

QUESTIONS BY COMMISSIONER ROHR

COMMISSIONER ROHR: I am interested in the joint precompetitive R&D programs that were initiated in the European Community. Could you tell us whether you think the Europeans because of these programs are gaining a competitive edge in certain fiber components, and if so why?

DR. POLISHUK: Well, I think what we saw earlier on, there was some initial developed by the French, British, and Germans individually in which they invested heavily in fibers. What the joint programs that we are now seeing in Race and Esprit in Europe is that now they are talking about broader implications of the technology into larger networks. If indeed they can get broad band networks developed that will mean increased production. Increased production means higher -- lower on the learning curve, lower prices, making their industries more competitive.

The tack taken by the Europeans is to develop a broad band ISDN network. The focus in the states with telephone companies, the Bell operating companies, and others is narrow band, of which twisted wire pair is sufficient, but for broad band ISDN you must have fiber.

COMMISSIONER ROHR: Okay. What, if any, measures would you recommend that the U.S. government take to provide our domestic industry with a competitive environment on a level with the Europeans or the Japanese?

DR. POLISHUK: Well, I think I pointed out some of these things in the testimony but certainly from the standpoint of what we are doing trying to open up the foreign markets, tit for tat, that has involved some involvement by the FCC and other government agencies, but I think on the other had with regards to trying to pump prime the industry similar to what other countries do that the government has a large procurement that it does in telecommunications and computer communications. This could be used to help the industry.

For example, there is a serious problem with regards to the standards for short data links where if the industry -- if the government got in there and took some risk with regards to procurement for wiring of buildings, local area networks, and that technology is coming, it would certainly be a great boost to the industry and put us in a very good position, but if you go to the GSA and ask them, where is your program with regards to fiber optics and GSA, I hardly think you would find an expert in fiber optics.

The government should be offloading part of the risk of the industry through its procurement, which it can do, at the same time, benefit from the technology. We ought not be wiring buildings out there with twisted wire and copper pairs when within a half a year or a year they are going to be obsolete.

COMMISSIONER ROHR: Thank you.

Another question. Is it correct that those companies who developed state of the art electro-optical technologies are goin to subsequently gain a controlling influence in the sale of optical fiber?

DR. POLISHUK: I don't think I understand your question.

COMMISSIONER ROHR: Okay. Am I right in thinking that companies who develop the leading edge of technology in the electro-optical areas are going to gain a controlling influence on the sale of optical fiber?

DR. POLISHUK: What we are finding is that, for example, in Japan you will find vertically integrated companies all the way from soup to nuts, from fibers to electro-optics, everything. In the U.S. what we are finding is, except for AT&T, that is the only vertically integrated company we have got, and it is part of our problem. We see Corning mainly in the fiber business now shifting more and more into optoelectronics because they have to. Fiber has become a commodity business. They need to get into more value added. They need to get into that business that puts things on the ends of that fiber.

COMMISSIONER ROHR: Is that the best way then to compete with the Japanese?

DR. POLISHUK: I think what we need is, we need -- yes, we need to become more vertically integrated. We have got nine Japanese firms that are vertically integrated in the fiber optics field, and we have got one in this country, and they are ready to come here.

COMMISSIONER ROHR: Very good. Thank you very, very much for your testimony and your responses.

DR. POLISHUK: I am sorry I didn't summarize it quicker.

COMMISSIONER ROHR: That is fine. It was very interesting, and very helpful. Thank you.

DR. POLISHUK: I appreciate the opportunity.

COMMISSIONER LODWICK: We will certainly make it part of the record. One other thing. Are there questions from staff?

QUESTIONS BY COMMISSION STAFF

MR. AVERY: Yes. What is your assessment of your firm's competitive strength for other U.S. industries or -- not your firm but the fiber optic industry's competitive strength for other U.S. inndustries, particularly industries other than telecommunications industries.

DR. POLISHUK: I think what we are seeing elsewhere as well as what can be done here is that besides the application of telecommunications, I mean, fiber to telecommunications, there is a great potential for using fiber in those sunset industries to increase their productivity, increase their effectiveness, decrease their costs, and we see that happening a lot in Japan. Fiber optics, local area networks, very high technology going into the steel mills to completely automate the steel production processes. The same all through manufacturing. In fact, that is part of the MITI program, is to push the application and subsidize the application into the sunset industries in order to make them more efficient, more productive through the use of, say, fiber technology.

COMMISSIONER LODWICK: Any other questions?

MR. AVERY: That is all.

COMMISSIONER LODWICK: Again, thank you very much, Dr. Polishuk.

Mr. Secretary, what is the nature of the next witness?

SECRETARY MASON: Mr. Chairman, the next witness listed on the printed calendar has notified us that he will not appear. I will call the last group, the National Soybean Processors Association, Mr. John Reed and Mr. Kevin Brosch, please.

COMMISSIONER LODWICK: Chairman Rohr, would you please take over? I find that there might be a conflict of interest or an appearance of conflict of interest if I took part in this.

COMMISSIONER ROHR: Thank you, Commissioner. See you tomorrow.

(Whereupon, at 6:50 p.m., Commissioner Lodwick left the room.)

COMMISSIONER ROHR: Gentlemen, please proceed.

STATEMENT OF KEVIN BROSCH, OF COUNSEL, STEPTOE AND JOHNSON, ON BEHALF OF THE NATIONAL SOYBEAN PROCESSORS ASSOCIATION

ACCOMPANIED BY:

JOHN G. REED, JR., CHAIRMAN, NATIONAL SOYBEAN PROCESSORS ASSOCIATION

(Having been first duly sworn by Secretary Mason.)

Appendix D

Review of Literature on Competitiveness and Methodological Concerns

A. Previous Studies of competitiveness

The studies discussed below are believed to be a representative sampling of the extensive recent economic literature on the issue of international competitiveness of U.S. industry. The listing should not, however, be taken to be exhaustive. The focus of the discussion will be on the basic methodologies and measures of competitiveness employed in these studies, rather than on their conclusions for the particular industries under investigation.

1. Annotated bibliography

a. William H. Branson and James P. Love, "Dollar Appreciation and Manufacturing Employment and Output," NBER Working Paper No. 1972, 1986.

They estimate the responsiveness of U.S. manufacturing output and employment to changes in the real exchange rate, using quarterly data from 1963 to 1985, at the level of individual industries.

b. Dennis M. Busche, Irving B. Kravis, and Robert E. Lipsey, "Prices, Activity, and Machinery Exports: An Analysis Based on New Price Data," Review of Economics and Statistics, vol. 68 (May 1986), pp. 248-255.

Irving B. Kravis and Robert E. Lipsey, "Prices and Market Shares in the International Machinery Trade," Review of Economics and Statistics, vol. 64 (February 1982), pp. 110-116.

Robert E. Lipsey, "Recent Trends in U.S. Trade and Investment," in Miyawaki (ed.), Problems of Advanced Economies (Heidelberg: Springer-Verlag, 1984), pp. 58-79.

