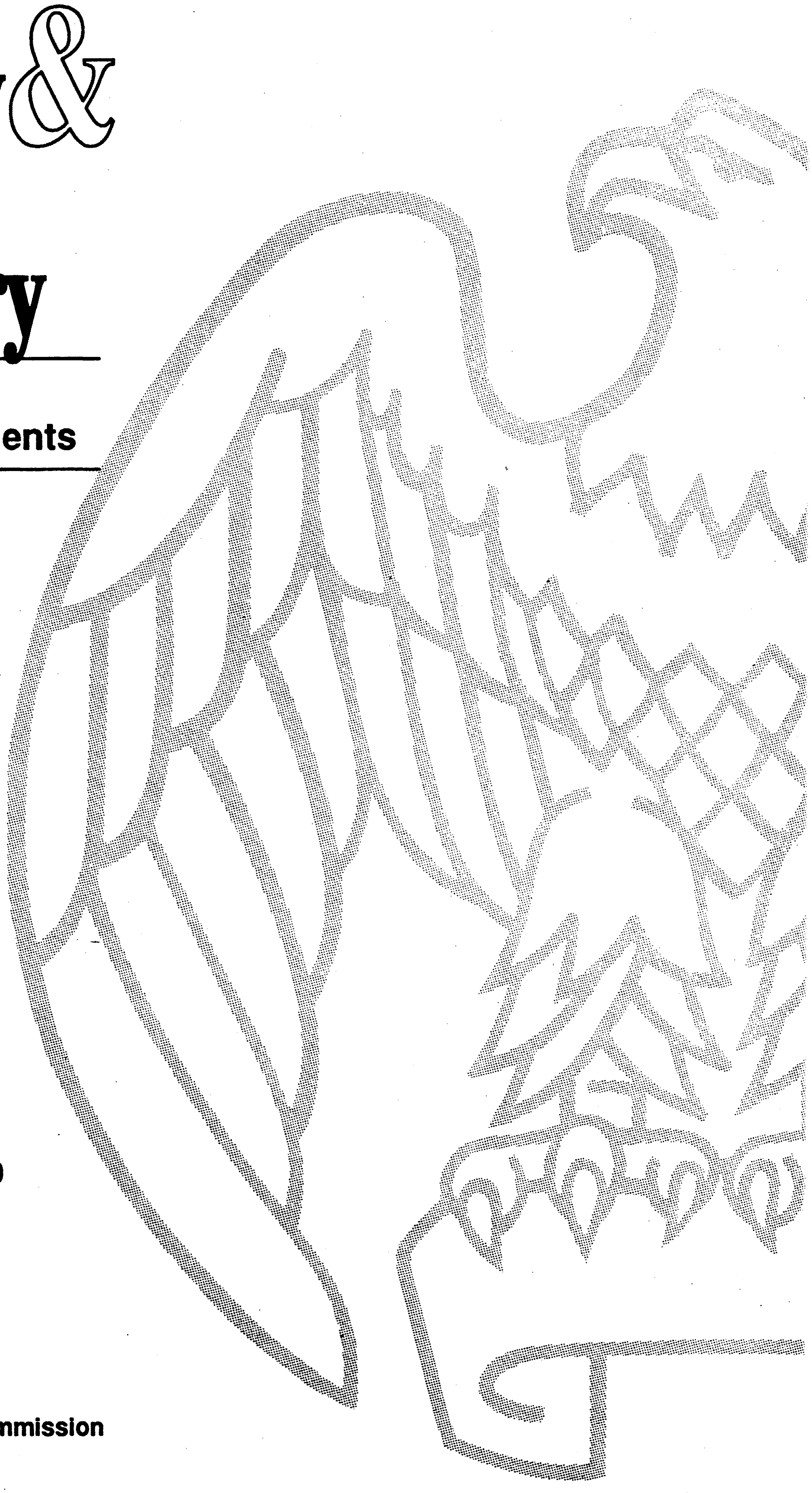
Industry & Trade Summary

Navigational and Surveying Instruments



USITC Publication 2730
February 1994

OFFICE OF INDUSTRIES
U.S. International Trade Commission
Washington, DC 20436

UNITED STATES INTERNATIONAL TRADE COMMISSION

COMMISSIONERS

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PREFACE

In 1991, the United States International Trade Commission initiated its current *Industry and Trade Summary* series of informational reports on the thousands of products imported into and exported from the United States. Each summary addresses a different commodity/industry area and contains information on product uses, U.S. and foreign producers, and customs treatment. Also included is an analysis of basic factors affecting trends in consumption, production, and trade of the commodity, as well as those bearing on the competitiveness of U.S. industries in domestic and foreign markets.[1]

This report on navigational and surveying instruments covers the period 1988 through 1992 and represents one of approximately 250 to 300 individual reports to be produced in this series during the first half of the 1990s. Listed below are the individual summary reports published to date on the electronic technology, instruments and precision manufactures sector.

USITC publication number	*Publication date*	*Title*
2445	January 1992	Television Receivers and Video Monitors
2648	July 1993	Measuring, testing, controlling, and analyzing instruments
2674	September 1993	Medical goods
2708	December 1993	Semiconductors
2728	February 1994	Capacitors
2730	February 1994	Navigational and surveying instruments

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[1] The information and analysis provided in this report are for the purpose of this report only. Nothing in this report should be construed to indicate how the Commission would find in an investigation conducted under statutory authority covering the same or similar subject matter.

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INTRODUCTION

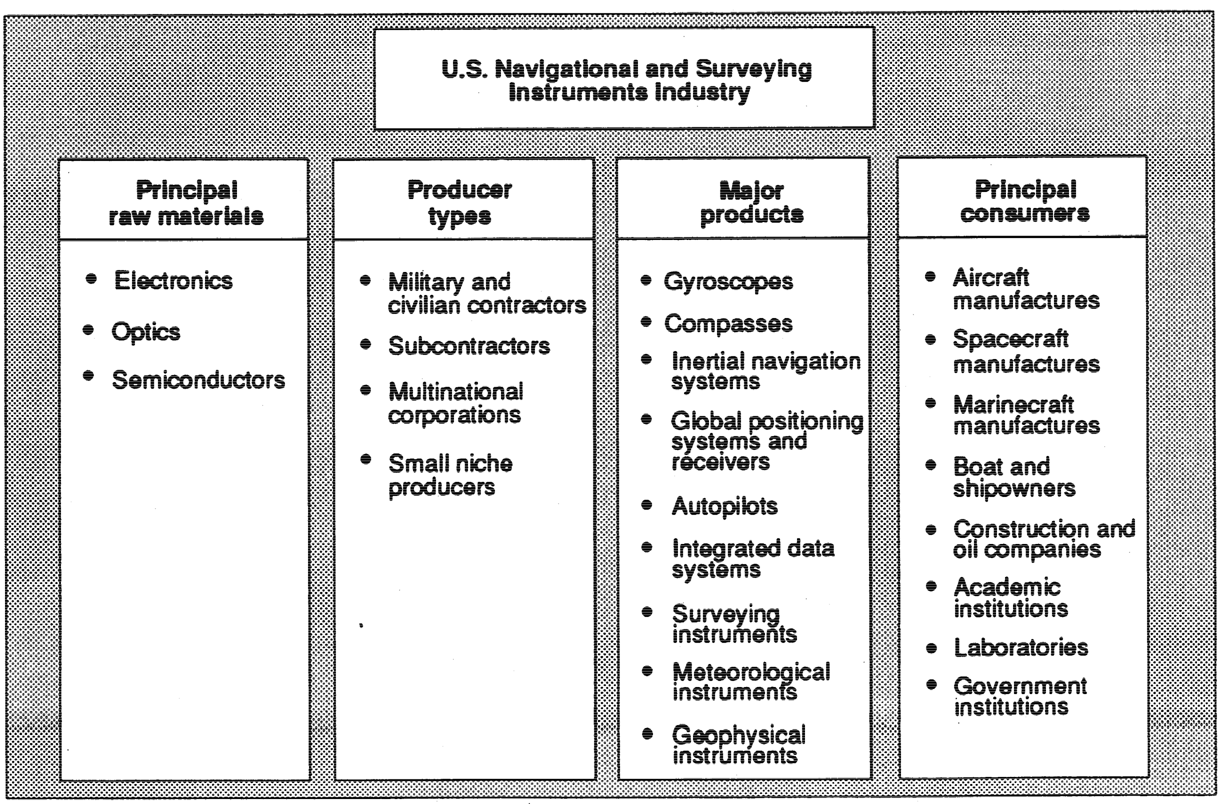
The products covered in this report include equipment, instruments, and parts and accessories that are used in navigational, surveying, meteorological, hydrological, oceanographic, and geophysical operations (hereafter called navigational and surveying instruments). These instruments are produced by approximately 336 companies in the United States, ranging in employment from only a handful of employees to thousands. Many of these companies also produce other articles with a wide range of scientific, laboratory, commercial, and industrial applications.

Despite a sluggish U.S. market, U.S. shipments of navigational and surveying instruments averaged a 3-percent annual growth during 1988-92, increasing from $6.4 billion in 1988 to $7.2 billion in 1992. The growth in U.S. output can be attributed largely to significant overseas demand for U.S.-produced instruments. U.S. exports of these instruments increased by an average annual rate of 9 percent, from $1.2 billion in 1988 to $1.7 billion in 1992. As a result, the ratio of exports to domestic shipments rose from 19 to 24 percent during the period. Imports rose slowly in this period, increasing by 3.6 percent annually, to $562 million in 1992. Consequently, the U.S. trade surplus in these products widened from $716 million in 1988 to $1.1 billion in 1992. Apparent U.S. consumption increased by 4 percent annually, increasing from $5.7 billion in 1988 to $6.2 billion in 1990. Economic recession and the end of the Cold War slowed the demand for these instruments in 1991 and 1992 to just over $6 billion per year. Imports accounted for between 7 and 9 percent of consumption.

Most of the data in this report are estimated. Existing data on industry structure and other economic indicators, such as those collected and published by the Bureau of the Census, are of limited use. In most cases the Census surveys collect data based on broad industry categories, which encompass a larger number of products than are covered in this summary.

Navigational instruments and systems represent approximately 90 percent of U.S. shipments of all products covered in this summary. They are produced by large military and civilian contractors, multinational corporations having diversified operations, and a large number of small producers supplying specialty products to niche markets, either directly or as subcontractors (figure 1). The primary purchasers of navigational instruments are the U.S. Government (e.g., U.S. Department of Defense and National Aeronautics and Space Administration (NASA)), certain foreign governments, aircraft builders, owners and operators, boat and ship owners and builders, and ship operators.

Figure 1
U.S. navigational and surveying instruments industry: Principal raw materials, producer types, major products, and principal consumers



Source: USITC.

Navigation is the science and art of getting ships, aircraft, or spacecraft from place to place by means of instruments and systems used as aids, which determine position, course, and distance traveled over the surface of the earth, using the principles of geometry and astronomy. Most of these instruments and aids are high-technology products and include direction-finding compasses (magnetic and gyroscopic) and aeronautical instruments, such as altimeters, air speed indicators (including airborne computing systems), mach meters, climbing and diving speed indicators, turning and banking indicators, accelerometers, gyroscopes (inertial and noninertial), thermocouple and thermocouple lead wire, position indicators, hydraulic systems, and cabin environmental measuring and control instruments.[1]

Airborne navigational systems include inertial navigational systems (INS), the global positioning systems (GPS), automatic pilots or autopilots, airborne integrated data systems/flight recorders, flight recorders/situation displays, heads-up display (HUD) systems, proximity warning/collision avoidance equipment and so forth. The INS, which completely controls navigation by providing steering signals to the autopilot and pilot instruments, is considered the heart of the modern aircraft. The INS controls navigation without reference to radio signals from the ground and can navigate over water to the most remote parts of the world. The GPS was developed by the U.S. Department of Defense to simplify accurate navigation. GPS uses satellites and computers to compute positions anywhere on earth. GPS receivers have a wide range of military and commercial applications. The automatic pilot in an airborne system temporarily replaces the pilot by controlling the equilibrium and flight of the aircraft in accordance with a pre-established setting. Autopilot in a ship controls the ship's rudder in relation to the readings of a gyroscopic compass. Instruments used for marine navigation include GPS receivers and systems, course recording or directional finder kits, inclinometers, logs, sounding leads, echo-sounding instruments, and ultrasonic sounding or detecting equipment, (e.g., asdic or sonar).

Surveying and other instruments represent approximately 10 percent of domestic shipments of products covered by this summary. They are produced by a few large companies with diversified operations and many small producers supplying specialty products to niche markets. Most are high-technology products used by engineers, scientists, map-makers and construction workers as "tools of the trade" while working in academic institutions, laboratories, government institutions, and the construction and oil industry. These instruments and systems have a wide range of applications and include products with various capabilities and accuracy ranges. The instruments and appliances used in geodesy, topography, surveying, or leveling are intended for use in the field, for example, in cartography (land or hydrographic map making), in the preparation of plans, for triangular measurements, in calculating the area of a piece of land, in determining heights above or below a horizontal reference level, and in similar measurements for construction (building of roads, dams, bridges, etc.), mining, military operations and other purposes.

This class of instruments includes range finders, theodolites, tachymeters (theodolites incorporating a range finder), transits, levels, alidades, plane tables, land chains, pickets or ranging poles, and other special measures for surveying. Photogrammetrical surveying instruments and appliances are used for plotting topographic and other maps, but they are also used for other purposes, such as in the study of tides or ground swells. The maps are usually plotted from photographs taken from two different viewpoints with known bearings to accurately determine the shape, size, and coordinates of the area photographed.

Hydrographic instruments are used to plot water courses, depths, tide levels, etc. Oceanographic instruments include special level recorders for calculating fluctuations in the level of lakes or rivers, bucket-wheel current meters and hydrometric paddle-wheels, for measuring the speed of currents in rivers and canals, and swell or tide recorders. Meteorological instruments are used to observe atmosphere and its phenomena, such as temperature, density, winds, clouds, and precipitation, and include instruments such as anemometers, anemographs, wind transmitters, rain gauges, sunshine recorders, nephoscopes, and ceilometers. Geophysical instruments are used in oceanography, geodesy, and seismology, and include instruments such as geophones, seismometers, seismographs, gravimeters, magnetometers and other magnetic or gravimetric geophysical instruments used in prospecting for ores, oil, and so forth.[2]

U.S. INDUSTRY PROFILE

Industry Structure

The U.S. Departments of Commerce and Labor collect data on domestic shipments, employment and other economic indicators on an industry-by-industry basis through the Standard Industrial Classification (SIC) system. Establishments primarily engaged in producing navigational instruments are classified in SIC 3812, Search, Detection, Navigation, Guidance, Aeronautical, and Nautical Systems and Instruments. Establishments producing surveying and other instruments are classified in SIC 3829, Measuring and Controlling Devices, Not Elsewhere Classified. These industries also include establishments that produce a number of instruments with a wide range of scientific, laboratory, industrial, and commercial applications. Navigational instruments account for an estimated 15 percent of shipments in SIC 3812; surveying and

[1] See "Glossary of Terms" in appendix C for a brief description and for uses of instruments covered in this summary.

[2] See appendix C for a brief description and for uses of surveying and other instruments.

Other instruments, an estimated 20 percent of shipments in SIC 3829.[3]

Number of firms, employment, and major U.S. producers

In 1992, approximately 336 firms, employing 50,000 people, produced navigational and surveying instruments valued at $7.2 billion. The firms producing navigational instruments are relatively large, and they averaged 181 employees per firm, compared with those producing surveying instruments, which consist mostly of small firms and which averaged 74 employees per firm. The majority of employees are nonproduction workers, including a high proportion of R&D, engineering and scientific staff.[4]

[3] Estimated by the USITC staff, based on data from the U.S. Department of Commerce.