Robert E. Lipsey and Irving B. Kravis, "The Competitiveness and Comparative Advantage of U.S. Multinationals, 1957-83," NBER Working Paper No. 2051, 1986.

This series of papers examines changes in U.S. shares of world exports and investigates the causes. The first two listed make no explicit mention of competitiveness, but focus on determinants of the demand for U.S. exports of machinery and transport equipment. They find that changes in U.S. export prices relative to those of our competitors have a substantial effect on relative export quantities (and so shares of the world export market) but that the full effect may take up to 4 years to be felt—this suggests that it may take several years for the desirable trade balance effects of a currency depreciation to be felt.

The last two papers analyze trends in U.S. export shares, as an indicator of U.S. competitiveness. The comparative advantage of the United States and its multinational firms is measured in terms of the distribution of exports across industries (e.g., industries with larger shares of U.S. exports than of world exports are taken to be industries in which the United States has a comparative advantage vis-a-vis the rest of the world). They do point out two limitations of measuring international competitiveness by export share movements: (1) a decline in the U.S. share of world trade has accompanied declines in the U.S. share of world population and income, suggesting that a constant share "is not a reasonable norm against which to judge changes in the U.S. share of trade;" and (2) this measure of competitiveness ignores distortions in the composition of trade due to government intervention.

The paper by Lipsey and Kravis distinguishes between factors determining the competitiveness of the United States as a production location and those determining the competitiveness of U.S. firms (whatever the geographical distribution of their production). They identify two competing hypotheses for the loss of U.S. competitiveness: (1) macroeconomic factors, such as national price levels and incomes; and (2) factors internal to firms, such as research and development, technology, investment, or management strategies. These latter factors are transferable across countries, within firms, and so will be unlikely to contribute to national competitiveness or comparative advantage. Lipsey and Kravis suggest that a large difference between the trade performance of the United States and U.S.-based firms would allow one to determine the policy relevance of the two hypotheses. They report that although the U.S. share in world manufacturing exports fell from 22 percent to 14 percent over that period, the share of U.S.-based multinationals was steady at about 18 percent. The conclusion is that American management and technology remained competitive, maintaining export shares in rapidly growing world markets, and that the decline in the U.S. country share of world exports is largely because of relative price changes determined primarily by movements in exchange-rates and inflation.

c. James M. Jondrow, David E. Chase, and Christopher L. Gamble, "The Price Differential between Domestic and Imported Steel," Journal of Business, vol. 55 (July 1982), pp. 383-399.

They discuss reasons why imports of a seemingly homogeneous product (steel) sell for a lower price than the domestic product without rapidly increasing their share of the market. The explanation supported by evidence is unfavorable service characteristics (e.g., long lead times required and insecurity of supply). This suggests that—in the absence of specifically controlling for all such relevant characteristics—domestic and foreign product are best treated as imperfect substitutes, with the demand for imports depending on the prices of both imports and domestic goods. To the extent changes in relative costs pass through into differences in the prices of imports and domestic goods, import penetration will be affected.

d. Robert Z. Lawrence, Can America Compete (Washington: Brookings Institution, 1984).

This study, looking only at the period up to 1980, analyzes the sources of structural change in U.S. manufacturing. The author finds changes in domestic consumption to be a more important cause of structural change than changes in international trade, with U.S. comparative advantage declining in products of unskilled labor and standardized capital-intensive products, but increasing in high-tech products. Lawrence mentions the terms "international competitiveness" and "U.S. industrial competitiveness" without explicit definition, but seems to use a country's "success" in international markets as synonymous with international competitiveness and focuses in his analysis on growth in exports compared with import growth, the trade balance, the U.S. share of world trade in manufacturing, productivity growth, investment and R&D spending, and profit rates as indicators of that success.

He compares U.S. industrial performance with that of other developed economies from 1973 to 1980, and generally the U.S. manufacturing sector fares well—in terms of growth in production, employment, R&D, and capital spending. He estimates the effects of exchange rates on U.S. manufacturing and attributes most of the changes in U.S. exports and imports during 1980-83 to the dollar appreciation; however, by measuring real-exchange-rate movements with relative export and import prices (which may be related to relative costs and industrial structure) this doesn't rule out the importance of more industry-specific explanations for changes in U.S. competitiveness.

e. Richard Baldwin and Paul R. Krugman, "Market Access and International Competition: A Simulation Study of 16K Random Access Memories," NBER Working Paper No. 1936, 1986.

Marvin Lieberman, "Learning-By-Doing and Industrial Competitiveness: Autos and Semiconductors in the U.S. and Japan," NBER Working Paper, 1986.

John Zysman and Laura Tyson (eds.), American Industry in International Competition (Ithaca: Cornell University Press, 1983).

These works take a more dynamic view of industrial (and international) competition than that traditionally taken by economists.

Baldwin and Krugman model international competition in an oligopoly market with "strong learning effects," simulating the U.S.-Japanese rivalry in 16K RAM's from 1978 to 1983. Their results suggest that a protected home market was a crucial advantage to export performance of Japanese firms but that this policy produced more costs than benefits for Japan (through higher prices for consumers). Lieberman discusses the implications of "learning-by-doing" — "production technology undergoing continual improvement that is largely a function of accumulated experience" — which he claims to be a common feature of complex manufacturing industries. In these industries, the behavior of prices, profits, and shares of the market will depend on the slope of the learning curve (rate of productivity gains), the time horizon used by firms in decision making, and the rate at which learning diffuses among firms. A role for government in influencing these factors will be important in international competition.

The Zysman and Tyson volume is a series of industry case studies depicting the problems of adjustment and change in response to international competition in seven sectors: consumer electronics, steel, semiconductors, footwear, textiles, apparel, and autos. The editors, in their introductory essay, state that "[the] well-being of firms in these sectors depends on defending home markets against foreign firms and selling in markets abroad." This suggests at least an implicit view of international competitiveness in terms of export-shares and import-penetration. They do define "comparative advantage" as the relative export strength of a particular sector compared with other sectors in the same nation (and acknowledge the need to adjust for market-distorting government policies). On the other hand, "competitive advantage" is defined as the relative export strength of the firms of one country compared with the firms of other countries selling in the same sector in international markets.

Zysman and Tyson argue that in many cases a nation can create its own comparative advantage by the efforts of government and industry to create competitive advantage in the market; they refer specifically to government policies protecting a home market so as to allow either production economies of scale or learning curve economies. The case studies highlight the role of Japanese industrial policy in promoting expansion of growth-linked industries. Typical of competition between advanced countries is apparently that market success depends on the management of complex processes of product development and manufacturing, not simply national differences in factor costs such as wages or raw materials.

f. J. David Richardson, "Constant-Market-Shares Analysis of Export Growth," Journal of International Economics, vol. 1 (May 1971), pp. 227-239.

This is a critique of the constant-market-shares analysis, both in theory and in practice. This analysis attributes any change in a country's exports in a particular sector not due to growth in the market but to changed "competitiveness." Richardson questions the use of relative prices to measure relative competitiveness (ignoring quality, service, financing differences between the products of competing nations) and suggests that a measure of "a country's true competitiveness ... might be whether the country was increasing its export shares in rapidly growing commodities and markets" (the analysis assumes the commodity and geographic distribution of exports to be unrelated to competitiveness).

g. John W. Suomela, "The Meaning and Measurement of International Price Competitiveness," Business & Economics Section, Proceedings of the American Statistical Association, 1978.

This paper discusses the ambiguities in the term "competitiveness," as it applied to firms, industries, and countries. It reviews several empirical studies that have attempted to measure "competitiveness" or "price competitiveness"— these have interpreted the measures employed as predictors of relative export quantities or relative export shares or the balance of trade in an industry sector. These measures include ratios of wholesale price indexes, export unit values, relative unit labor costs, import prices divided by export prices, and relative profits. An import demand model is formulated to specify theoretically correct price indexes, which unfortunately do not correspond to available data.

h. U.S. Federal Trade Commission, Staff Report on the U.S. Steel Industry and its International Rivals: Trends and Factors Determining International Competitiveness, Bureau of Economics, 1977.

Despite the title, no definition or strict measure of international competitiveness is given. At various places the study suggests the importance of exports, import penetration, and rates of growth in production as indicators of a country's "competitive position" or "importance" in the world steel industry or "relative standing ... among the world's steel producing nations." However, in the summary chapter, the study is described as one attempting to explain the pattern of trade flows of the U.S. steel industry over a 20-year period.

Chapter 3 examines relative trends in steel-producing costs in the United States Japan and the EC, evaluating the impact of relative costs on international trade flows. Implicitly, the authors seem to have a spatial oligopoly model in mind—changes in relative production costs among countries may have a strong influence on trade flows as relative cost reductions by one country allow it to expand into areas formerly controlled by other countries. (This is not to say that relative cost changes do not play a role in spaceless models; there, cost changes imply supply shifts which are likely to lead to changes in export shares even if, in a homogeneous world market, price and marginal cost are unchanged.)

After comparing quantities and average prices for inputs involved in steelmaking in the United States and Japan, covering 70 percent of variable costs in the United States, comparisons of levels and trends in unit costs in the two countries are given. Problems with these comparisons are acknowledged: (1) the assumption that the relative cost of excluded inputs has not changed significantly over time is crucial (and no check of the realism of this assumption is given); and (2) price and quantity data are not exactly comparable for the two countries because of industry definition differences, product-mix differences, and differences in the use of spot vs. contract prices or arms-length versus transfer prices. The primary difference between U.S. and Japanese unit costs was found to be unit labor costs, mainly because of the wage-rate differential; the overall Japanese cost advantage increased from 1956 to 1968, but changed little during the 1968-76 period.

Less sophisticated methods, using product-specific average revenue less an overall-industry return on sales, were used to estimate the U.S./EC cost differential; results showed relative U.S. costs increasing from 1954 to the late 1960's and then decreasing. Some discussion of shipping costs is given but there is no analysis of changes over time.

Partly on the basis of a simple linear regression of Japanese and EC import penetration in the United States on relative costs, the study concludes that the primary explanation for increasing import penetration is relative production cost changes. It should be noted that since exchange-rate effects are incorporated in the measured cost changes there is no allowance for a separate influence for these effects.

i. U.S. Department of Labor, Office of Foreign Economic Research, Report of the President on U.S. Competitiveness, 1980.

This is essentially a study of U.S. export performance, although other indicators of international competitiveness used include the trade balance and the "terms of trade"; the latter is measured by the U.S. export/import price ratio. A long list of determining factors is considered: inflation, rates of investment, productivity growth, skilled labor resources, technological innovation, unit labor costs, tariff and nontariff barriers to U.S. exports, U.S. foreign investment and technology transfer, tax measures, energy factors, labor-management relations, the role of engineering, and other services in the export of capital goods. Of these factors, investment, technology, and productivity were seen as areas where the United States had lagged behind its competitors; in addition, nontariff barriers and exchange-rate movements had major impacts on U.S. exports. As an index of "revealed comparative advantage" the study adjusts the U.S. export-share in a particular product by the U.S. share of total world exports; similarly, for industries without much exporting, a relative import penetration ratio might be useful in judging comparative advantage among U.S. industries.

2. Summary of results

The conclusion to be drawn from these studies is that "international competitiveness" does not have a precise, theoretically derived definition, but rather is a term that different people use to mean somewhat different things. However, the unifying theme is that the interest is always in some measure of "success" in world markets. The most common measures of this success in particular product markets seem to be shares of world exports or production or the level and trends of a country's trade balance in a sector. Determinants of this success are the relative production costs and exchange rate effects predicted by a simple static model of international competition, as well as more dynamic factors such as productivity growth, investment, and management (and perhaps government) strategies. The comparison of these studies should alert one to the importance of choosing appropriate statistics to answer a question: e.g., R.Z. Lawrence finds R&D in manufacturing grew faster in the United States than in other OECD countries, and the Labor Department study finds that the U.S. ratio of R&D to GNP has declined in the United States relative to other developed nations. Both of these results are correct yet they lead a reader towards opposite conclusions on the trend of U.S. investment in technology.

B. Methodological concerns

The preceding section found that discussions of international competitiveness of U.S. industries generally fail to precisely define how competitiveness should be measured. The problem is that there is no unique measure, but rather several dimensions of the issue. The purpose of this section is to set out an analytical framework relating several measures of competitiveness to determinants of industrial performance in world markets.

1. Definitions of competitiveness

Consider the U.S. industry facing a competing industry in world markets, with the two industries selling somewhat differentiated, though similar, products; for example, suppose the U.S. and Japanese automobile industries competed in markets throughout the world but were viewed by consumers as selling products not perfectly substitutable for each other. Separate but interrelated markets for the products of the two industries exist with prices and quantities sold determined by elements of supply and demand. Given that the U.S. and foreign products are substitutes, anything that serves to lower the price of the U.S. [foreign] product will reduce the demand for the foreign

[U.S.] product. In turn, the U.S. price will be determined by marginal cost, the sensitivity of demand to price (price elasticity of demand), and the market structure and strategic behavior of the U.S. industry.

Now, what is meant by competitiveness? At the most basic level, it is simply "success" in world markets, which can be measured by the share of the combined markets for U.S. and foreign-made products held by U.S. producers (or the U.S. share of world exports); this seems to be the most commonly adopted measure of international competitiveness. Clearly, by this measure, any change that increases world sales of U.S. products while reducing (or even increasing less than proportionally) sales of foreign-made products implies an increase in U.S. competitiveness; it should be recognized that competitiveness so defined includes the effects of all governmentally imposed aids and sanctions affecting both the U.S. and foreign industries. Such a measure, if examined over a period of years, will be quite sensitive to the changing stages of economic development occurring in both competitor and consumer nations. It has been argued, for example, that with the post-war re-emergence of Japan and the European Community, followed by the rise of the newly industrializing countries of the Pacific Rim, that one would expect to see the U.S. share of world exports declining (and whether we view this as a decline in competitiveness or not may be a matter of semantics).