[4] Interviews with company officials at Litton Systems, Sperry Marine, Interstate Electronics, Trimble Navigation, and EG&G Geometrics indicated that these firms employ a high proportion of engineers, scientists, and technical personnel.

The skill levels of production workers are high, and most of the firms are in high-labor-cost areas, such as New York, Los Angeles, and San Francisco. Therefore, wage levels in these industries are high (see table 1 for industry structure).

Litton Systems dominates the U.S. and international market in gyroscopes and inertial navigational systems having military applications. Other major producers of gyroscopes and INS in the United States are Honeywell (which is involved with both civilian and military aircraft and missiles and land navigation), Delco Electronics (a division of General Motors and primarily a supplier to commercial aircraft), Sperry Marine (the market leader in marine navigation), Astronautics-Kearfott (supplier to military aircraft, mostly missiles), Bendix, Rockwell Collins, and Precision Products Group of Northrop. In satellite-based navigational and position data products, Interstate Electronics is the leading U.S. producer of inertial-based integrated GPS systems for military use, followed by Rockwell Collins, Texas Instruments, ITT

Table 1
Navigational and surveying instruments: Industry structure, 1987-91

	1987	1988	1989	1990	1991
Navigational instruments:[1]					
Establishments (*number*)	256	269	251	244	232
Employees (*1,000*)	54.5	54.2	50.9	47.1	42.0
Production workers (*1,000*)	25.5	24.8	22.5	20.7	18.5
Value of shipments (*million dollars*)	4,981	5,547	6,205	6,380	6,388
Wages per hour (*dollars*)	14.21	14.99	14.99	14.49	14.08
Value added/production worker (*dollars*)	155,883	158,832	169,918	191,342	210,795
Capital expenditure/shipments (*percent*)	4.0	3.7	3.9	3.1	2.3
Payroll/value added (*percent*)	50	51	52	49	49
Wages/value added (*percent*)	18	18	17	16	15
Materials/shipments (*percent*)	34	32	31	31	32
Payroll/shipments (*percent*)	34	34	35	33	32
Wages/shipments (*percent*)	12	12	12	11	10
New capital expenditure/ worker (*dollars*)	9,068	8,813	9,708	8,630	7,390
Surveying instruments:[2]					
Establishments (*number*)	107	116	107	111	104
Employees (*1,000*)	8.2	7.8	7.7	7.5	7.7
Production workers (*1,000*)	4.0	4.2	4.0	4.0	4.1
Value of shipments (*million* dollars).	707	857	761	833	911
Wages per hour (*dollars*)	10.40	10.59	10.78	11.86	11.95
Value added/production worker (*dollars*)	111,832	114,420	117,853	139,155	140,564
Capital expenditure/shipments (*percent*)	3.0	3.2	3.8	3.1	3.0
Payroll/value added (*percent*)	49	47	47	46	46
Wages/value added (*percent*)	18	18	19	17	17
Materials/shipments (*percent*)	36	37	36	37	37
Payroll/shipments (*percent*)	32	30	29	29	29
Wages/shipments (*percent*)	12	12	12	11	11
New capital expenditure/ worker (*dollars*)	5,149	5,643	7,216	7,006	6,744

[1] Includes data for all of SIC 3812, except data on establishments, employment, and value of shipments.

[2] Includes data for all of SIC 3829, except data on establishments, employment, and value of shipments.

Source: U.S. Department of Commerce, Bureau of the Census.

Avionics, and Magnavox Advanced Products and Systems. There are many commercial suppliers of position data products in the United States; the major companies are Trimble Navigation, Magellan, Ashtech, Litton Aeroproducts, and Rockwell Collins. In geophysical instruments, Halliburton Geophysical is the leading producer followed by a number of small-to-medium producers; the leading ones are Syntron, EG&G Geometrics and Bison Instruments. Generally these companies have manufacturing and R&D operations in the United States, but most of them compete worldwide through their global sales and service network systems. Only a few of them maintain offshore operations, which primarily supply local markets. The global nature of their business is somewhat restricted to instruments having military applications.

Geographic distribution

Establishments producing navigational instruments are primarily in California, Florida, Massachusetts, New Jersey, New York, and Texas. These States accounted for 55 percent of total establishments and two-thirds of total employment in 1991. California is by far the largest producer, accounting for 22 percent of establishments and 35 percent of employees. California is also the largest producer of surveying instruments, accounting for 17 percent of total establishments and 12 percent of total employees in the industry. Other States that are major producers of surveying instruments are Connecticut, Illinois, Massachusetts, Michigan, Minnesota, New York, Ohio, Pennsylvania, and Texas.

Concentration

According to U.S. Department of Commerce data, the industries producing navigational and surveying instruments (SICs 3812 and 3829) are not highly concentrated.[5] The four and eight largest companies in SIC 3812 accounted for 29 and 49 percent, respectively, of industry shipments, while the four and eight largest companies in SIC 3829 represented 15 and 28 percent, respectively, of industry shipments, as shown in the following tabulation (in percent):

	Percent of shipments accounted for by the—			
Industry group	4 largest	8 largest	20 largest	50 largest
SIC 3812 (including navigational instruments)	29	49	76	92
SIC 3829 (including surveying instruments)	15	28	45	63

Navigational and surveying instruments manufacturing operations account for a small part of overall operations of the establishments classified in SICs 3812 and 3829. Therefore, concentration levels for segments producing navigational and surveying instruments may significantly differ from those of SICs 3812 and 3829. Many industry officials interviewed by the Commission staff indicated that the industry segment producing navigational instruments is dominated by a few large firms, and therefore, highly concentrated.

The navigational instrument industry includes some large publicly held companies. One in twelve establishments in this industry employed 1,000 or more employees each, and together they accounted for 76 percent of total industry employment (table 2).[6] More than 60 percent of the establishments employed fewer than 50 employees each and accounted for only 3 percent of total industry employment. The industry producing surveying instruments is composed of small establishments, 81 percent employing fewer than 50 employees each, and less than 1 percent employing more than 1,000 employees each, as seen in table 2.

Conditions of competition and competitiveness

Because most navigational and surveying instruments can be characterized as "advanced-technology" products, R&D intensity, rates of inventiveness, innovation and automation, managerial competence, the securing of capital, and the ability of the firm to function internationally are important to the global competitiveness of a firm. As a result, production of these instruments is concentrated in countries with the needed resources, both physical and human, to produce them. Because direct labor costs represent a small part of total production costs for most products, there has been little movement of production to low-wage countries.

Although an estimated 336 companies are engaged in producing navigational and surveying instruments and systems, only a few of them control the bulk of industry output. The key factors affecting the competitiveness of large firms tend to differ from those

[5] Industry concentration is measured by the Herfindahl-Hirschman index (HHI), introduced for the first time in 1982. The index is calculated by squaring the concentration ratio for each company and summing those squares to a cumulative total. The largest 50 companies or the complete universe, whichever is lower, is used to find this cumulative total. The higher the index, the more concentrated the industry is. For SIC 3812, this index in 1987 was 401 vs. 134 for SIC 3829. Under U.S. Department of Justice merger guidelines, an industry characterized by an HHI exceeding 1,800 may be termed "concentrated," one between 1,000 and 1,800 "moderately concentrated," and one of less than 1,000 "not concentrated."

[6] However, the group controlling the bulk of output of navigational instruments also included some medium-size firms.

Table 2
Navigational and surveying instruments: Establishments and employees by employment size, 1990

Employment size	SIC 3812 (including navigational instruments) percent of:		SIC 3829 (including surveying instruments) percent of:	
	Establishments	Employees	Establishments	Employees
Fewer than 20	44	1	61	8
20 to 49	18	2	20	13
50 to 99	11	2	8	12
100-249	8	4	8	27
250-499	6	6	2	12
500-999	5	10	1	15
1,000 and over	8	76	1	14
Total	100	100	100	100

[1] Less than 0.5 percent.

Note.—Individual sums may not add to total due to independent rounding.

Source: U.S. Department of Commerce, Economic Surveys Division of the Bureau of the Census, *County Business Patterns, 1990, United States.*

affecting small firms. Large firms are more likely to have access to internal resources and standing lines of credit; they are also more likely to compete in terms of established reputation for quality and reliability. They tend to be product-oriented, with new product development seen as part of an overall corporate strategy. They spend significant amounts on product development and produce a full line of instruments and systems for both military and civilian uses. Small firms, which tend to produce specialized products and serve niche markets, are more affected by the performance criteria of the technology they offer, the availability of specialized expertise, and the quality and decision-making ability of the firm's management. They look for R&D support to exploit opportunities that they might otherwise not be able to perform independently. These firms often lack financial and physical resources to take on large projects and generally exploit market niches too narrow to be of interest to large firms. Some of the small and medium-size firms work as subcontractors to large defense or civilian contractors. Some small producers of surveying and other instruments also import and distribute foreign-made products to complement their domestic lines. Production runs of these firms are normally small, limited to a few items, and often customized.

Industrial organization of large military contractors is distinct from that of firms supplying the civilian market. Because military instruments and electronic systems are highly complex and sophisticated, because they require multiyear development and production time, they are produced by only a few large firms. These firms control the bulk of industry shipments either as rivals, subcontractors, or partners. Barriers to entry are high because of the limited market and high cost of investment. By contrast, a relatively large number of firms supply the civilian market. Because the diffusion of technology is widespread and a large number of firms compete for market share, the competition is keen in the civilian market.

The worldwide homogeneity of navigational and surveying instruments, the limited number of manufacturers, and the high ratios of product value to transportation costs make the competition and trade in this industry highly global. The U.S.-produced instruments and systems having military applications dominate the military part of the global market, although export restraints restrict exports of certain instruments. This domination is attributed, in large part, to superior technology, resulting from significant R&D spending by the government and large military contractors. Firms producing instruments with military applications tend to be large and oriented in their product lines towards the military. Smaller civil-oriented firms find the market difficult to enter. In the civilian sector, the international competitiveness of U.S. firms is based more on product quality, price, and volume, rather than technological advantage. The producers in the United Kingdom and France, the major U.S. competitors in Europe, are not currently price-competitive in the international markets, and are therefore less global. They are reportedly subsidized by their respective governments, which enables them to remain competitive in their home markets.[7]

Productivity

Significant productivity growth in the industry producing navigational instruments has enabled the industry to continue to remain globally competitive. Although official productivity data are not available for industry segments producing navigational and surveying instruments, estimated productivity in the industry segment producing navigational instruments,

[7] Information obtained from Honeywell, Minneapolis, MN.

as measured by constant dollar shipments per production employee, averaged a 10-percent gain annually during 1987-91. The major contributing factors to productivity growth in this sector are rapid technological advances, efficient management of materials and purchased services, and improved labor productivity.[8] By contrast, in the surveying instrument industry, productivity fluctuated, but averaged 2-percent annual growth as shown in table 3 (figure 2).

Factor costs of production

Because industries producing navigational and surveying instruments are highly capital-intensive, direct labor costs account for only about 13 to 14 percent of total production costs (tables 4 and 5). A large part of production costs is attributed to R&D and other indirect personnel, materials, manufacturing overhead, and sales and marketing.[9] Capital costs are

[8] Interview with officials at Litton Systems, Aug. 18, 1992. The navigational industry buys a significant portion of its materials from external sources, mostly from U.S. producers. The amount of materials sourced from external sources has increased in recent years, which partly explains the much larger output per employee in this industry. Officials of other companies, which the Commission staff interviewed during July and August 1992, also indicated that the industry's global

8—*Continued*
competitiveness is attributed to its productivity growth through automation and improved manufacturing systems.

[9] Interviews with officials of Litton, Interstate, Trimble, Geometrics, and Sperry, July-Aug. 1992.

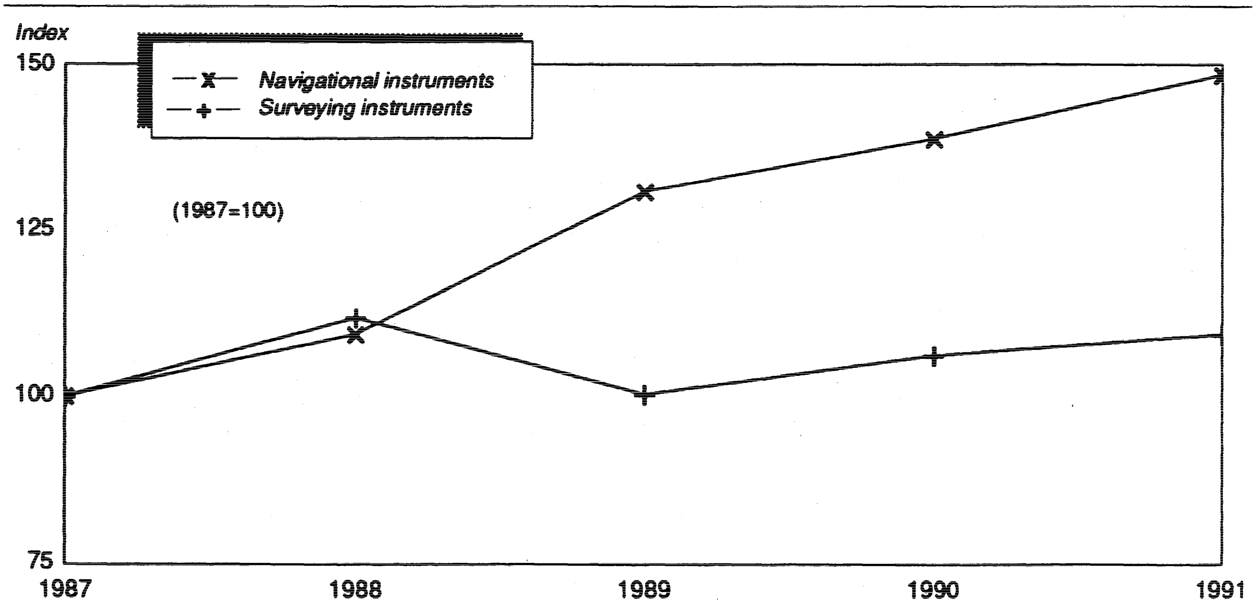
Table 3
Navigational and surveying instruments: Indexes of constant dollar shipments per production employee, 1987-91

Year	Productivity indexes (1987=100)[1]	
	Navigational instruments	Surveying instruments
1987	100.0	100.0
1988	109.3	111.8
1989	130.9	100.3
1990	138.9	106.1
1991	148.5	109.3

[1] These productivity measures, based on estimated shipments and number of production employees, reflect overall trends in real output per unit input of labor. These indexes do not reflect factor productivity measures for capital, material, and other purchased services, or labor.

Source: Computed by the USITC staff, based on data from Commerce and Bureau of Labor Statistics.

Figure 2
Navigational and surveying instruments: Productivity as measured by indexes of constant dollar shipments per production employee, 1987-91



Source: Computed by the USITC staff, based on data from Commerce and Bureau of Labor Statistics.

Table 4
Navigational instruments (SIC 3812): Cost of production, by factor, 1987-91

(Percent)

Cost factor	1987	1988	1989	1990	1991
Direct labor	15.0	14.9	14.5	13.8	12.7
R&D and indirect personnel	26.5	27.1	29.0	27.7	27.8
Material	33.7	31.5	30.8	30.7	31.5
Fuel and electricity	0.9	0.9	0.9	0.9	0.9

Source: U.S. Bureau of the Census, *Annual Survey of Manufactures,* various issues.

Table 5
Surveying instruments (SIC 3829): Cost of production, by factor, 1987-91

(Percent)

Cost factor	1987	1988	1989	1990	1991
Direct labor	14.6	14.5	14.2	13.1	13.5
R&D and indirect personnel	24.2	22.5	21.3	22.2	21.9
Material	35.7	36.5	36.4	35.7	36.9
Fuel and electricity	1.0	0.9	1.0	1.1	1.1

Source: U.S. Bureau of the Census, *Annual Survey of Manufactures,* various issues.

not available, but are believed to account for a significant percentage of industry sales. Energy costs have remained low at about 1 percent of industry shipments during 1987-91.