An alternative measure of competitiveness is simply the profitability of the domestic industry, although, again, this measure is quite sensitive to government-imposed import barriers and export aids. Finally, net investment in the domestic industry is both an indicator of competitiveness and a predictor of future profitability and market share. These latter two measures are probably more directly affected by the overall state of the domestic economy than is the share of world consumption or world exports (although this will also be affected by macroeconomic factors influencing exchange rates and inflation). While there are exceptions, <u>generally</u> all three of these indicators of competitiveness will move together and will be similarly affected by changes in circumstances of supply or demand.

2. Determinants and indicators

Suppose there is an increase in the cost of producing an additional unit of the domestic product; this could be because of increases in resource costs, inefficiencies in management techniques, use of outdated or inappropriate technologies, increasing interest rates, higher regulation-related costs, or a depreciation of the domestic currency value (raising the cost of imported inputs). This increase in costs will be translated into reduced supply and a higher price for the U.S. product. The higher price will stimulate increased world demand for the foreign-made product. The result will be a reduced U.S. share of the world market (and of world exports), lower profits, and (especially if the lower profits are expected to persist) reduced investment in the U.S. industry. Similar results would ensue from reduced costs to the foreign industry: a lower foreign product price would lead to reduced demand for the U.S. product, a smaller world market share, and reduced profits and investment.

If transportation costs are an important consideration in world trade of a particular product (as where the ratio of value to weight is relatively low), a reduction in costs in the industry of one country will enable it to expand the geographical area in which, including transport costs, it enjoys a cost advantage. We would expect to see this translated into increases in world export shares, profitablity, and domestic investment. Similarly, a reduction in transportation costs specific to a particular producing country (as could occur if shipping cost was subsidized by the government) would expand that country's geographical marketing area and increase the three measures of competitiveness discussed above.

It should be emphasized that anything which affects the cost of production to the U.S. industry relative to foreign production will have an influence on competitiveness. The cost factors mentioned above are just examples and should not be taken to be an exhaustive list; different elements of cost will be more important in determining U.S. competitiveness in different products.

Changed conditions of demand, specific to one of the two countries' industries, would also have an impact on international competitiveness. An increase in demand for the product of the U.S. industry could be due to a change in consumer tastes or an improvement in the perceived quality either of the basic product or of service and distributional aspects related to the U.S. product; it could also be due to more rapid income growth in parts of the world targeted by the U.S. producers than in the rest of the world market. Regardless of the cause, an increase in demand for the U.S.-made product would increase sales and the price of that product. Although there may be a resulting increase in demand for the foreign-made product as well this should be of smaller magnitude, leading to the conclusion that the world market share of the domestic industry will rise, as will profits and investment. Improved technology, resulting from increased research and development in the industry, may have the dual effect of reducing costs and improving quality (and, therefore, demand).

Finally, the nature of competition in the domestic industry may affect the industry's success in world markets. The U.S. industry will be better able to compete with imports and to sell abroad, to the extent that vigorous competition among domestic producers allows for pricing closely aligned to costs, and still allow for profits to be invested in research and development and capital equipment. Such competition may also stimulate improved management techniques, which by lowering costs will further reduce prices and enhance the U.S. industry's competitive position.

3. Summary

The brief discussion above suggests that international competitiveness is an issue that needs to be evaluated from a multidimensional perspective, examining both indicators and determinants of competitiveness. Three indicators of competitiveness are (1) world export shares (or shares of world consumption); (2) profitability of the domestic industry; and (3) trends in net investment in the domestic industry. Determinants of competitiveness are (1) cost factors, both specific to the industry (including resource costs, labor costs, interest rates) and economy-wide (such as capital costs, general input-cost inflation, exchange-rate changes); (2) demand factors, including the quality and reputation of the domestic product, as well as the growth of incomes in primary export markets; and (3) domestic market structure and conduct considerations. To the extent government actions influence any of these factors they will affect the international competitiveness of the industry. Of course, explicit nontariff barriers erected by governments will have more direct impacts on indicators of competitiveness.

Under the cost factors determining competitiveness, one may consider differing U.S./foreign trends in—

(a) wage rates and labor productivity, or unit labor costs (which effectively combines the two);
(b) intensity of use of inputs, which may be related to differing technologies, age of capital equipment, or the degree of vertical integration;

(c) transportation and distribution costs —their importance, and the geographical distance to major markets from U.S. and other suppliers. Note that to the extent cost measures are converted to dollar equivalents, the issues of general inflation and exchange rates are controlled for.

Under demand factors, one may consider whether the U.S. and foreign products are homogeneous or differentiated in some way, whether primary markets of the U.S. industry have grown at different rates than primary markets of foreign competitors, patterns and changes in delivery lags, service, and quality from competing sources.

Market structure can be evaluated by looking at the number of firms in the industry, the share of the top firms, conditions of entry into the global industry, the type of ownership, and the degree of vertical integration and diversification in the industry. Some qualitative assessment on the competitive environment, the extent to which firms compete or cooperate, is useful.

Finally, government aids such as subsidies (including subsidies to related industries), tariffs, quotas, and other nontariff measures should be mentioned, with some attempt at assessing their impact.

Appendix E

Survey Design and Methodology

Because of the limited and incomplete nature of available data on the U.S. optical fiber industry, the commission found it necessary to use questionnaires as a primary data-gathering technique in order to obtain the type of information requested by the Senate Finance committee. The collection of information did not e4mploy statistical methods. Questionnaires we4re sent to all known U.S. producers and importers. Questionnaires were also sent to 40 purchasers out of an unknown universe size. The purpose of the questionnaire for purchasers was to obtain an objective assessment of the factors of competition between domestically produced and foreign-produced optical fibers, optical fiber cable, and optical fiber put up in other multiple fiber forms.

The questionnaire responses were reviewed by Commission staff for accuracy. The following tabulation presents the useable response rate by type of questionnaire.

	Producers	Importers	Purchasers
Applicable questionnaires.......	47	51	33
Questionnaires with useable information..................	33	27	28
Useable response rate 1/ (percent).....................	70	53	85

1/ Useable response rate is defined as the number of questionnaires returned with useable infomation as a percent of total applicable questionnaires.

Much of this resport's analysis is based on the data provided by U.S. producer and purchaser questionnaire respondents. The two questionnaires total 64 pages. Copies of the blank questionnaires can be obtained from the General Manufactures Division, Office of Industries, U.S. International Trade Commission, Washington, D.C. 20436.

Appendix F

Glossary of Technical Terms

Attenuation: A measure of the decrease in energy transmission (loss of light) expressed in decibels per kilometer (db/km). The greater the value of db/km, the greater is the indicated loss of light.

Avalanche photodiode (APD): A photodiode designed to take advantage of avalanche multiplication of photocurrent. As the reverse bias voltage approaches the breakdown voltage, hole-electron pairs created by absorbed photons acquires sufficient energy to create additional hole-electron pairs when they collide with substrate atoms; thus a multiplication effect is achieved.

Bandwidth: The range of frequencies handled by a device or system, or the amount of voice, video, and or data information that can be handled by such a system.

Cladding: The low refractive index material which surrounds the core of the fiber and protects against surface contaminant scattering.

Coherent bundle: A collection of optical fibers arranged non-randomly to permit the transmission of images.

Connector: A device which temporarily joins the ends of the optical fibers together.

dB/km: Decibels per kilometer (See the definition for attenuation above).

Decibel (dB): A logarithmic unit used in comparisons of power. The difference of the power levels of two signals in decibels equals 10 times the base 10 logarithmim of their ratio.

Dispersion: The cause of bandwidth widening in an optical fiber. Dispersion causes a broadening of input pulses along the length of the fiber. The term can be used to describe the process by which an electromagnetic signal is distorted because the various frequency components of the signal have different propagation characteristics. The term is also used to describe the relationship between refractive index and frequency (or wave length). Because dispersion causes a broadening of input pulses along the length of the fiber, this mechanism is often referred to as pulse spreading.

Faceplate: A fused coherent bundle used for the transmission of images over a short distance.

Fiber kilometers (fkm): The unit of quantity obtained by multiplying the number of optical fibers contained in an optical cable by the length of the cable in kilometers.

Fiber optic sensors: Optical fibers used in apparatus designed to detect or sense environmental effects such as pressure, temperature, magnetic fields, electric fields, and rotation.

Integrated Services Digital Network (ISDN): A broadband system that integrates a variety of voice, video, and data services over a single network.

<u>LAN-campus communications cable</u>: Optical cables used for various self-contained local area networks (LANS) and internal communications systems connecting the telecommunications and data network systems for campuses and other building premises environments.

<u>Light emitting diode (LED)</u>: A semiconductor diode which emits visible or infrared light. It is used as a transmitter in optical fiber systems, especially those used in shorter distance network applications.

<u>Local area network (LAN)</u>: A self-contained internal communications and data network system involving telephone, computer, and other voice/data/service interconnects and linkages within a single building or group of related buildings and plants.

<u>Multiplex</u>: Putting two or more signals into a single channel.

<u>Monomode (or single mode) optical fiber</u>: An optical fiber that supports the propagation of only one mode of a given wavelength of light at a time.

<u>Monopoly</u>: A market structure in which a commodity is supplied by only one firm.

<u>Monopsony</u>: A market structure in which there is only one purchaser of a given commodity.

<u>Multimode optical fiber</u>: An optical fiber that supports the propagation of more than one mode of a given wavelength of light at a time.

<u>Nanometer (nm)</u>: One billionth of a meter.

<u>Natural monopoly</u>: A firm or industry whose average cost per unit of production falls sharply over the entire range of its output. Thus a single firm, a monoply, can supply the industry output more efficiently than can multiple firms.

<u>Noncoherent bundle</u>: A collection of optical fibers arranged randomly for the purpose of transmitting light but not images.

<u>Oligopoly</u>: A situation of imperfect competition in which an industry is dominated by a small number of suppliers.

<u>Optical cable</u>: Optical fibers incorporated into an assembly of materials that provides tensile strength, external protection, and handling properties comparable to those of equivalent coaxial cables.

<u>Optical fiber</u>: A long thin strand of transparent glass, plastic, or other material usually consisting of a fiber optical core and a fiber optical cladding capable of conducting light along its axial length by internal reflection.

<u>Optical fiber for data purposes</u>: Optical fiber used in the transmission of voice, video, and/or data information.

<u>Optical fiber for nondata purposes</u>: Optical fiber used for purposes other than in the transmission of voice, video or data information. Non-data optical fiber elements include, but are not limited to, noncoherent bundles, coherent bundles, faceplates, fiber optic sensors, fiber optic gyros, fiberscopes, and other medical, and industrial instrumentation.

Plenum cable: Polyvinyl chloride jacketed optical cables designed for use in building risers and in horizontal and vertical distribution. They are classified by Underwriters Laboratories as to flame propagation characteristics and contain no metallic elements.

Quaternary compounds: Chemical combinations containing four different elements.

Refractive index: Denoted by n, the ratio of light in a vacuum to its velocity in a medium (such as glass or plastic in an optical fiber).

Repeater: A device which detects a weak signal in a fiber optic communication system, amplifies and retransmits it.

Semiconductor laser: The most commonly used long distance lightwave source used in long distance telecommunications optical fiber systems.

Telco-cable: Optical cables used in telecommunications systems, including long haul, feeder, and local loop applications.

Ternary compounds: Chemical combinations containing three different elements.

Time-division multiplexing: A digital technique for combining two or more signals into a single stream of data by interweaving bits from each signal.

Wavelength division multiplexing (WDM): Multiplexing involving the use of several distinct optical sources (lasers), each having a distinct center frequency.

The discription of terms and systems in this glossary were developed primarily from notes taken in Commission interviews with engineers and technology experts of leading fiber optics manufacturers and from definitions and overviews of fiber optic technology contained in U.S. Long Distance Fiber Optic Networks: Technology Evolution and Advanced Concepts, IGI Consulting, Inc., prepared for NASA, October 1986, International Fiber Optics and Communications, Annual Handbook and Buyers Guide, IGI Consulting, 1986, and Fiber Optics and Lightwave Communication Standard Dictionary, Martin Wein, Van Nostrand Reinhold Company, 1981.

Appendix G

Selected Portions of the Tariff Schedule of the United States Annotated, 1987

Item	Stat. Suf-fix	Articles	Units of Quantity	Rates of Duty		
				1	Special	2

PART 2. - OPTICAL GOODS; SCIENTIFIC AND PROFESSIONAL INSTRUMENTS; WATCHES, CLOCKS, AND TIMING DEVICES; PHOTOGRAPHIC GOODS; MOTION PICTURES; RECORDINGS AND RECORDING MEDIA

Part 2 headnotes:

1. This part does not cover --
   - (i) measuring cups, graduates, or other measuring containers;
   - (ii) laboratory and industrial chemical ware, and sanitary ware, of ceramic ware (see part 2D of schedule 5);
   - (iii) pharmaceutical, hygienic, and laboratory glassware (see part 3C of schedule 5);
   - (iv) toilet and sanitary wares of metal (see part 3F of schedule 6);
   - (v) tuning forks (see part 3B of this schedule);
   - (vi) furniture provided for in part 4A of this schedule;
   - (vii) toys (see part 5E of this schedule); or
   - (viii) articles of rubber or plastics provided for in items 772.40 and 772.42 of part 12 of this schedule.

2. Cases, boxes, and containers of types ordinarily sold at retail with the instruments or other articles provided for in this part are classifiable with such articles if imported therewith.

3. The term "optical instruments", as used in this part, embraces only instruments which incorporate one or more optical elements, but does not include any instrument in which the incorporated optical element or elements are solely for viewing a scale or for some other subsidiary purpose.