Capacity utilization

Between 1989 and 1990, the capacity utilization rate for navigational instrument producers (SIC 3812) increased from 69 to 71 percent, but declined from 79 to 75 percent for surveying instrument producers (SIC 3829).[10] According to industry sources, capacity utilization rates for these industries declined significantly in 1991 and 1992 as overall demand for navigational and surveying instruments slowed, largely because of the economic recession and slowdown in military spending. A number of companies in both sectors adjusted to the slowdown by streamlining their operations and reducing excess capacity.[11]

Capital expenditures

The industry producing navigational instruments is more capital-intensive than most industries in the industrial sector. Industry competitiveness is indicated by the level of investment by the industry on new plant and equipment. During 1987-91, new capital expenditures per production worker averaged $8,721 annually in the industry producing navigational instruments (SIC 3812), compared with $7,558 in all industries and $6,352 in the industry producing surveying instruments (SIC 3829). In terms of constant (1987) dollars, annual capital expenditures averaged $8,362 in the industry producing navigational instruments and $6,065 in the industry producing surveying instruments, compared with $7,217 in all industries as shown in table 6. According to a number of industry officials, new capital expenditures per employee in companies producing navigational and surveying instruments are much higher than those shown for SICs 3812 and 3829. Some of the companies, which the Commission staff visited during July-August 1992, spend as much as 10 percent of sales on new machinery and equipment—nearly three times higher than that spent in SICs 3812 and 3829. Litton, Honeywell, and Raytheon, the large manufacturers of navigational instruments spent between 4 and 6 percent of their sales on capital equipment, compared with 3.9 percent for SIC 3812.[12] Because of this capital intensity, production worker wages accounted for only 17 to 18 percent of value added in the industry producing navigational instruments compared with 21 percent in all industries and 30 percent in labor-intensive industries, such as apparel products and footwear. Large capital investment and limited markets are significant barriers to entry into the business. Therefore, the industry is dominated by a few large companies that have the financial resources to invest heavily in capital equipment. Because of the financial and business risk involved in developing a new product, many small producers tend to purchase instruments and build navigational systems.[13]

[10] This is based on full production capacity. Full production capacity is broadly defined as the maximum level of production an establishment can attain under normal operating conditions. The full production utilization rate is a ratio of the actual level of operations to the full production level. See Bureau of the Census' *Survey of Plant Capacity,* 1990, MQ-C1(90)-1.

[11] The Commission staff interview with officials of Litton, Interstate, Geometrics, and Sperry, July-Aug. 1992.

[12] *Electronic Business,* Sept. 1992, p. 84.

[13] Interview with officials of Litton Systems, Aug. 18, 1992.

Table 6
Navigational, surveying, and all industries: Capital expenditures per production employee, 1987-91

Year	SIC 3812 (including navigational instruments)		SIC 3829 (including surveying instruments)		All industries	
	In current dollars	*In 1987 dollars*	*In current dollars*	*In 1987 dollars*	*In current dollars*	*In 1987 dollars*
1987	9,062	9,062	5,149	5,149	6,424	6,424
1988	8,813	8,573	5,643	5,489	6,496	6,319
1989	9,708	9,228	7,216	6,859	7,874	7,485
1990	8,630	8,065	7,006	6,548	8,406	7,856
1991	7,390	6,881	6,744	6,279	8,591	7,999
Average 1987-91	8,721	8,362	6,352	6,065	7,558	7,217

Source: U.S. Bureau of the Census, *Annual Survey of Manufactures,* various issues.

Research and development expenditures

The level of technology and competitiveness of an industry can be measured by its R&D intensity. Two ways of examining the R&D intensity of an industry are to look at the ratio of R&D expenditures to sales, and the ratio of R&D scientists and engineers (R&D S&E) to total employment. A high ratio indicates that an industry and its products are technically sophisticated and competitive. In 1990, the R&D intensity in the industry sector producing scientific instruments[14] ranked third among all industries (table 7, figure 3).

Approximately 11 percent of employees were engaged in R&D work in U.S. companies producing navigational and surveying instruments, and these companies spent an average of 9.4 percent of their sales volume on research (table 7). This is significantly higher than the portion spent in most other sectors, and it ranked third-largest behind computers and pharmaceuticals. Because most foreign affiliates of U.S. companies get R&D support from parent companies, R&D performed by U.S.-owned foreign affiliates accounted for only 1.4 percent of sales, and R&D employees accounted for only 2.7 percent of total employment.[15]

Most new product development starts with existing equipment. Field engineering staff work closely with the customers of existing equipment and obtain feedback concerning the operational performance of the equipment, reliability, accuracy, and test results. These field data are used by the R&D staff in the development and design of the next generation of equipment. It may take anywhere from 18 months to 8 years for a company to develop and market a new product.

Most companies in the navigational and surveying instruments industries use their own funds for both basic and applied research. The average annual real growth in industrial R&D spending in these industries declined sharply in the 1980s, to 3.9 percent in the first half of the decade, and to 1.7 percent in the second half, following a rapid 22.3-percent growth during 1975-80, as shown in table 8. Significant decline in the Federally supported portion of industrial R&D spending perhaps slowed the rate of growth in industrial R&D spending, as the priority shifted to defense-related R&D during the 1980s. These changes were coupled with the reluctance of large corporations to invest on costly R&D in the United States, where development of new products proceeded at a much slower pace than in other countries. In addition, the industries spent a good portion of their sales dollars on R&D in the early stages of product development during 1975-80, when the rate of growth was much larger on a small R&D base. In subsequent years, as the thrust of R&D shifted away from new markets toward existing markets, the growth rate declined, as calculated on a much larger R&D base.

Trade performance

Export performance of an industry is a leading indicator in measuring its competitiveness in the global market. The U.S. navigational and surveying instruments industry continues to remain the leading supplier of instruments in the global market. However, its competitive edge has been somewhat eroded since 1980. In 1989, U.S.-produced instruments accounted for 25.2 percent of the global market, but this share declined from 28.3 percent in 1980 (table 9, figure 4).[16] In contrast, the shares accounted for by

[14] Includes navigational instruments, reported under SIC 381, and surveying instruments, reported under SIC 382. Navigational and surveying instruments covered in this summary account for roughly 10 to 12 percent of total product shipments of the establishments classified under SICs 381 and 382.

[15] The Census Bureau of Economic Analysis, Survey of Current Business, *U.S. Direct Investment Abroad: The 1989 Benchmark Survey Result,* Oct. 1991, pp. 29-55; and *U.S. Affiliates of Foreign Companies: Operations in 1989*, July 1991, pp. 72-93.

[16] This trend pertains to all scientific and measuring instruments classified in SICs 381 and 382. Although global share for U.S. exports of navigational and surveying instruments are not available, export performance of the U.S. navigational and surveying

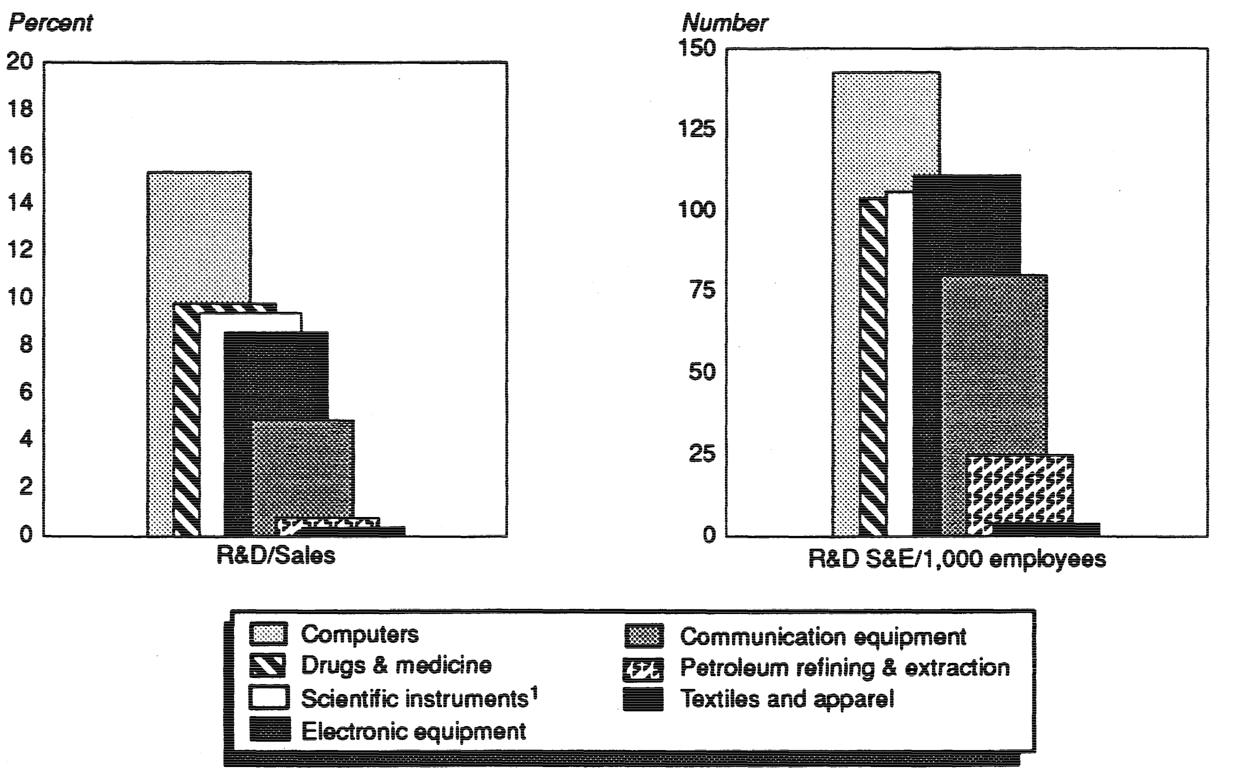
Table 7
R&D intensity in selected industry segments with the highest and lowest intensity rates, 1990

Industry segment	R&D/Sales	R&D S&E/1,000 employees
	(Percent)	*(Number)*
Highest six:		
Computers	15.4	143
Drugs and medicines	9.8	104
Scientific instruments[1]	9.4	106
Electronic components	8.6	111
Optical and surgical instruments	6.9	53
Communication equipment	4.9	80
Lowest six:		
Petroleum refining and extraction	.8	25
Paper and allied products	.8	12
Lumber and wood products	.7	5
Ferrous metals and products	.6	10
Food and tobacco products	.5	7
Textiles and apparel	.4	4

[1] Includes navigational and surveying instruments.

Source: National Science Board, Committee on Industrial Support for R&D, *The Competitive Strength of U.S. Industrial Science and Technology: Strategic Issues*, Aug. 1992, pp. 15, 69, and 70.

Figure 3
R&D intensity in navigational and surveying instruments and in other selected industries, 1990



[1] Including the products covered in this summary.

Source: National Science Board, Committee on Industrial Support for R&D, *The Competitive Strength of U.S. Industrial Science and Technology: Strategic Issues*, Aug. 1992.

Table 8
Rates of changes in industrial R&D spending for selected industries: 1975-80, 1980-85, 1985-90, and 1990-92

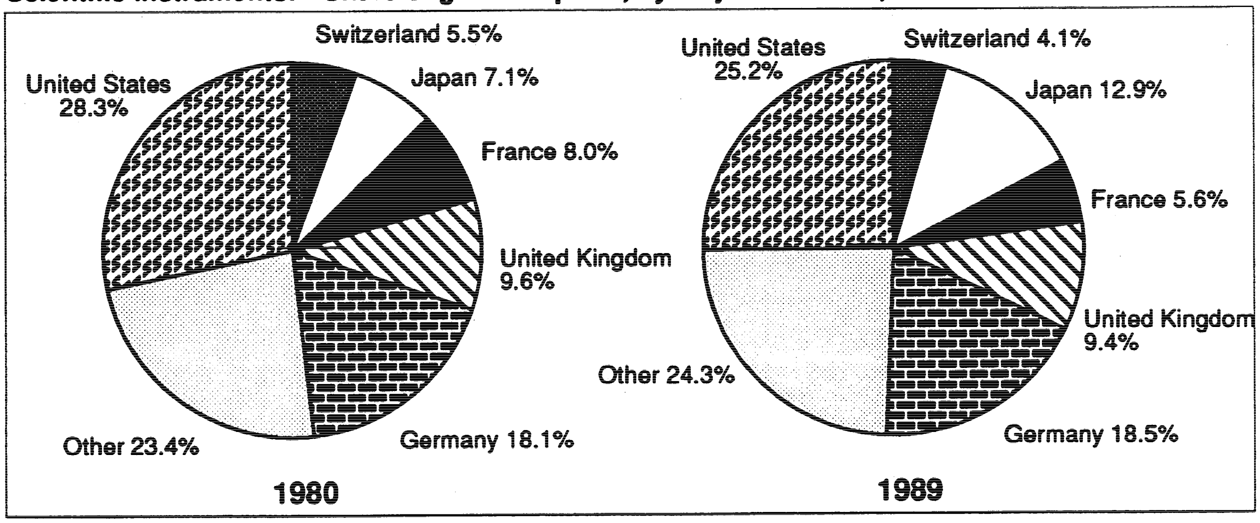
(Percent)

Industry segment	Average annual real change in industrial R&D spending 1975-80	1980-85	1985-90	1990-92
Scientific instruments[1]	22.3	3.9	1.7	-1.0
Optical and surgical instruments	5.9	9.6	2.0	NA
Computing and office machines	6.3	13.2	1.9	-0.4
Drugs and medicines	4.2	8.5	6.3	7.8
Electronic components	17.4	13.0	7.0	NA
Communication equipment	4.1	10.7	-2.2	NA
Petroleum refining and extraction	6.8	3.5	-4.5	-1.7

[1] Includes navigational and surveying instruments.

Source: National Science Board, *The Competitive Strength of U.S. Science and Technology: Strategic Issues,* Aug. 1992, p. 66.

Figure 4
Scientific instruments:[1] Share of global exports, by major countries, 1980 and 1989



[1] Navigational and Surveying instruments account for about 12 percent of scientific instruments in SICs 381 and 382.

Source: National Science Board, *The Competitive Strength of U.S. Industrial Science and Technology: Strategic Issues,* Aug. 1992.

Table 9
Navigational and surveying instruments:[1] Share of global exports by major countries and their R&D spending, 1980 and 1989

(Percent)

Country	Share of global exports 1980	Share of global exports 1989	Nondefense R&D/GDP 1980	Nondefense R&D/GDP 1989
United States	28.3	25.2	1.7	1.9
Germany	18.1	18.5	2.3	2.7
Japan	7.1	12.9	2.2	3.0
United Kingdom	9.6	9.4	[2]1.8	1.9
France	8.0	5.6	1.4	1.8
Switzerland	5.5	4.1	([3])	([3])

[1] In SICs 381 and 382.
[2] 1981 data.
[3] Not available.

Source: National Science Board, *The Competitive Strength of U.S. industrial Science and Technology: Strategic Issues,* Aug. 1992, pp. 71 & 74.

Germany and Japan increased, and they paralleled the growth in their respective nondefense industrial R&D spending, as shown in table 9.

The competitiveness of the navigational and surveying instruments industry can be better illustrated by export performance indexes, import penetration indexes, and trade advantage indexes.[17] These indexes indicate the increasing importance of the industry as an exporter and declining importance as an importer, thereby reflecting its continued competitiveness in the global market (table 10).

Financial performance

During 1987-91, profitability ratios, as measured by the return on sales and assets, in SICs 3812 and 3829 generally declined, recording their lowest levels in 1991 (table 11, figure 5).

The major reason for the decline in profits can be attributed to declining sales without corresponding decline in fixed obligations such as interest on long-term debt, rent, salaries, depreciation etc. Against these odds, the industries still managed to record decent profits by efficiently managing their current assets, such as working capital (WC), credit and collections, and inventory (table 12).

Because of falling profits and inadequate retained earnings, navigational industry liquidity ratios generally worsened (table 13). The debt ratio in the capital structure as measured by total liabilities to net worth increased sharply during 1987-91, reflecting increased leverage and vulnerability of the industry to a business downturn as experienced in 1991. The earnings before interest and taxes (EBIT), divided by annual interest expenses (I), which measures industry ability to meet its interest obligations of a loan, plummeted from 3.9 in 1987, to 2.7 in 1989; increased to 3.4 in 1990; and dropped again to 2.9 in 1991. However, increased leverage improved the industry return on net worth (table 11). By comparison, liquidity ratios for the industry producing surveying instruments generally improved thus indicating industry efforts to diversify its resources to more profitable sales and service-related activities.

[16]*—Continued*
instruments industry segment has been excellent. During 1988-92, U.S. exports of navigational and surveying instruments increased their share of domestic output from 19 to 24 percent, although worldwide demand for these instruments was reportedly sluggish in this period.

[17] Export performance index is denoted by $(^{x}t-^{x}t-1)/(^{s}t-^{s}t-1)$, import penetration index is denoted by $^{m}t/^{s}t$, and trade advantage index is denoted by (x-m)/(x+m), where X represents exports of domestic merchandise in constant dollars, S represents domestic shipments in constant dollars, M represents imports for consumption in constant dollars, t represents the year involved, and t-1 represents the base year.

Table 10
Navigational and surveying instruments: Export performance index, import penetration index, and trade advantage index, 1988-92

(1988=100)

Year	Export performance index	Import penetration index	Trade advantage index
1988	100.0	100.0	100.0
1989	106.1	85.0	120.6
1990	109.3	90.2	118.1
1991	121.6	94.4	123.5
1992	122.5	108.1	112.0

Source: Computed by the USITC staff based on Commerce data.

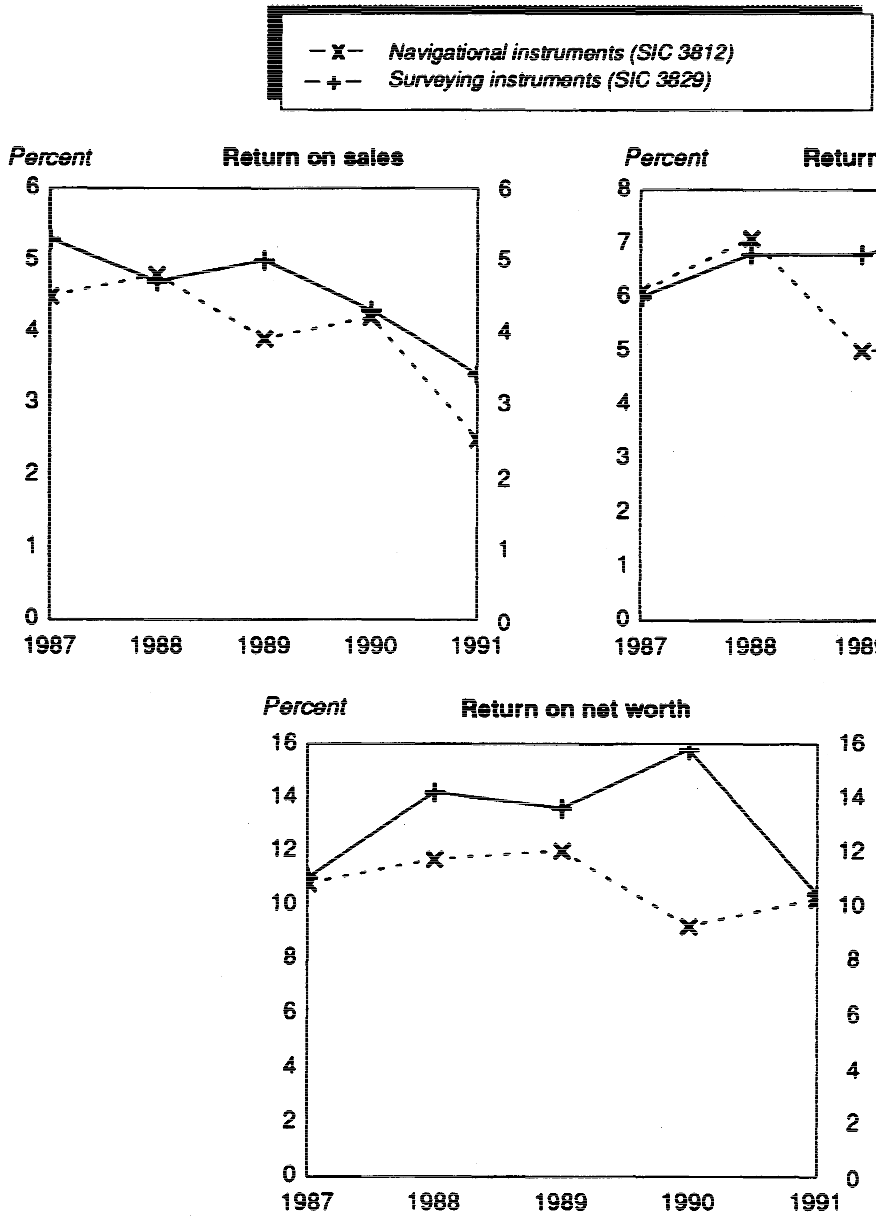
Table 11
Navigational (SIC 3812) and surveying (SIC 3829) instruments: Profitability ratios, 1987-91

(Percent)

	Return on sales		Return on assets		Return on net worth	
Year	SIC 3812	SIC 3829	SIC 3812	SIC 3829	SIC 3812	SIC 3829
1987	4.5	5.3	6.1	6.0	10.8	11.0
1988	4.8	4.7	7.1	6.8	11.7	14.2
1989	3.9	5.0	5.0	6.8	12.0	13.6
1990	4.2	4.3	5.1	7.2	9.2	15.8
1991	2.5	3.4	3.3	5.2	10.2	10.4

Source: Dun and Bradstreet, *Key Business Ratios*, various annual issues.

Figure 5
Navigational and surveying instruments: Profitability ratios, 1987-91



Source: Dun and Bradstreet, *Key Business Ratios*, various annual issues.

Table 12
Navigational (SIC 3812) and surveying (SIC 3829) instruments: Efficiency ratios, 1987-91

	Navigational					Surveying				
Efficiency ratios	**1987**	**1988**	**1989**	**1990**	**1991**	**1987**	**1988**	**1989**	**1990**	**1991**
Collection period *(days)*	53	60	61	57	54	56	57	54	49	50
Inventory turnover *(days)*	63	61	69	66	60	47	55	55	51	46
Assets/sales *(percent)*	59	63	68	60	66	58	61	57	54	52
Net WC/sales *(percent)*	29	26	26	22	22	23	28	23	22	23
Payables *(days)*	18	16	16	19	19	16	17	19	21	19

Source: Dun and Bradstreet, Inc., *Key Business Ratios*, various annual issues.

Table 13
Navigational (SIC 3812) and surveying (SIC 3829) instruments: Liquidity ratios, 1987-91

Liquidity ratios	Navigational					Surveying				
	1987	1988	1989	1990	1991	1987	1988	1989	1990	1991
Quick ratio	1.5	1.1	1.1	1.1	1.2	1.3	1.4	1.2	1.1	1.4
Current ratio	2.6	2.4	2.2	2.2	2.0	2.4	2.6	2.3	2.4	2.8
Current liabilities/ net worth (*percent*)	44	49	56	65	76	57	49	52	55	42
Current liabilities/ inventory (*percent*)	94	112	118	104	115	134	105	109	108	93
Total liabilities/net worth (*percent*)	58	63	90	98	118	83	73	70	64	62
Fixed assets/net worth (*percent*)	32	39	39	36	44	32	27	27	26	27

Source: Dun and Bradstreet, Inc., *Key Business Ratios*, various annual issues.

U.S. Investment Abroad and Foreign Investment in the United States[18]

The U.S. direct investment position abroad in scientific and measuring instruments industries (including navigational and surveying instruments) dropped rapidly from $1.8 billion in 1987, to $1.4 billion in 1989, before increasing to $1.6 billion in 1990, and $2.1 billion in 1991.[19] However, the 1990 and 1991 increases were mainly the result of changes in prices and exchange rates. As the dollar fell sharply relative to major European currencies and the Japanese yen, it boosted the dollar value of U.S. foreign investment denominated in foreign currencies. By contrast, foreign direct investment in the U.S. scientific and measuring instruments industry rose sharply during 1987-91, increasing from $2.3 to $3.6 billion.[20] Reportedly, three factors: (1)excess funds available in Japan and several other countries, (2) a rate of return on U.S. investments higher than those of home country investments, and (3) the depreciation of the U.S. dollar against most foreign currencies in the latter half of the 1980s, attracted greater investment in the United States.[21]

The overall rate of return on foreign investments in the United States was significantly lower than that of U.S. investments abroad (table 14). Reportedly, the weaker financial performance of U.S. affiliates of foreign companies relative to foreign affiliates of U.S. companies can be attributed to a number of factors. Foreign investments in the United States were mostly new and presumably incurred to acquire a number of unprofitable units, in contrast to U.S. investment abroad, the bulk of which incurred during the 1970s.[22] In addition, with a vertically integrated multinational company, the profits resulting from economies of scale can be allocated among the parent and its affiliates in order to maximize total returns. Such decisions can affect the rate of return on individual investments. Tax treatment across countries can also affect both the location of direct investment and, through "transfer pricing," the distribution of profits between parent and affiliate.[23]

The United Kingdom is the largest investor in the U.S. instruments-manufacturing sector. U.S. affiliates of British parent companies accounted for 42 percent and 55 percent, respectively, of all foreign affiliates' employment and assets.[24] Other foreign investors with large investments include Germany, Canada, Switzerland, and Japan.

Of total import value of navigational and surveying instruments in 1990, 24 percent was between affiliated firms. A large part of such imports by affiliates is by U.S. subsidiaries of foreign producers of surveying instruments; U.S. subsidiaries act as distribution outlets. The 10 largest firms accounted for 71 percent of such trade.

Exchange Rates

The fluctuation of exchange rates in the 1980s had a significant effect on international trade in navigational and surveying instruments. During 1980-85, foreign currencies depreciated significantly against the U.S. dollar, making foreign products less expensive and more competitive in the U.S. market. Since 1985, there has been a significant reversal of trade trends between the United States and its trading partners, as foreign currencies appreciated in value

[18] Investment position measured in terms of historical cost basis.

[19] U.S. Department of Commerce, Bureau of Economic Analysis, *Survey of Current Business*, Aug. 1992, p. 143. Navigational and surveying instruments covered in this summary account for only about 10 to 12 percent of total scientific and measuring instruments.

[20] Ibid, p. 113.

[21] Ibid, See article *Rates of Return on Direct Investment*, by J. Steven Landefeld, Ann M. Lawson, and Douglas B. Weinberg, pp. 79-87.

[22] Ibid. For the newly established companies, rates of return are low or negative because of the startup costs and for those acquired, rates of return are generally low or negative.

[23] Ibid, p. 80.

[24] The Census Bureau of Economic Analysis, Survey of Current Business, *U.S. Direct Investment Abroad: The 1989 Benchmark Survey Result*, July 1991, pp. 87 and 89.

Table 14
Navigational and surveying instruments:[1] Rate of return on U.S. investment abroad and foreign investment in the United States, 1987-91[2]

(Percent)

Industry	1987	1988	1989	1990	1991
U.S. investment abroad:					
All industries	12.3	15.0	14.4	13.0	10.9
Manufacturing	14.1	18.7	18.2	14.4	10.6
Instruments and related products	13.1	15.3	14.9	13.2	10.7
Scientific and measuring instruments[1]	8.8	10.6	6.0	6.6	8.2
Medical instruments	19.9	20.5	19.3	17.0	16.7
Foreign investment in the United States:					
All industries	3.3	4.1	2.0	0.4	-0.7
Manufacturing	5.1	5.1	3.6	2.1	0.6
Instruments and related products	3.8	3.1	1.8	-1.2	1.9
Scientific and measuring instruments[1]	2.7	1.9	2.5	0.5	1.4
Medical instruments	5.6	7.6	([3])	-2.1	3.9

[1] Navigational and surveying instruments account for approximately 10 to 12 percent of total shipments of scientific and measuring instruments reported under SICs 381 and 382.
[2] Investment position is taken on a historical cost basis.
[3] Suppressed to avoid disclosure of individual companies.

Source: U.S. Department of Commerce, *Survey of Current Business*, Aug. 1992.

against the U.S. dollar, which made foreign products less competitive in the United States. Figure 6 shows changes in exchange rates between the United States and its major trading partners, denoted in terms of indexes of U.S. dollar equivalent per unit of foreign currency.

Effect of exchange rates on labor costs

Although direct labor costs account for only about 13 percent of total production costs of instruments, total payroll costs, including those of R&D and indirect personnel, represent approximately 40 percent of production costs. Large fluctuations in exchange rates have significantly affected labor and other production costs, thereby affecting the price competitiveness of U.S. and foreign instruments. Measured in U.S. dollars, labor costs in the U.S. industry producing navigational and surveying instruments and related products (SIC 38) averaged twice as high as those of major European countries and Japan in 1985. More recently, labor costs in several European countries have risen rapidly, as measured in U.S. dollars, as a result of the appreciation of European currencies. Currently labor costs in countries such as Germany and Switzerland are higher than those of the United States. The wide fluctuation in labor costs, as measured in U.S. dollars, during the 1980s was attributed, in large part, to changes in exchange rates. It does not reflect the underlying wage trends in those countries as shown in table 15, and figures 7 and 8.

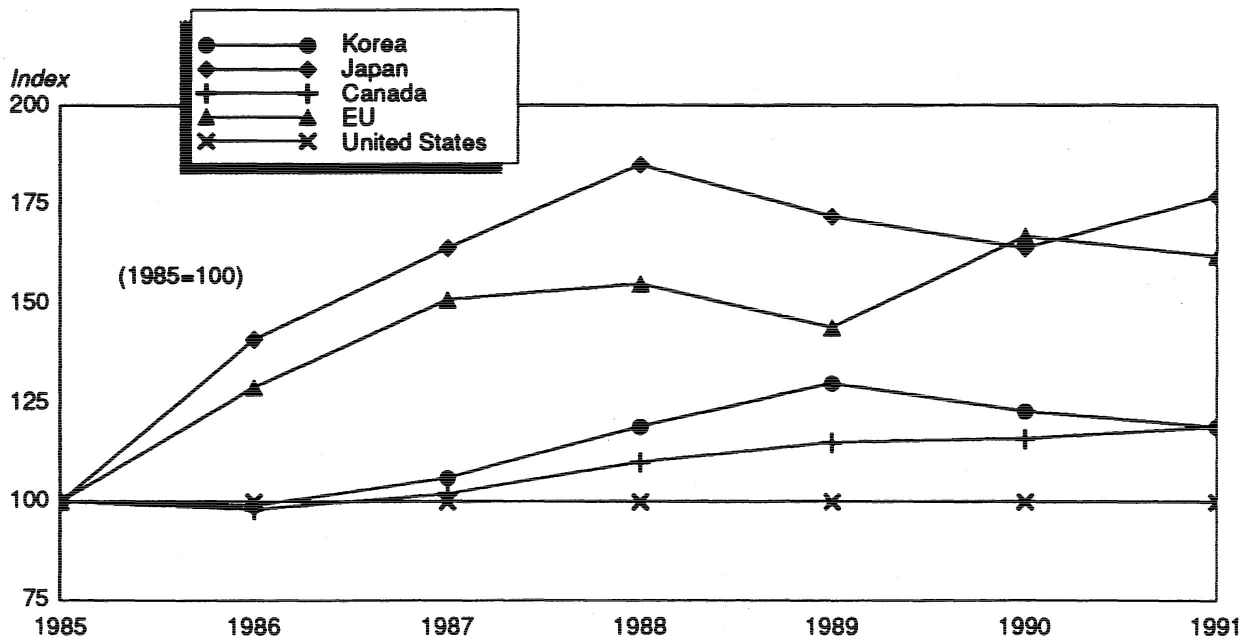
Unlike the industrialized countries of the West and Japan, the increases in labor costs of newly industrialized countries (NICs) of the Far East during 1985-91 largely reflected the rapid increases in wages brought about by increased industrial development. Continued inflationary pressures on wages in these countries doubled and tripled their labor costs during 1985-91, as illustrated for Korea in table 15.