Item	Stat. Suf-fix	Articles	Units of Quantity	Rates of Duty 1	Rates of Duty Special	Rates of Duty 2
		Subpart A. - Optical Elements, Spectacles, Microscopes, and Telescopes, Optical Goods Not Elsewhere Provided For				
		<u>Subpart A headnotes</u>: 1. The provisions for optical elements in this subpart do not cover -- (i) unmounted optical elements of glass or synthetic optical crystals unless such elements have been optically worked (see part 3A of schedule 5); (ii) plates or sheets of polarizing material unless cut to shape or mounted (see part 3A of schedule 5); (iii) photographic filters (see subpart F of this part) 2. The term "<u>optically worked</u>", as used in this subpart, means that the glass or the synthetic optical crystals have been subjected to grinding or polishing incident to surface shaping for producing optical properties. 3. The provisions for mounted optical elements cover such elements when in a permanent frame or other mounting suitable for fitting to an apparatus or instrument and do not include mounted elements which are themselves separate instruments or apparatus such as spectacles, medical or dental mirrors, and hand magnifying glasses. 4. Sets comprised of tools, implements, and other articles fitted into and imported with cases containing microscopes provided for in item 708.71, and ordinarily sold at retail, and used, in conjunction with such microscopes, are classifiable therewith.				
		<u>Subpart A statistical headnote</u>: 1. The unit of quantity of "<u>Fiber meters</u>" as used in item 707.9010 is obtained by multiplying the number of optical fibers contained in the cable or ribbon by the length of the cable or ribbon in meters.				
707.90		Optical fibers, whether or not in bundles, cables or otherwise put up, with or without connectors and whether mounted or not mounted..........................	....	8.4% ad val.	Free (A,E) 3.4% ad val.(I)	65% ad val.
		For transmission of voice, data, or video communications:				
	10	Put up in cables, ribbons, or similar multiple fiber forms..........................	Fiber meters			
	20	Other....................................	Meters			
		Other:				
	60	Plastic optical fibers........................	Meters			
	70	Other....................................	Meters			

Appendix H

Selected Portions of the TSUS Converted to the Harmonized System Showing Final MTN Concession Rates of Duty Applicable to Optical Fiber and Cable

CHAPTER 85

ELECTRICAL MACHINERY AND EQUIPMENT AND PARTS THEREOF; SOUND RECORDERS AND REPRODUCERS, TELEVISION IMAGE AND SOUND RECORDERS AND REPRODUCERS, AND PARTS AND ACCESSORIES OF SUCH ARTICLES

Notes

1. This Chapter does not cover:

   (a) Electrically warmed blankets, bed pads, foot-muffs or the like; electrically warmed clothing, footwear or ear pads or other electrically warmed articles worn on or about the person;

   (b) Articles of glass of heading 7011; or

   (c) Electrically heated furniture of chapter 94.

2. Headings 8501 to 8504 do not apply to goods described in heading 8511, 8512, 8540, 8541 or 8542.

   However, metal tank mercury arc rectifiers remain classified in heading 8504.

3. Heading 8509 covers only the following electromechanical machines of the kind commonly used for domestic purposes:

   (a) Vacuum cleaners, floor polishers, food grinders, processors and mixers, and fruit or vegetable juice extractors, of any weight;

   (b) Other machines provided the weight of such machines does not exceed 20 kg, exclusive of extra interchangeable parts or detachable auxiliary devices.

   The heading does not, however, apply to fans or ventilating or recycling hoods incorporating a fan, whether or not fitted with filters (heading 8414), centrifugal clothes dryers (heading 8421), dishwashing machines (heading 8422), household washing machines (heading 8450), roller or other ironing machines (heading 8420 or 8451), sewing machines (heading 8452), electric scissors (heading 8508) or to electrothermic appliances (heading 8516).

4. For the purposes of heading 8534 "printed circuits" are circuits obtained by forming on an insulating base, by any printing process (for example, embossing, plating-up, etching) or by the "film circuit" technique, conductor elements, contacts or other printed components (for example, inductances, resistors, capacitors) alone or interconnected according to a pre-established pattern, other than elements which can produce, rectify, modulate or amplify an electrical signal (for example, semiconductor elements).

   The term "printed circuits" does not cover circuits combined with elements other than those obtained during the printing process. Printed circuits may, however, be fitted with nonprinted connecting elements.

   Thin- or thick-film circuits comprising passive and active elements obtained during the same technological process are to be classified in heading 8542.

5. For the purposes of headings 8541 and 8542:

   (A) "Diodes, transistors and similar semiconductor devices" are semiconductor devices the operation of which depends on variations in resistivity on the application of an electric field;

   (B) "Electronic integrated circuits and microassemblies" are:

      (a) Monolithic integrated circuits in which the circuit elements (diodes, transistors, resistors, capacitors, interconnections, etc.) are created in the mass (essentially) and on the surface of a semiconductor material (doped silicon, for example) and are inseparably associated;

      (b) Hybrid integrated circuits in which passive elements (resistors, capacitors, interconnections, etc.) obtained by thin- or thick-film technology and active elements (diodes, transistors, monolithic integrated circuits, etc.) obtained by semiconductor technology, are combined to all intents and purposes indivisibly, on a single insulating substrate (glass, ceramic, etc.). These circuits may also include discrete components;

      (c) Microassemblies of the molded module, micromodule or similar types, consisting of discrete, active or both active and passive components which are combined and interconnected.

   For the classification of the articles defined in this note, headings 8541 and 8542 shall take precedence over any other heading in the tariff schedule which might cover them by reference to, in particular, their function.

6. Records, tapes and other media of heading 8523 or 8524 remain classified in those headings, whether or not they are entered with the apparatus for which they are intended.

Additional U.S. Notes

1. For the purposes of headings 8501 and 8503, 746 watts (W) is taken to be equivalent to 1 horsepower (hp.).

2. For the purposes of subheading 8516.72, the term "toasters" covers toaster-ovens which are designed essentially for toasting bread but can also bake small items, such as potatoes.

3. For the purposes of heading 8525 the term "transceivers" refers to combinations of radio transmitting and receiving equipment in a common housing, employing common circuit components for both transmitting and receiving, and which are not capable of simultaneously receiving and transmitting.

4. For the purposes of subheading 8529.90.15 and 8529.90.20--

   (a) each subassembly that contains as a component, or is covered in the same entry with, one or more of the following television components, viz.,

      tuner, channel selector assembly, antenna, deflection yoke, degaussing coil, picture tube mounting bracket, grounding assembly, parts necessary for fixing the picture tube or tuner in place, consumer operated controls, or speaker,

   shall be classified in subheading 8529.90.15; and

   (b) each subassembly shall be counted as a single unit, except that two or more different printed circuit boards or ceramic substrates covered by the same entry and designed for assembly into the same television models shall be counted as one unit.

Statistical Notes

1. For the purposes of heading 8528 the video display diagonal is determined by measuring the maximum straight line dimension across that part of the faceplate used for displaying video.