Effect of exchange rates on U.S. balance of trade

The change in exchange rates is believed to have a significant effect on the U.S. balance of trade for navigational and surveying instruments. During 1985-91, import prices rose by 44 percent,[25] and most of the increase was attributed to change in the exchange rates. As a result, imports grew by just over 1 percent annually in real dollars during 1985-91. U.S. imports from the European Union (EU), "formerly known as European Community", Japan, Canada, and Switzerland, which accounted for a combined 76 percent of total imports in 1991, declined by 6 percent during 1987-91. Israel, which supplied 11 percent of navigational and surveying instruments in 1991, compared to 4 percent in 1987, benefited from a 30-percent depreciation of its currency against the U.S. dollar during the period. By contrast, U.S. export prices increased by only 29 percent, which made U.S. products relatively more competitive in foreign markets, as reflected by a 31-percent real export growth during 1985-91. As a result, the trade surplus for navigational and surveying instruments increased each year, from $0.5 billion in 1987 to $1.2 billion in 1991.

[25] U.S. Department of Labor, Bureau of Labor Statistics (BLS), *U.S. Import and Export Price Indexes*, published quarterly.

Figure 6
Indexes of U.S. dollar equivalents per unit of selected foreign currencies, 1985-91



Source: Developed by the USITC staff, based on International Monetary Fund statistics. Period averages are used in computation.

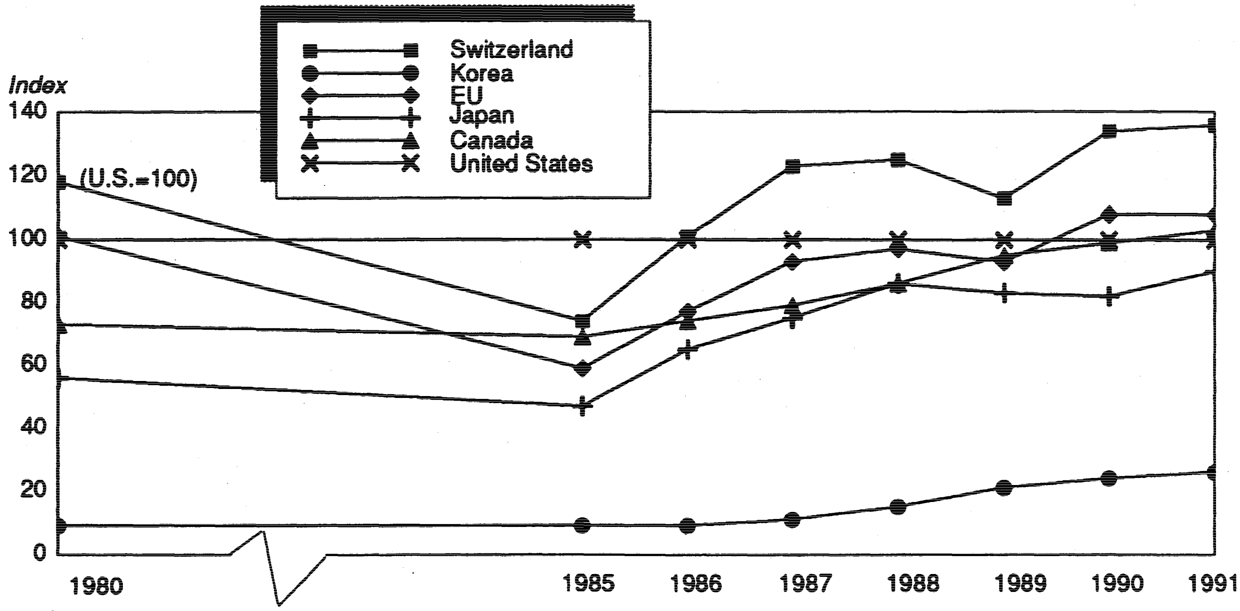
Table 15
Navigational and surveying instruments and related products:[1] Labor cost indexes for selected countries, 1980, 1985-91

Year	United States	Canada	Japan	EU[2]	Korea	Switzerland
Unadjusted for changes in exchange rates:						
1980	100	73	56	101	9	118
1985	100	69	47	59	9	74
1986	100	74	65	77	9	101
1987	100	79	75	93	11	123
1988	100	86	86	97	15	125
1989	100	95	83	93	21	113
1990	100	99	82	108	24	134
1991	100	103	90	108	26	136
Adjusted for changes in exchange rates:						
1980	100	73	56	101	9	118
1985	100	77	49	92	11	101
1986	100	83	49	95	12	103
1987	100	85	49	98	13	104
1988	100	87	49	100	16	104
1989	100	92	51	103	20	105
1990	100	94	53	105	24	107
1991	100	97	54	108	27	112

[1] In SIC 38.
[2] European Union (EU), formerly known as European Community (EC).

Source: Computed by the USITC staff, based on U.S. Bureau of Labor Statistics (BLS) and International Monetary Fund (IMF) data.

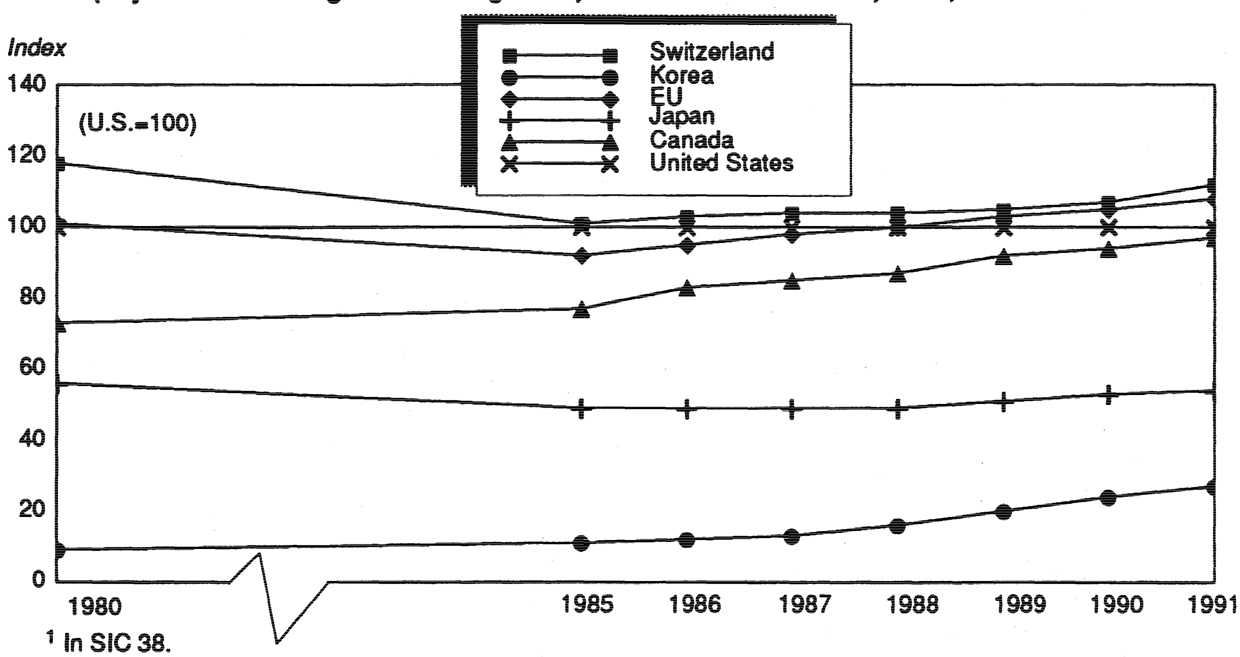
Figure 7
Navigational and surveying instruments and related products:[1] Labor cost indexes in U.S. dollars (unadjusted for change in exchange rate) for selected countries, 1980, 1985-91



[1] In SIC 38.

Source: Developed by the USITC staff, based on data from U.S. Bureau of Labor Statistics and International Monetary Fund.

Figure 8
Navigational and surveying instruments and related products:[1] Labor cost indexes in U.S. dollars (adjusted for change in exchange rate) for selected countries, 1980, 1985-91



[1] In SIC 38.

Source: Developed by the USITC staff, based on data from U.S. Bureau of Labor Statistics and International Monetary Fund.

Technology and Competitiveness

One of the product areas where the United States has a significant technological lead over its competitors is in high-precision ring laser gyros (RLG) including fiber-optic gyros (FOG) and INS. Although the French industry claims to have been producing integrated RLGs, INS, and global positioning systems (GPS), and Russia and the People's Republic of China are believed to have developed RLG-based systems, foreign technology in high-precision RLGs is ranked inferior to that of the United States.[26] However, in the broad-based, medium-accuracy civilian market, European producers are roughly on par with the U.S. technology. The remaining product differentiators favoring the U.S.-based industry are volume, product maturity, reliability, and cost.[27]

The United States dominates the military use of the GPS and has a clear technological lead over their foreign counterparts. U.S. military receivers and systems are being used in many countries under agreements between the U.S. Department of Defense and foreign governments. Several countries have developed GPS receivers funded by their military, notably France, the United Kingdom, Canada, and Germany. In the civilian sector, there is technological parity between the U.S. and foreign industries.[28] Many countries are building GPS receivers and systems for their civilian markets and for export, most notably Japan, and therefore the competition is intense. Nevertheless, the United States is a leading supplier of GPS receivers and systems to the global market. The U.S. competitive strength is based on producing differentiated products and systems through integration of state-of-the-art hardware and software, superior quality, and continued innovation.[29] In the next 5 years, as the diffusion of technology accelerates, technological lead will be less of a competitive factor; instead, distribution, solution of customer problems, and development of software to customer needs will likely be the key competitive factors.[30]

In space technology, the United States enjoys the overall technical advantage over its foreign counterparts. However, the U.S. lead is gradually eroding as foreign competitors become more organized and form large consortia across national boundaries, which gives them much-needed strength and resourcefulness to compete with the U.S. industry. The collapse of the eastern bloc and the end of the Cold War will allow Western European countries to focus more of their energies on economic and technological development.[31]

A significant portion of lower priced marine and river navigation instruments that are sold in the U.S. civilian market are produced in Pacific Rim countries, primarily because of lower production costs there. Marine production runs are typically low-volume runs and highly price-competitive. The product concept and R&D are developed in the United States, and production is carried out in Pacific Rim countries. In the higher end recreational/fishing and merchant shipping markets, cost becomes less of a factor, and the product is typically manufactured in the company's home country. In Europe, a number of niche producers have been able to survive by supplying their home country.[32]

Another factor affecting the domestic marine navigational segment of the industry is the erosion of the competitive position of U.S. commercial shipbuilders in the 1980s. It is believed that the United States has not built any commercial ships since 1986 because of greater demand for military ships. Plants and equipment were generally designed to support the military, and, as a result, commercial shipbuilding lost its international competitiveness. With the loss of military orders now, U.S. shipbuilders are finding it difficult to adjust to international competition in commercial shipbuilding.[33]

The industry segment producing surveying, geophysical, meteorological and other instruments consists of small firms and is relatively less capital-intensive than that of navigational instruments. This segment has adopted a number of technical developments carried out in other industries, which enabled them to bring down costs and improve quality. The technology in this segment is high, the cost of investment is generally large, and the market is relatively small. Although U.S. producers remained active in some niche markets, foreign producers, especially those from Japan and Western Europe, have dominated the global market. The competitive edge of foreign producers is based on the performance criteria of their technology, the availability of specialized expertise, and more importantly, the products manufactured by them are more compact, precise, versatile, and convenient to use than U.S. products. These factors, together with the large infrastructure of optical manufacturing skills of foreign producers,

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[26] Information obtained from Honeywell, Minneapolis, MN. In addition, according to officials of Litton Systems, the major European producers such as France and the United Kingdom are not competitive in the global market because of their high cost of production, lower productivity, and inferior quality. As a result, 95 percent of French production is sold locally. Besides, Litton is a major supplier of INS to British Aerospace. French international sales are based mostly on lucrative financial terms offered by them to their customers. As far as Russia and the PRC are concerned, their technology is less advanced than that of the United States. According to *Flight International*, Mar. 5, 1991, p. 5, Ilyushin-made Russian navigation systems have been heavily criticized by Russian Aeroflot as less accurate and less dependable. *Flight International*, Aug. 27, 1991, p. 8, reported that China Aero-Technology Import/Export Organization has sought assistance from Honeywell to co-develop digital air data computer and other navigational systems for the McDonnell Douglas MD-90-30 aircraft expected to be built in China.

[27] Information obtained from Honeywell.

[28] Interview with officials of Interstate Electronics Corporation, Aug. 19, 1992.

[29] Interview with officials of Trimble Navigation, Aug. 20, 1992.

[30] Ibid.

[31] Information obtained from Honeywell Inc., Space Systems Group, Clearwater, FL.

[32] Information obtained from Raytheon Marine, Hudson, NH.

[33] Interview with officials of Sperry Marine, July 30, 1992.

and a decline in U.S. price competitiveness due to the appreciation of the dollar during the early and mid-1980s, caused a number of U.S. producers to close their operations or lose market share to foreign competitors.

Although products covered in this summary range from low- to high-technology instruments and systems, many are high-technology products, especially those produced by the aeronautical navigational industry. The impressive technological advances achieved in solid-state and digital technology of the last two decades are fully utilized by the instruments industry. The latest advances in solid-state microelectronics, high-speed integrated circuits, fiber optics, and microwave and other technologies are continually integrated into the products. Consequently, a large number of medium- to highly skilled workers and professional people are employed in R&D, designing products, operating high-technology capital equipment, assembling products, and performing extensive quality control functions.

There has been rapid technological development in the design and use of INS during the past few decades. INS are used in aircraft, helicopter and ship navigation, missile guidance, weapon delivery, surveying by land vehicle or helicopter, fire control, torpedo guidance, and other applications. Early systems used spinning mass gyroscopes in a gimbaled platform configuration. Systems using this approach are still in volume production. Newer systems used a strapped-down mechanization, eliminating the mechanical gimbals together with their moving parts. Now in production are systems using RLGs, with their inherently more reliable features and shorter alignment times. RLGs are being applied to various strapdown systems with emphasis on stringent navigation requirements for high-performance aircraft, strategic missiles, and various marine applications.[34]

The next generation of military aircraft is moving toward a higher level of functional integration within the avionics system. This is true throughout the full complement of sensors, communications, computers and navigation subsystems. Major work is underway in the inertial system area to support the functions of navigation, attitude control, flight control, and radar antenna stabilization with an integrated strapdown system architectural approach. The advent of high-precision RLG sensors, advanced strapdown system design, and fault-tolerant system architecture provides the functional basis for this approach. Advanced electronics packaging and technology allows this to be accomplished at a reasonable size and weight.[35]

Interferometric FOG technology is the latest technology. FOGs use optical fiber as the light path in contrast to RLGs, in which light is beamed around a cavity. The light beam confined inside the optical fiber accounts for the increased ruggedness of FOGs. FOGs are not believed to be as accurate as RLGs, and are currently used for medium-accuracy applications, such as in guided missiles or other vehicles with short flight times. As the accuracy improves, the FOG technology with GPS receiver is expected to be very useful in future navigation. The GPS can update position frequently with extremely accurate information that eliminates drift problems associated with inertial systems while INS can continue to provide altitude and position during periods when the navigation system is out of touch with GPS or the signals are being jammed. If successful, the FOG technology would achieve a significant reduction in the size of the navigational package and a reduction in cost.[36] FOG technology is being evaluated for several missile programs.

A new magnetic compass that, unlike conventional types, does not need gimbals, has been devised by the scientists at Chemicalizing Laboratory in Tokyo, Japan. The small-size magnetic compass system includes three-axis gravity sensors and an integrated computer, which can provide information on magnetic direction, roll angle, and pitch angle. The compass is said to be able to endure oscillation and can be used in any position. Applications include navigational systems for marine, automotive, and personal use.[37]

Industry sources consider GPS as the "new utility" of the future. GPS was developed in the United States primarily for military use and was funded in large part by U.S. tax dollars. GPS technology uses satellites. Military GPS receivers use P-code, the precise or protected code. The uniquely designed multichannel P-code receiver, integrated with strap-down inertial reference units, guarantees optimum GPS accuracy for high-performance aircraft. Translator-based systems continue to prove their value in missile tracking.[38] Commercial GPS receivers use C/A code, the standard (course acquisition) GPS code, and they are relatively less accurate than P-code receivers. A GPS receiver needs four satellites, the minimum required to obtain 3-D positional data and, using a method called "satellite ranging," calculates its position on earth by measuring the length of time it takes the satellite signals to reach the receiver. The receiver then multiplies the travel time by the speed of light to determine its range measurement. Within a second, positional coordinate data—longitude, latitude, and elevation—are displayed on the GPS receiver screen. Because they are portable, GPS receivers can be used to gather positional data by foot, vehicle, or airplane.

Since the introduction of GPS, the technology has managed to achieve significant accomplishments, particularly in military applications. But its highest accomplishments may be just over the horizon, as GPS technology begins to penetrate the huge commercial

[34] Litton Guidance & Control Systems, *Capabilities, Experience and Facilities*, Dec. 1989, p. 4.

[35] Ibid, p. 18.

[36] "Darpa Contract Boosts Integrated FOG/GPS," *Aviation Week and Space Technology*, Jan. 14, 1991.

[37] "Magnetic Compass without Gimbals," *New Technology, Japan*, Apr. 1992, p. 36.

[38] Interview with officials of Interstate Electronics Corporation, Aug. 19, 1992. Interstate is primarily a producer of GPS receivers and tracking systems for high-performance military aircraft and missiles.

market. The commercial applications of GPS are many, such as surveying, mapping, photogrammetry, navigation, resource management and related areas. The position data gathered from a GPS receiver can now be converted automatically to portable geographic information systems (GIS) and displayed. The receiver technology has advanced to the point that the GPS receivers now offer accuracies of up to a few meters. Such conversion software can also tie GPS data to remotely sensed imagery, such as aerial photos and satellite images. By pinpointing locations on the ground with the GPS and converting the data to a mapping system, users can directly correlate their GIS to remotely created maps.

The commercial application of GPS was first studied in the early 1980s. Since then small lightweight low-power GPS receivers have been developed, based on integrated circuits and software for use in aeronautical and nautical navigation, surveying, and mapping. A broad range of receivers were developed by adding communication equipment, data bases, special-user interfaces, task-specific software, and other features to create value-added GPS solutions. The industry also developed tracking and differential GPS systems to increase accuracy. In 1989, a battery-operated GPS receiver about the size of a pair of binoculars was introduced.[39]

Studies are being undertaken in the United States and Europe to assess the suitability of the GPS as a perceived cheaper alternative to the microwave landing system (MLS), which the International Civil Aviation Organization (ICAO) plans to introduce to replace the current instrument landing system (ILS) as of 1998. Based on these studies, the ICAO Future Air Navigation Systems (FANS) Committee has proposed to use GPS for en-route and terminal-area navigation, but not for precision approach and landing where the system requirements are much greater. A land-based system such as ILS or MLS has major advantages because it is easily maintained and monitored and its signal is inherently more accurate as the aircraft approaches the runway. Conversely, GPS is very well suited to long-range area navigation where reliability and integrity are much less demanding. In that sense, the two systems are entirely complementary. A simple GPS and MLS together can provide for take-off, en-route navigation, and landing guidance system.[40]

The increasing automatization of many surveying, meteorological, and geophysical instruments, the integration of microprocessors, and the use of computers in these instruments have helped to provide more precise electronic measurement of angles, distances, and other required data. Building and engineering surveys can now be performed using a comprehensive range of optical and electro-optical products. High flexibility in the recording and processing of measuring data and integrated programs allow calculations to be carried out even in the field. Photogrammetrical instruments produce extremely accurate maps and plans in an economical way, predominantly with the use of aerial photographs. Camera and aided-by-GPS navigation can now be performed and evaluated with the aid of new photo flight management systems. Software packages have been added to the systems for photogrammetry, cartography, and land information. The joint management of attributes and geometrical data, for example, allows the selective monitor display of all two-storied, gas-heated houses within a certain district. The new photogrammetric image-processing system turns digitized images into photogrammetric products, such as ortho photos, which combine clarity with precision.

The inertial technology is also used in the survey system employed by the U.S. Army. The Army's new position- and azimuth-determining system (PADS) provides instant surveys for field artillery, cannons, and missile battalions. It is an automatic, vehicle-mounted system, which provides survey control at driving or helicopter speeds. This technology is employed for commercial surveying. With this technology, surveying has become a simple push-button operation with distances and position determined by the system's space-age gyroscopes, accelerometers, and computers. This is basically a rugged land navigation system, and is used in vehicles on the road or in helicopters.

Globalization

The worldwide homogeneity of navigational and surveying instruments tends to make navigational and surveying instruments truly global products, similar to other consumer and industrial electronic products.[41] Some industry leaders formerly viewed the market in distinct domestic and international segments. They no longer do so. Now they set their commercial and military strategies from a single global perspective, just as do their competitors offshore.[42]

The reason for the extent of globalization in the navigational and surveying instruments industry falls into three major categories: marketing, environment, and economics. The key marketing factors are homogeneous market needs and shorter product life-cycles that require a global distribution approach to achieve required volume levels. Environmental factors are those found in many industries: falling transportation costs, improved communications, ever-improving technology, and availability of technological resources, both physical and human. From an economic point of view, worldwide economies of scale in both manufacturing and distribution make a global business approach a distinct cost advantage. Rising product development costs force companies to look for volume, which

[39] This unit was developed by Trimble Navigation and its TRIMPAK version of such a receiver was employed by the U.S. Army during Operation Desert Storm. Trimble filled orders for 10,000 units over a period of less than a year. Written statement by Sandra Bateman, Public Relations Manager, Trimble Navigation, Sept. 1991, p. 3.

[40] "Precision Landing Guidance: GPS or MLS?" *Aerospace World*, Sept. 1991, p. 42.

[41] Interview with officials of Interstate Electronics Corp., Aug. 19, 1992.

[42] Information obtained from Honeywell, Minneapolis, MN.

requires a global approach. Significant differences in production costs from one country to another and worldwide sourcing efficiencies make globalization a definite advantage.[43] However, unlike most manufacturing sectors, the navigational instruments industry is highly capital-intensive and heavily research oriented. Direct labor cost represents only a small part of its overall production costs, and therefore, is not a significant factor in the globalization of the industry.[44]

In the civilian sector, a number of manufacturers compete in international markets. The majority of producers enter foreign markets through licensing arrangements and maintain a more profitable network of services. Globalization, however, is less prevalent in products having military applications and is sought mostly to improve distribution, sales, and after-sales service.[45] This is because the U.S. Munitions Control Act subjects U.S. goods and technologies intended exclusively for military use to unilateral export controls, and thus it limits the ability of U.S. producers to expand their markets. For the most part, these limitations are based on national security concerns. However, a few licensing agreements among North Atlantic Treaty Organizations (NATO) countries enabled some producers to penetrate foreign markets.[46]

There have been some acquisitions, joint ventures, or joint-production arrangements among firms in recent years. Honeywell has signed an agreement with China Aero-Technology Import/Export Organization covering codevelopment of the digital air data computer (DADC) for the McDonnell Douglas MD-90-30 aircraft, expected to be built in China under its domestic Trunkliner program. The deal also covers further coproduction of MD-90 avionics, initially for China's domestic program, and subsequently, for other MD-90 customers, if quality, cost, and schedule requirements are met.[47]

Alenia of Italy and Honeywell have merged as Space Controls Alenia Honeywell, to make space systems equipment in Europe. According to Honeywell, the new firm will look for European commercial and government contracts for spacecraft control systems, including flight control equipment and antenna pointing systems. The new firm will employ about 150 people and will be 60 percent held by Alenia.[48]

Fernau Avionics of United Kingdom, a navigational aids maker, has acquired Aviation Systems International, a U.S. competitor. The acquisition has boosted Fernau's product range, and also gives Fernau access to the American civil aviation sector.[49] Raytheon Marine of Hudson, NH, has acquired Nautech of the United Kingdom, which makes nautical instruments, including autohelm recreational autopilots. The new Raytheon division will make electronics for various marine markets, such as recreational, workboat and high seas.[50] In another acquisition, BF Goodrich has acquired the British firms Simmonds Precision Products, Hercules Aerospace Display Systems, and Hercules Aerospace, from Hercules Aircraft and Electronics Group, for $169 million. The acquired units will produce aircraft actuators along with a number of other instruments.[51]

Government Policy

The U.S. commercial and technical and production base is almost entirely supported through corporate research, development, and capital investment. Industry sources believe that foreign competitors' expenses for research and development are underwritten through government concessionary customer financing.[52] In addition, industry sources claim that U.S. policies restricting export licenses for defense-related products limit the U.S. industry's ability to expand its market. Although these restrictions are based on national security considerations, industry sources contend that governments of several European countries often relax rules to enable their producers to successfully bid for export orders.[53]

The U.S. Government's monetary policy of recent years has resulted in a decline in the cost of capital, which has been a great help to domestic manufacturers. However, declining interest rates in the United States have weakened the U.S. dollar, causing an increase in the price of imported products and components. Given the global nature of the navigation and surveying instruments industries, and that the U.S. market for surveying instruments is dominated by imports, monetary policy is having some beneficial impact on the U.S. industry. According to marine industry officials, however, U.S. Government action during 1991-92 to levy a luxury tax on vessels costing over $100,000 hurt boat builders and consequently affected producers of instruments used in these boats. This tax has been now repealed retroactive to January 1, 1993, which according to industry sources should help the instruments industry.

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43 Information obtained from officials of Raytheon Marine Co., Hudson, NH.

44 Interview with officials of Litton Systems, Aug. 17-18, 1992.

45 Interview with officials of Litton Systems, Aug. 17-18, 1992. Litton does business in 52 countries, and in most of the countries its functions are related to marketing and sales and after-sales service. Once the sale goes through and the service is provided in a country, it becomes significant part of Litton Systems' revenue. This has driven the company to establish a sales and service network throughout the world.

46 Interview with officials of Litton Systems, Aug. 18, 1992.

47 "Honeywell Gains Chinese Cooperation," *Flight International*, Aug. 27, 1991, p. 8

48 "Alenia/Honeywell Team," *Space News*, Dec. 22, 1991, p. 2.

49 "Fernau buys out U.S. competitor," *Electronics-Weekly*, June 5, 1991, p. 6.

50 "Raytheon buys British firm," *Soundings-Trade-Only*, Jan. 1991, p. 6.

51 "BF Goodrich pays $169 million for Hercules component businesses," *Interavia-Air-Letter*, Jan. 4, 1991, p. 5.

52 Information obtained from Honeywell.

53 Ibid.

Consumer Characteristics and Factors Affecting Demand

The factors affecting demand for navigational instruments include the health of the commercial airline and marine navigation industry and the demand for new aircraft, space vehicles, ships, and boats, and their overhaul. The factors also include demand for military aircraft, missiles, space vehicles, and ships. A slow-down in military activities and a cut in defense budget will lower demand for instruments and systems used in the military. An economic recession will generally bring a slump in air travel and consequently, a decline in demand for navigational instruments. The demand for surveying instruments is mainly responsive to the level of engineering and construction activity and varies directly with it.

The primary customers for navigational instruments having military applications are the U.S. Department of Defense, NASA, and various prime contractors to these customers. Other customers include allied nations. For instruments having commercial applications, the primary customers are aircraft builders, aircraft owners, shipowners, shipbuilders, and ship operators. The major customers for surveying, meteorological, and geophysical instruments are academic institutions, laboratories, government institutions, the oil and the construction industry.

U.S. producers of navigational instruments market most of their products by direct sales, and the remainder through distributors. Foreign sales are conducted directly, by the producers' overseas affiliates and subsidiaries, or through local distributors or agents. Foreign military sales are conducted through the U.S. Government's Foreign Military Sales (FMS) programs, either by sales directly to the U.S. Government or through U.S. prime contractors. Extensive support is provided to all end users either directly, through the prime contractor, through the applicable logistics agency of the U.S. Government in the case of FMS programs, or a combination of all three.[54] Most U.S. producers of surveying instruments market their products through dealers, and the foreign producers, through their affiliates in the United States. The majority of producers of hydrographic, meteorological, hydrological, and geophysical instruments market the bulk of their products by direct sales, and the remainder through distributors or company salesmen.

FOREIGN INDUSTRY PROFILE

The major foreign producers of navigational and surveying instruments are in the United Kingdom, Germany, France, and Japan. Other countries with sizable industries are Canada, Italy, Switzerland, Sweden, Norway, Korea, and the Netherlands. The United Kingdom, Germany, and France are known for their navigational instruments, and Japan, Germany and Switzerland are the major foreign producers of surveying and other instruments.

The foreign navigational and surveying instruments industry is also comprised of a large number of small producers. However, the bulk of the shipments is accounted for by a few large and medium-size subsidiaries of large companies, which in addition to these instruments also produce a wide range of articles having scientific, commercial, and industrial applications.

The producers in the United Kingdom and France, the major U.S. competitors in Europe, are not currently price-competitive in the international market, and are therefore, less global. They are reportedly subsidized by their respective governments, which enable them to remain competitive in their home markets.[55] The foreign technology in the navigational instruments, especially designed for civilian market, is considered roughly on a par with that of the U.S.-produced instruments.

According to industry sources, there is not much integration of foreign firms with U.S. suppliers or producers. Trimble Navigation has a licensing agreement with Pioneer of Japan, which allows Pioneer to use Trimble's technology only in the car navigation market in Japan. In return, Trimble gets royalties, the right to place their engineers in Pioneer's plant in Japan, and rights to obtain Japanese manufacturing technology. In addition, other GPS companies, such as Magellan, have contracted for manufacturing in Japan. The major foreign producers' U.S. subsidiaries generally perform marketing, sales, and service-related functions. In addition, some U.S. affiliates of foreign producers of surveying instruments also perform assembly operations from imported components. A number of U.S. companies work as distributors for imported products and do service-related activities.

The leading foreign producers of INS and other instruments for air and space navigation are Plessey, GEC/Ferranti, Smith Industries, and British Aerospace in the United Kingdom; Sagem and Sextant-Avionique in France; and Japan Aviation Electronics (JAE) in Japan. According to industry sources, all these companies have increased their investments in recent years and now have significant inertial capability, including RLG sensors and integrated INS/GPS systems. GEC/Ferranti produces INS for military use. U.S. producers are the major suppliers of INS for British Aerospace. Sagem of France produces INS for airborne, land, and ship navigation, and its products are sold predominantly in France. Tamam, a division of Israel Air Institute, has the capability to produce inertial systems. In Canada, Germany, Korea, and Italy, these systems are produced under license from Litton Industries of the United States. India reportedly had the system built under license from Sagem. Russia and China reportedly use old technology to develop inertial systems. Although the United States has

[54] Litton Guidance and Control Systems, "Capabilities, Experience and Facilities," Dec. 1989, p. 40.