2. For the purposes of this chapter the terms "AM" and "FM" refer to the entertainment broadcast bands of 550-1650 kHz and 88-108 MHz, respectively.

3. For statistical reporting purposes under subheading 8539.10, the size of a sealed beam lamp units is determined by measuring the largest diagonal dimension across the faceplate.

TARIFF SCHEDULE OF THE UNITED STATES ANNOTATED

(Converted to the Harmonized System and reflecting final MTN concession rates of duty)

85-26

Heading	Stat. Suf-fix	Article Description	Units of Quantity	Rates of Duty 1 General	Rates of Duty 1 Special	Rates of Duty 2
8544		Insulated (including enameled or anodized) wire, cable (including coaxial cable) and other insulated electric conductors, whether or not fitted with connectors; optical fiber cables, made up of individually sheathed fibers, whether or not assembled with electric conductors or fitted with connectors:				
		Winding wire:				
8544.11.00		Of copper................................	....	5.3%	Free (B)	40%
	20	33 AWG (0.0071 mm in diameter) and finer............................	kg			
	40	Other............................	kg			
8544.19.00	00	Other................................	kg......	4.9%	Free (B)	35%
8544.20.00	00	Coaxial cable and other coaxial electric conductors................................	kg......	5.3%	Free (B)	35%
8544.30.00	00	Ignition wiring sets and other wiring sets of a kind used in vehicles, aircraft or ships....	X.......	5%	Free (B,C)	30%
		Other electric conductors, for a voltage not exceeding 80 V:				
8544.41.00	00	Fitted with connectors..................	X.......	5.3%	Free (B)	35%
8544.49.00	00	Other................................	kg......	5.3%	Free (B)	40%
		Other electric conductors, for a voltage exceeding 80 V but not exceeding 1,000 V:				
8544.51.00	00	Fitted with connectors..................	X.......	5.3%	Free (B)	35%
8544.59		Other:				
8544.59.20	00	Of copper........................	kg......	5.3%	Free (B)	40%
8544.59.40	00	Other............................	kg......	4.9%	Free (B)	35%
8544.60		Other electric conductors, for a voltage exceeding 1,000 V:				
8544.60.20	00	Fitted with connectors..................	X.......	5.3%	Free (B)	35%
		Other:				
8544.60.40	00	Of copper........................	kg......	5.3%	Free (B)	40%
8544.60.60	00	Other............................	kg......	4.9%	Free (B)	35%
8544.70.00	00	Optical fiber cables.........................	X.......	8.4%		65%
8545		Carbon electrodes, carbon brushes, lamp carbons, battery carbons and other articles of graphite or other carbon, with or without metal, of a kind used for electrical purposes:				
		Electrodes:				
8545.11.00	00	Of a kind used for furnaces.............	kg......	2.4%		45%
8545.19		Other:				
8545.19.20	00	Of a kind used for electrolytic purposes..........................	kg......	2.4%		45%
8545.19.40	00	Other............................	kg......	4.9%		45%
8545.20.00	00	Brushes....................................	kg......	3.7%	Free (B)	45%
8545.90		Other:				
8545.90.20	00	Arc light carbons......................	kg......	2.8%		60%
8545.90.40	00	Other................................	kg......	4.9%		45%
8546		Electrical insulators of any material:				
8546.10.00	00	Of glass....................................	No......	5.8%		50%
8546.20.00	00	Of ceramics................................	No......	6%		60%
8546.90.00	00	Other......................................	No......	3.7%	Free (B)	30%
8547		Insulating fittings for electrical machines, appliances or equipment, being fittings wholly of insulating material apart from any minor components of metal (for example, threaded sockets) incorporated during molding solely for the purposes of assembly, other than insulators of heading 8546; electrical conduit tubing and joints therefor, of base metal lined with insulating material:				
8547.10		Insulating fittings of ceramics:				
8547.10.40	00	Ceramic insulators to be used in the production of spark plugs for natural gas fueled, stationary, internal combustion engines.........................	No......	3.5%		60%
8547.10.80	00	Other................................	No......	6%	Free (B)	60%
8547.20.00	00	Insulating fittings of plastics..............	No......	3.7%	Free (B)	30%
8547.90.00	00	Other......................................	No......	5.8%	Free (B)	45%
8548.00.00	00	Electrical parts of machinery or apparatus, not specified or included elsewhere in this chapter....	X.......	3.9%	Free (B)	35%

CHAPTER 90

OPTICAL, PHOTOGRAPHIC, CINEMATOGRAPHIC, MEASURING, CHECKING, PRECISION, MEDICAL OR SURGICAL INSTRUMENTS AND APPARATUS; PARTS AND ACCESSORIES THEREOF

Notes

1. This chapter does not cover:

   (a) Articles of a kind used in machines, appliances or for other technical uses, of vulcanized rubber other than hard rubber (heading 4016), of leather or of composition leather (heading 4204) or of textile material (heading 5911);

   (b) Refractory goods of heading 6903; ceramic wares for laboratory, chemical or other technical uses, of heading 6909;

   (c) Glass mirrors, not optically worked, of heading 7009, or mirrors of base metal or of precious metal, not being optical elements (heading 8306 or chapter 71);

   (d) Goods of heading 7007, 7008, 7011, 7014, 7015 or 7017;

   (e) Parts of general use, as defined in note 2 to section XV, of base metal (section XV) of similar goods of plastics (chapter 39);

   (f) Pumps incorporating measuring devices, of heading 8413; weight-operated counting or checking machinery, or separately entered weights for balances (heading 8423); lifting or handling machinery (headings 8425 to 8428); paper or paperboard cutting machines of all kinds (heading 8441); fittings for adjusting work or tools on machine-tools, of heading 8466, including fittings with optical devices for reading the scale (for example, "optical" dividing heads) but not those which are in themselves essentially optical instruments (for example, alignment telescopes); calculating machines (heading 8470); valves or other appliances (heading 8481);

   (g) Searchlights or spotlights of a kind used for cycles or motor vehicles (heading 8512); portable electic lamps of heading 8513; cinematographic sound recording, reproducing or re-recording apparatus (heading 8519 or 8520); sound-heads (heading 8522); radar apparatus, radio navigational aid apparatus and radio remote control apparatus (heading 8526); sealed beam lamp units of heading 8539; optical fiber cables of heading 8544;

   (h) Searchlights or spotlights of heading 9405;

   (ij) Articles of chapter 95;

   (k) Capacity measures, which are to be classified according to their constituent material; or

   (l) Spools, reels or similar supports (which are to be classified according to their constituent material, for example, in heading 3923 or section XV).

2. Subject to note 1 above, parts and accessories for machines, apparatus, instruments or articles of this chapter are to be classified according to the following rules:

   (a) Parts and accessories which are goods included in any of the headings of this chapter or of chapter 84, 85 or 91 (other than heading 8485, 8548 or 9033) are in all cases to be classified in their respective headings;

   (b) Other parts and accessories, if suitable for use solely or principally with a particular kind of machine, instrument or apparatus, or with a number of machines, instruments or apparatus of the same heading (including a machine, instrument or apparatus of heading 9010, 9013 or 9031) are to be classified with the machines, instruments or apparatus of that kind;

   (c) All other parts and accessories are to be classified in heading 9033.