[55] Information obtained from Honeywell, Minneapolis, MN.

significant advantages in instruments and systems having military applications, U.S industry sources believe that foreign systems, especially those for civilian uses, can perform nearly as well as U.S.-produced systems. However, their significantly lower volumes tend to make them less price competitive outside their home markets.

In marine navigation, the major foreign producers are Sagem (France), C. Plath and Anschutz Kiel (Germany), Tokyo Keiki Co., Furuno, and Yokogawa Navitec (Japan), Microtecnica (Italy), Robertson Tritech (Norway), and Navico Ltd. (U.K.). The U.S. market for surveying instruments is dominated by foreign producers, the major competitors being Carl Zeiss of Germany, Leica and Wild Heerbrugg of Switzerland, and Topcon of Japan. Carl Zeiss, however, is reported to be struggling under the collapse of East European markets and a reorganization will result in a downsizing of its workforce to one-seventh of its previous size. The East German products dominated the East Bloc markets and were well respected in the West. However, German integration has ended the available supply of cheap labor and a protected pricing system. In addition, sales to the former Soviet Union and the rest of Eastern Europe declined due to the lack of hard currency.[56] However, this trend is expected to reverse in the coming years with assistance from industrialized nations and world lending institutions.

The major foreign competition to Halliburton and Syntron of the United States in geophysical instruments and services come from Sercel (France) and Oyo (Japan). Scientrex and GEM of Canada are the major foreign producers of magnetometers, which are prime competitors to EG&G Geometrics and Fisher of the United States. In seismographs, the major foreign competition comes from Oyo of Japan (which has a production facility in Houston) and Abem of Sweden, which compete with EG&G Geometrics and Bison Instruments of the United States in refraction and reflection seismographs.[57] Bison is primarily an export-oriented company, and its overseas sales in 1990 constituted about 63 percent of its total shipments. In addition, portable blasting seismographs are produced in the United States by a few small manufacturers; the major foreign competition to such seismographs comes from Instantel, a Canadian company.

In satellite-based navigation and position data products, there are a large number of commercial suppliers around the world, but the market is dominated by U.S. producers. The major foreign competition for military GPS receivers come from Sagem and Sextant-Avionique in France, Plessey in the United Kingdom, MBB in Germany, and Alenia in Italy.

[56] *Wall Street Journal*, [Eastern Princeton, NJ edition], *German Firm Finds Reuniting Hard to Do*, Dec. 14, 1990, p. B3C.

[57] *Electronics Business*, Mar. 4, 1991, p. 45.

U.S. TRADE MEASURES

Tariff Measures

Navigational, surveying, and other instruments covered by this summary are classified for tariff purposes in chapter 90 of the *Harmonized Tariff Schedule* (HTS). The current column 1-general rates of duty range from free to 7.9 percent ad valorem with a trade-weighted average of 3.4 percent in 1993.[58] Column 2 rates vary and are generally much higher than column 1 rates. The recently completed (December 1993) GATT Uruguay Round of trade negotiations many result in further reductions in U.S. and foreign duties on the articles covered by this summary. The U.S. Uruguay Round schedule of concessions was not available at the time that this summary was prepared. (See table B-1 for duty rates and trade data at each 8-digit HTS subheading level).

Navigational and surveying instruments classified under chapter 90 are eligible for duty-free treatment under the Generalized System of Preferences (GSP), the Caribbean Basin Economic Recovery Act (CBERA), United States-Israel Free-Trade Implementation Act of 1985, and the Andean Trade Preference Act (ATPA). In addition, navigational instruments are eligible for duty-free treatment pursuant to the Agreement on Trade in Civil Aircraft. Imports from Canada are provided preferential duty rates under the United States-Canada Free-Trade Agreement. The North American Free Trade Agreement (NAFTA), as implemented by the North American Free Trade Implementation Act (Pub. Law 103-182, approved Dec. 8, 1993), provided for elimination of U.S. duties, effective January 1, 1994 on navigational and surveying instruments imported from Mexico. Mexico eliminated its duties on imports of such goods from the United States effective January 1, 1994. The NAFTA became effective for both the United States and Mexico on January 1, 1994. (See appendix A for an explanation of the trade and tariff terms.)

Navigational and surveying instruments can also be entered duty-free and classified in subchapter X of chapter 98 of the HTS, when imported under the provisions of annex D to the Florence Agreement relating to duty-free entry for scientific instruments.[59]

[58] Based on 1992 trade.

[59] The Florence Agreement was adopted by the General Conference of the United Nations Educational, Scientific and Cultural Organization (UNESCO) in July 1950, and entered into force in 10 countries on May 21, 1952. The United States signed the agreement and an accompanying protocol of reservation in 1959, but implementing legislation was not approved until Oct. 14, 1966; the agreement entered into force in the United States on November 2, 1966. The agreement obligated contracting parties to refrain from applying custom duties or other charges on a number of articles and objects of cultural and artistic interest in order to promote the free exchange of ideas. Annex D to the agreement covered scientific instruments or apparatus, intended exclusively for educational purposes or pure scientific research, and the duty-free provision applied only in cases where instruments or apparatus of equivalent scientific value are

According to Commerce estimates, imports of all scientific instruments under the provision totaled between $30 million and $45 million annually during the past few years.[60] Imports of navigational and surveying instruments under the provision are not available, but are believed to be small.

Less than 1 percent of 1990 imports of navigational and surveying instruments entered under HTS heading 9802.00.80 (which provides preferential tariff treatment for eligible imported goods assembled in foreign locations and containing U.S.-made components). The duty-free U.S.-origin components accounted for 51 percent of the total value of imports under this provision.

Trade-related Investigations

In 1992, the Commission conducted a preliminary investigation under the U.S. countervailing duty law with respect to portable seismographs from Canada. In that investigation (No. 701-TA-313), the Commission made an affirmative preliminary injury determination.[61] However, the investigation was terminated later that year by the U.S. Department of Commerce at petitioner's request after Commerce found the subsidy to be *de minimis*.

FOREIGN TRADE MEASURES

Tariff Measures

Foreign countries generally impose higher duty rates on imports of navigational, surveying, and other instruments than the United States does. In addition, a number of countries levy supplementary taxes and charges on imports. Tariff rates in the EU are relatively low and range from free to 7.2 percent. In Japan, no tariffs were levied on these instruments for the year ending March 31, 1991, although general tariff rates on these instruments range from 15 to 20 percent. Canada, Australia, and New Zealand have higher duty rates than those of the United States, the EU, and Japan. These countries also have supplementary taxes such as sales tax, service tax, and value-added tax on imports, which increases the cost of importing. In Canada, tariffs range from free to 10.3 percent.

Several industrialized countries impose duty rates lower than their most-favored-nation (MFN) rates on imports from developing countries. Many countries also provide preferential duty rates on imports from countries with which they have signed a free-trade or other agreement. These countries also provide duty-free MFN rates on a number of navigational and surveying instruments. The EU and EFTA have trade agreements that generally provide duty-free trade among members. The EU also provides duty-free treatment on its imports from least developed countries and other GSP countries in Asia, Africa, and South America. Canada and Japan provide duty-free treatment on a number of navigational and surveying instruments imported from most countries.

Nontariff Measures

"Buy National" policies of the government-owned companies in the EU, which are not currently covered by the General Agreement of Tariffs and Trade (GATT) Government Procurement Code, favor EU members over nonmembers.[62] The United States is seeking removal of "buy national" policies as part of the renegotiation of the GATT Procurement Code, and through bilateral tecommunication talks. The Code renegotiations are in progress. The government support for Airbus remains a primary area of contention between the United States and the EU. The Governments of France, Germany, the United Kingdom, and Spain each provide significant financial support to their companies in the Airbus consortium.[63] Airbus continues to avoid commercial risks and costs through government support, and has an advantage over U.S. producers who must bear full market risks for new civilian aircraft development and production. This has reduced U.S. aircraft manufacturers' ability to invest in new technologies necessary for new product development and future competition,[64] and may have adversely affected U.S. manufacturers of navigational instruments for civilian aircraft.[65]

59—Continued
not being manufactured in the country of importation. Exceptions to these terms could be made on grounds relating to national security, public order, or public morals. On March 1, 1977, UNESCO opened for signature a protocol to the Florence Agreement, known as the Nairobi Protocol. The protocol represented an extension of the Florence Agreement to additional categories and reaffirmed and further promoted the principles of tariff exemption for educational, scientific, and cultural products, and to expand coverage of goods for the blind to include goods for all handicapped persons. The protocol added to annex D the inclusion of duty-free eligibility for spare parts, components, or accessories specifically matching eligible scientific instruments and apparatus, and tools used for the maintenance, checking, gauging, and repairing of eligible instruments and apparatus. As of January 1, 1991, the parties to the Nairobi Protocol to the Florence Agreement consisted of Barbados, Belgium, Denmark, Egypt, Finland, France, Germany, Greece, the Holy See, Iraq, Ireland, Italy, Luxembourg, Netherlands, Portugal, San Marino, the United Kingdom, United States, and Yugoslavia.

60 Office of the Statutory Import Programs of the U.S. Department of Commerce. According to Frank Creel of this office, the estimation is based on the number of applications submitted by qualified nonprofit institutions and the volume of imports involved per application.

61 U.S. International Trade Commission, *Portable Seismographs from Canada*, USITC publication 2496, Mar. 1992.

62 Office of the United States Trade Representative, *1992 National Trade Estimate Report on Foreign Trade Barriers*, Mar. 31, 1992, p. 75.

63 Ibid, p. 83.

64 Ibid.

65 Ibid. On July 17, 1992, the United States and EU signed a bilateral agreement limiting government support for large civil aircraft programs. The U.S. Administration is closely monitoring the implementation of this agreement and is seeking further improvement of rules in government support to aircraft through multilateral negotiations in the GATT Aircraft Code.

Members of the EU, Korea, Finland, Norway, and Japan provide subsidies and other forms of assistance to their shipbuilding and ship repair industry.[66] These include subsidized restructuring of their domestic shipbuilding industries, direct subsidies for operations and investment, indirect subsidies, home credit schemes, subsidized export credits, and other practices associated with public ownership of yards. These subsidies have helped to create advantages for foreign firms over U.S. shipbuilders, and adversely affect U.S. producers of instruments for marine navigation.

Import licensing, export subsidies, and investment barriers are some of the most common practices followed by a number of countries. Japan retains authority to restrict foreign investment in certain specified sectors, including aircraft and space development.[67] The Government of Japan has taken significant steps to enhance the competitiveness of its aerospace industry by providing incentives, which include government interest rate subsidies and preferential loans for the development and research stages of aircraft and engines.[68] Israel uses a practice known as "harama," which allows the Government of Israel to assess duty on imported products based on inflated values, rather than actual values, thereby allegedly violating the principles of the GATT customs valuation code.[69]

[66] Ibid, pp. 84, 151, 166, and 195.
[67] Ibid, pp. 148 and 152.
[68] Ibid.

U.S. MARKET

Consumption

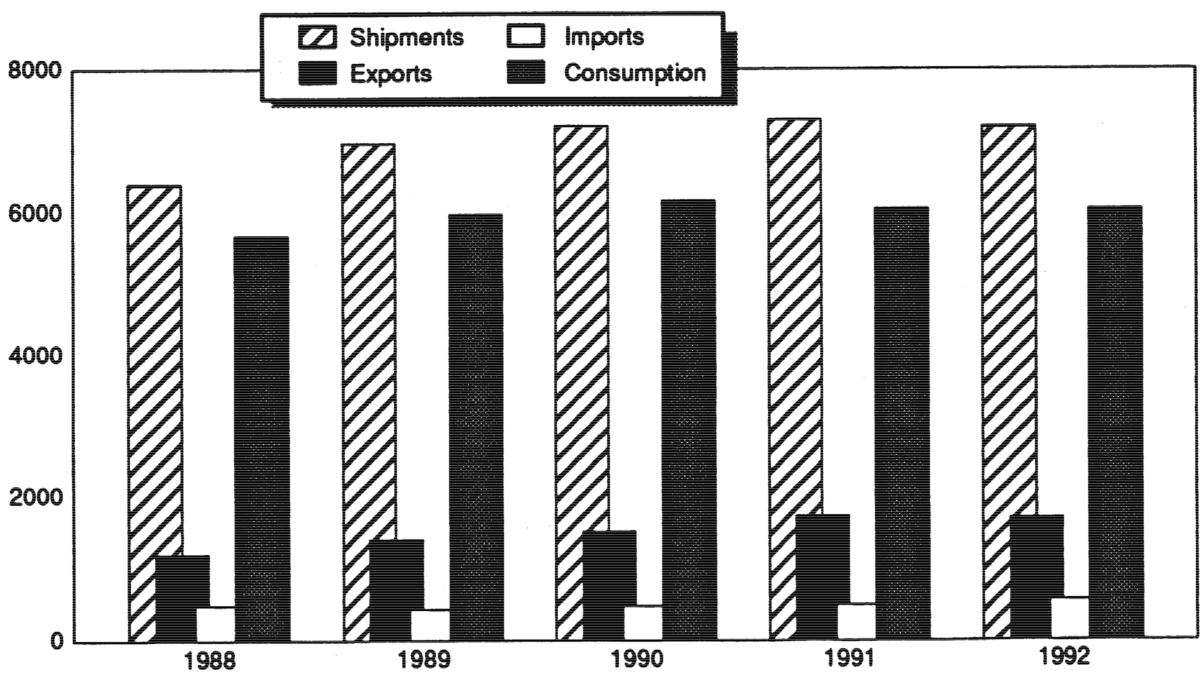
U.S. consumption of navigational and surveying instruments totaled $6.1 billion in 1992; imports accounted for 9 percent (table B-2, figure 9). U.S. consumption of these instruments grew by 4 percent annually, increasing from $5.2 billion in 1988 to $6.2 billion in 1990. Economic recession and the end of Cold War slowed the demand for these instruments in 1991 and 1992 to just over $6 billion. In constant dollars, consumption rose by just over 2 percent in 1989 from its year-earlier level, and then declined thereafter every year at an average annual rate of 3 percent (table B-2).

Navigational instruments accounted for roughly 95 percent of the U.S. market for navigational and surveying instruments in 1991, of which domestic

[69] Ibid, p. 130.

Figure 9
Navigational and surveying instruments: U.S. producers' shipments, imports, exports, and apparent consumption[1], 1988-92

Million dollars



[1] Apparent consumption = Producers' shipments + imports - exports.

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

production provided about 94 percent. By contrast, only 5 percent of the U.S. market in 1991 was accounted for by surveying and other instruments, of which domestic production provided just 52 percent.