3. The provisions of note 4 to section XVI apply also to this chapter.

4. Heading 9005 does not apply to telescopic sights for fitting to arms, periscopic telescopes for fitting to submarines or tanks, or to telescopes for machines, appliances, instruments or apparatus of this chapter or section XVI; such telescopic sights and telescopes are to be classified in heading 9013.

5. Measuring or checking optical instruments, appliances or machines which, but for this note, could be classified both in heading 9013 and in heading 9031 are to be classified in heading 9031.

6. Heading 9032 applies only to:

   (a) Instruments and apparatus for automatically controlling the flow, level, pressure or other variables of liquids or gases, or for automatically contolling temperature, whether or not their operation depends on an electrical phenomenon which varies according to the factor to be automatically controlled; and

   (b) Automatic regulators of electrical quantities, and instruments or apparatus for automatically controlling non-electrical quantities the operation of which depends on an electrical phenomenon varying according to the factor to be controlled.

Additional U.S. Notes

1. For the purposes of headings 9001 and 9002, the term "optically worked" refers to glass the surface of which has been ground or polished in order to produce the required optical properties.

2. For the purposes of this chapter, the term "electrical" when used in reference to instruments, appliances, apparatus and machines, refers to those articles the operation of which depends on an electrical phenomenon which varies according to the factor to be ascertained.

3. For the purposes of this chapter, the terms "optical appliances" and "optical instruments" refer only to those appliances and instruments which incorporate one or more optical elements, but do not include any appliances or instruments in which the incorporated optical element or elements are solely for viewing a scale or for some other subsidiary purpose.

Heading	Stat. Suf-fix	Article Description	Units of Quantity	Rates of Duty 1 General	Rates of Duty 1 Special	Rates of Duty 2
9001		Optical fibers and optical fiber bundles; optical fiber cables other than those of heading 8544; sheets and plates of polarizing material; lenses (including contact lenses), prisms, mirrors and other optical elements, of any material, unmounted, other than such elements of glass not optically worked:				
9001.10.00		Optical fibers, optical fiber bundles and cables........	....	8.4%	Free (A,E)	65%
		Optical fibers:				
	30	For transmission of voice, data or video communications............	m			
	60	Other.............................	X			
	90	Optical fiber bundles and cables.........	Fiber m			
9001.20.00	00	Sheets and plates of polarizing material......	kg......	10%	Free (A,E)	50%
9001.30.00	00	Contact lenses..............................	Prs.....	5.6%	Free (A,E)	40%
9001.40.00	00	Spectacle lenses of glass....................	Prs.....	5.6%	Free (A,E)	40%
9001.50.00	00	Spectacle lenses of other materials..........	Prs.....	5.6%	Free (A,E)	40%
9001.90		Other:				
9001.90.40	00	Lenses...................................	No......	5.6%	Free (A,C,E)	45%
9001.90.50	00	Prisms...................................	X.......	8%	Free (A,C,E)	65%
9001.90.60	00	Mirrors..................................	X.......	8%	Free (A,C,E)	45%
		Other:				
9001.90.80	00	Half-tone screens designed for use in engraving or photographic processes............................	X.......	3.1%	Free (A,E)	25%
9001.90.90	00	Other.............................	X.......	8.4%	Free (A,C,E)	85%
9002		Lenses, prisms, mirrors and other optical elements, of any material, mounted, being parts of or fittings for instruments or apparatus, other than such elements of glass not optically worked; parts and accessories thereof:				
		Objective lenses and parts and accessories thereof:				
9002.11		For cameras, projectors or photographic enlargers or reducers:				
9002.11.40	00	Projection.........................	No......	7%	Free (A,E)	45%
9002.11.80	00	Other..............................	X.......	6.6%	Free (A,E)	45%
9002.19.00	00	Other..................................	X.......	6.6%	Free (A,E)	45%
9002.20		Filters and parts and accessories thereof:				
9002.20.40	00	Photographic...........................	X.......	5.8%	Free (A,E)	20%
9002.20.80	00	Other..................................	X.......	8.4%	Free (A,E)	65%
9002.90		Other:				
9002.90.20	00	Prisms.................................	X.......	8%	Free (A,C,E)	65%
9002.90.40	00	Mirrors................................	X.......	8%	Free (A,C,E)	45%
		Other:				
9002.90.70	00	Half-tone screens designed for use in engraving or photographic processes............................	X.......	3.1%	Free (A,E)	25%
9002.90.90	00	Other.............................	X.......	8.4%	Free (A,C,E)	65%

Appendix I

Customs Treatment for Selected Foreign Markets and Suppliers

TARIFFS FOR OPTICAL FIBER

Country and (Item Number)	Current Duty Rate Applicable to MFN	Preferential Duty Rates	Other Fees/ Charges
Argentina	10%		10% Import Surcharge 18% VAT 3% Statistical Fee 5% Export Promotion 2% Consular Fee 12% of Freight Charge for Merchant Marine Fund
Australia 1/ 70.18.100	20% f.o.b. Port of Export	15% LDCs 0% Pacific Islands	
Austria	6%	3% LDCs 0% LDDCS 0% EEC/EFTA	
Brazil	30%		
Canada 1/	10.2%	6.5% LDCs 10% British Commonwealth	
EC			
8544.70	8%	0% EEC/LDCs	
9001.10	7.5%	0% EEC/LDCs	
Finland	0%		
Hong Kong	0%		.5% Ad valorem c.i.f.
India	100%		40% Auxiliary Duty Import Substitution
Indonesia 70.18.190	5%		10% VAT
Israel			U.S. and EEC, duty free
Japan 2/ 70.18	15% 2.9% Temporary US & most others	0% LDCs 3.6% GATT (+USSR)	
Malaysia 70.18	0%		10% Sales Tax
New Zealand	34% f.o.b. Port of Export	20% Australia, Canada, LDCs 0% LDDCs and Pacific Island	

Country and (Item Number)	Current Duty Rate Applicable to MFN	Preferential Duty Rates	Other Fees/ Charges
Norway 70.20.901	3.2%	0% EEC/EFTA	
People's Republic China 70.18	12%		
Republic of Korea	20% (c.i.f.)		10% VAT 2.5% Defense Tax
Singapore 70.18	0%		
Sweden 70.20.909	7%	0% EEC/EFTA	
Taiwan 1/	5% (Non-bilateral treaty countries)	2.5% (c.i.f.) (other countries)	5% VAT (c.i.f.)
Venezuela 70.18	5% Ad valorem		5% Customs Surcharge

1/ Policy of domestic sourcing.
2/ Domestically designed standards.

**Domestically-designed standards.

Sources: U.S. Department of Commerce, Country Tariff Schedules, Japan External Trade Organization (JETRO).