The market for navigational and surveying instruments follows demand for civilian and defense-related aircraft and ships and trends in construction and engineering activities, which during the 1980s continued to expand largely because of a strong economy and increases in defense spending. The development of a new space shuttle orbiter to replace the Challenger and the decision to privatize the commercial space launch business also increased demand for navigational instruments during the period.[70]

Production

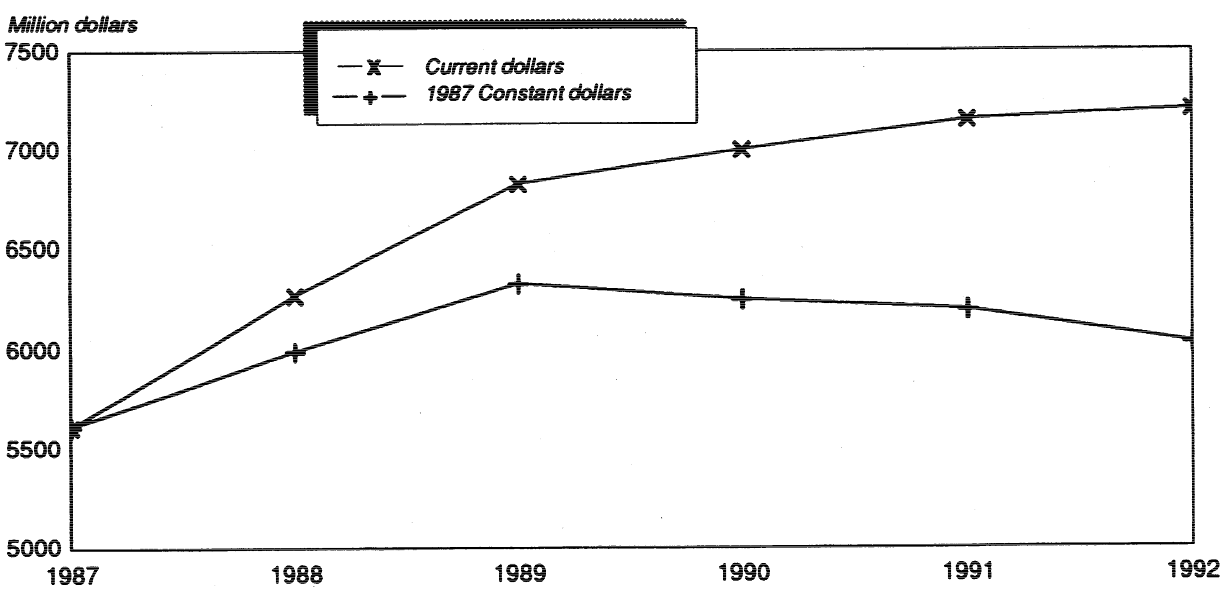
U.S. shipments of navigational and surveying instruments averaged a 3-percent annual growth during 1988-92, from $6.4 billion to $7.2 billion. In terms of constant dollars, shipments rose 5 percent in 1989, remained steady in 1990, before declining by 2 percent in 1991 and 5 percent in 1992 (figure 10). The growth in U.S. shipments was largely the result of overseas demand for U.S.-produced instruments. Navigational instruments accounted for 88 percent of shipments; meteorological and geophysical instruments, 10 percent; and surveying instruments, the remainder (table 16).

All major navigational systems and instruments showed significant increases during 1987-91. The major systems and their average annual growth rates were INS (4 percent), autopilots (21 percent), flight directors/HUD systems (16 percent), and surface (ship and ground) navigation systems (including direction finder kits) (12 percent). As shown in table 17, the major instruments and their average annual growth rates were magnetic and gyroscopic compasses (44 percent), airspeed indicators (13 percent), other nautical instruments (5 percent), and parts and accessories (22 percent).

Among other products covered by this summary, domestic shipments in 1991 of meteorological instruments totaled $359 million; geophysical electronics equipment, $390 million; and surveying instruments, $162 million.

[70] U.S. Department of Commerce, International Trade Administration, *U.S. Industrial Outlook 1989*, Jan. 31, 1989, p. 31-4.

Figure 10
Navigational and surveying instruments: U.S. shipments, 1987-92



Source: Compiled by the USITC staff, based on data from Commerce and Bureau of Labor Statistics.

Table 16
Navigational and surveying instruments: Shipments by major type, 1987-91

Year	Navigational instruments	Meteorological geophysical instruments	Surveying instruments	Total
		(Million dollars)		
1987	4,981	587	120	5,688
1988	5,547	715	142	6,404
1989	6,205	599	162	6,966
1990	6,380	656	177	7,213
1991	6,388	749	162	7,299
		Percent		
Average annual growth, 1987-91	6	6	8	6

Source: Estimated by the USITC staff based on Bureau of the Census, *Current Industrial Reports, Selected Instruments and Related Products,* MA38(B), annual series.

Table 17
Navigational instruments: Shipments by major type, 1987-91

Items	Shipments 1987	1988	1989	1990	1991	Average annual growth
	Million dollars					Percenrt
Inertial navigation system, including proximity warning collision avoidance equipment	532	540	620	657	616	4
Flight detectors/HUD systems	188	256	308	380	346	16
Autopilots	171	302	314	397	372	21
Distance measuring equipment	52	63	86	80	101	18
Other airborne navigation system	641	534	612	573	613	-1
Surface (ship and ground) navigation systems, including direction finder kits	462	613	683	770	722	12
Compasses (magnetic and gyroscopic)	80	152	305	296	343	44
Altimeters (except radio and radar)	51	36	55	56	([1])	([2])
Airspeed indicators (including air data computers and machine meters)	258	309	340	402	422	13
Rate of climb indicators	13	12	10	7	8	-11
Angle of attack indicators	9	9	9	16	16	15
Artificial horizon flight indicators	54	48	34	25	21	-21
Other aerospace and navigation instruments	446	449	381	423	477	2
Gyroscope sold separately	283	279	282	296	276	-1
Airframe equipment instruments	110	143	157	115	108	([3])
Other aerospace flight instruments	415	442	441	457	419	([3])
Other nautical instruments	88	99	104	113	109	5
Parts and accessories	97	181	160	129	218	22
All other	1,031	1,080	1,304	1,188	1,201	4
Total	4,981	5,547	6,205	6,380	6,388	6

[1] Data withheld to avoid disclosing figures for individual companies.
[2] Not available.
[3] Less than 0.5 percent.

Source: Bureau of the Census, U.S. Department of Commerce, *Current Industrial Reports,* MA38B, annual series.

Imports

Import levels and trends

U.S. imports of navigational and surveying instruments increased at an annual rate of 3.6 percent during 1988-92, from $488 million to $562 million (table 18). In constant dollars, imports increased by 1.4 percent per year.

Nonelectrical navigational instruments and appliances for use in civil aircraft and other air and space navigation were the primary products imported into the United States in 1992 (table 19). Imports of these products, which accounted for 31 percent of total navigational instruments and parts in 1992, increased by 5 percent between 1989 and 1992, to $131 million. Imports of instruments and appliances, used especially in marine and river navigation, increased by 153 percent to $52 million, or 13 percent of the total. Parts and accessories for navigational instruments represented $169 million or 41 percent of total imports. Those used in nonelectrical instruments for civil aircraft and other totaled $30 million, and autopilots, $15 million. Other primary imports included hydrographic, meteorological, and geophysical instruments ($53 million), theodolites and tachymeters ($28 million), levels ($11 million), and photogrammetrical instruments and appliances ($11 million). Parts and accessories for these instruments totaled $40 million, or 27 percent of the total.

Table 18
Navigational and surveying instruments: Imports in current and constant dollars, 1988-92

Year	U.S. imports	
	In current dollars	In constant 1987 dollars[1]
	(Million dollars)	
1988	488	471
1989	432	421
1990	479	445
1991	499	455
1992	562	497
	Percent	
Average annual growth	3.6	1.4

[1] Current dollar figures deflated by import price index for SIC 38.

Source: U.S. Department of Commerce, Bureau of the Census.

Table 19
Navigational and surveying instruments: U.S. imports by major types, 1989 and 1992

(Million dollars)

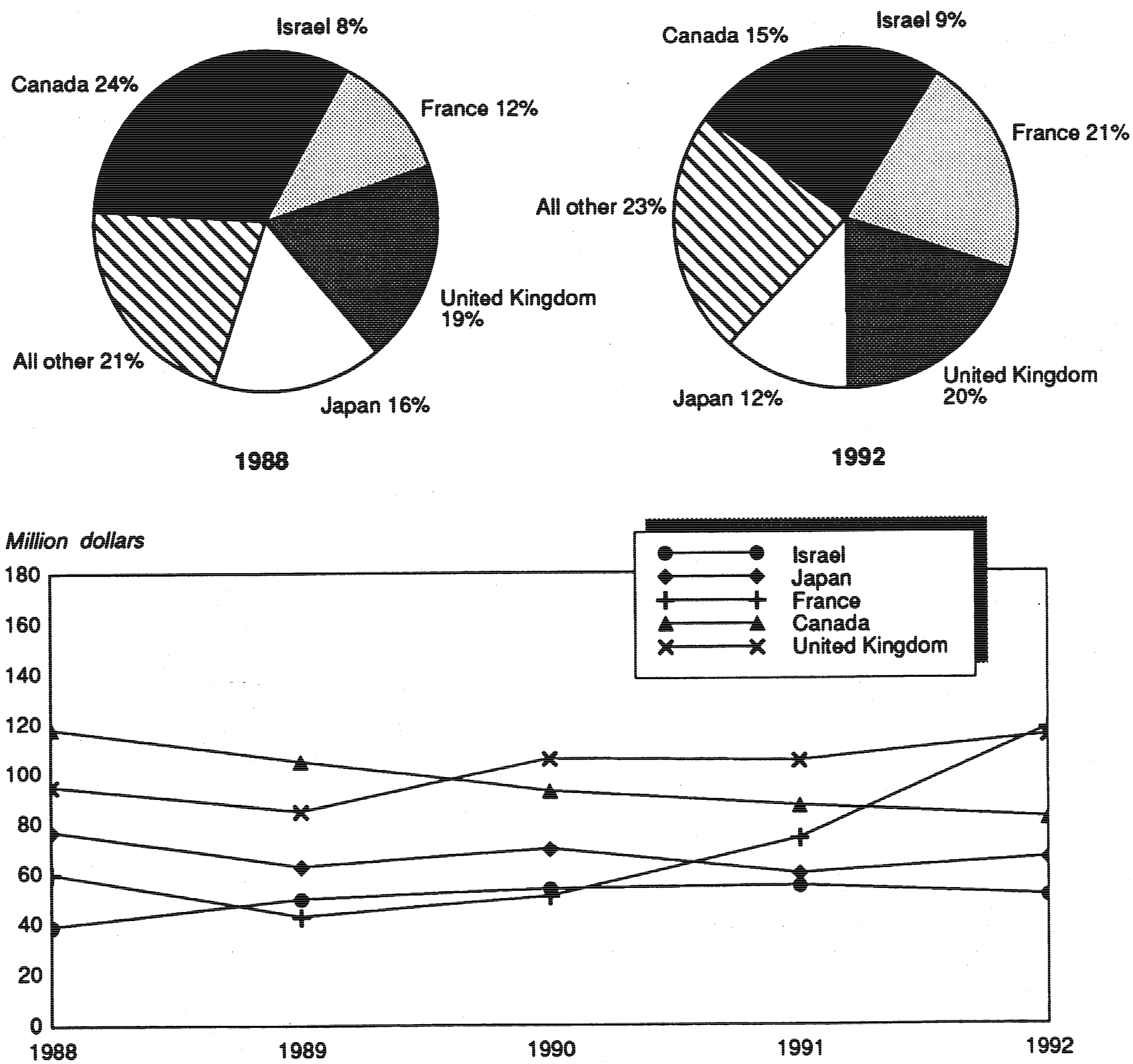
Types	1989	1992
Direction finding compasses	14.4	14.4
Optical instruments for air and space navigation	10.2	13.5
Autopilots	12.2	17.4
Other nonelectrical instruments for civil aircraft	124.9	130.9
Other nonelectrical instruments for air and space navigation	8.3	13.4
Optical instruments for marine and other navigation	9.4	4.8
Other instruments for marine and river navigation	20.7	52.4
Parts and accessories for navigation	98.0	169.4
Rangefinders	8.7	3.2
Hydrographic, meteorological and geophysical instruments	66.3	52.5
Theodolites and tachymeters	13.2	28.2
Photogrammetrical surveying instruments	11.6	11.1
Levels	8.7	10.9
Parts and accessories for surveying instruments	25.8	40.1
Total	432.4	562.2

Source: U.S. Department of Commerce.

Principal import suppliers

Developed countries are the major suppliers of navigational and surveying instruments to the United States. France and the United Kingdom led all suppliers in 1992 at $118 million and $115 million, respectively, which represented a combined 41 percent of total imports (table B-3, figure 11). Canada, Japan, and Israel together supplied an additional $199 million or 35 percent of total imports in 1992. Canada, the United Kingdom, and France were the major suppliers of instruments and appliances used in civil aircraft and other aeronautical and space navigation. These countries, along with Mexico and France, also supplied the bulk of parts and accessories used in such instruments. Japan supplied most of the theodolites, tachometers, and levels, and along with the United Kingdom also supplied the bulk of photogrammetrical instruments and appliances.

Figure 11
Navigational and surveying instruments: U.S. imports from leading sources, by share of total, 1988 and 1992, and by value, 1988-92



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

Imports under HTS heading 9802.00.80

U.S. imports of navigational and surveying instruments under HTS heading 9802.00.80 are small. Under this tariff provision, U.S. firms pay no duty on the value of the U.S.-made components contained in the assembled instruments when they are imported into the United States after being assembled abroad. In 1992, such imports represented less than 1 percent of total navigational and surveying instruments imported into the United States. After totaling $8.2 million in 1989, imports under HTS heading 9802.00.80 fell to $3 million in 1990, and increased again to $3.9 million in 1991, and $4.9 million in 1992. U.S. firms take advantage of these tariff concessions by shipping the components to proximate low-wage countries, such as Mexico, where they are assembled.

Korea and Mexico were the largest suppliers of heading 9802.00.80 imports. They supplied a combined 69 percent of total heading 9802.00.80 imports in 1992 and 73 percent of duty-free value of such imports. Over one-half of the value of heading 9802.00.80 imports was attributable to duty-free U.S. components as shown in the following tabulation (in percent):

	1989	1990	1991	1992
Ratio of 9802.00.80 imports to total imports	2	1	1	1
U.S.-made parts as share of 9802.00.80 imports ..	45	51	59	58

FOREIGN MARKETS

Foreign Market Profile

Western Europe, and Japan to a lesser degree, are the major markets for navigational and surveying instruments. Although these markets have been sluggish in recent years, the demand for navigational instruments is expected to grow worldwide as a result of increasing commercial aviation activities around the world and rapid growth in the application of navigational aids in automobiles.[71] In addition, increasing military activities in developing countries will lead to greater demand for instruments having military applications, and this is expected to offset the decline in the military market in the United States. The prospect for U.S. manufacturers to expand their global share looks good, especially in the military market, because of superior technology, product quality, price competitiveness, and an efficient distribution system that provides sales and service throughout the world.[72]

[71] According to Brian J. Havighurst, a *Leading Edge Reports* Industry Analyst from Cleveland, OH, auto navigation and instrumentation device sales will total $6.6 billion in 1995 compared with $1.7 billion in 1990. *Wards Auto-world*, Aug. 18, 1992.

[72] Interview with officials of Litton Systems in Woodland Hills, CA, Aug. 18, 1992.

The growth in the market for navigational instruments is expected to come mostly from the Middle East and Asia, where the tendency is to equip older airplanes with new equipment or to buy less expensive planes and equip them with high-technology instruments.[73] Market opportunities also exist in newly established democracies of Eastern Europe and the former Soviet Union.[74] The expected growth in these markets is likely to offset a significant drop in domestic demand resulting from cutbacks in military spending.[75] Industry sources foresee market potential for satellite-based commercial GPS receivers. U.S. producers, possessing significant competitive advantage in this technology over foreign competitors, are expected to capture the bulk of the commercial market.[76] With today's integrated circuit technology, GPS receivers are fast becoming small enough and cheap enough to be carried by just about anyone. The market for surveying and other instruments is expected to grow with the anticipated global economic recovery, and foreign producers will continue to meet most of the global demand.

U.S. Exports

Export levels and trends

U.S. exports accounted for 24 percent of domestic shipments of navigational and surveying instruments in 1992 compared with 19 percent in 1988 (figure 12). Exports grew by 9 percent annually during 1988-92, rising to $1.7 billion in 1992. The export growth was attributed, in large part, to a weak U.S. dollar and increased competitiveness of U.S. producers, especially those producing instruments having military applications. In terms of constant dollars, exports rose 5 percent annually (table 20, figure 13).

Principal markets

A number of countries in Europe, Asia, and Canada receive the bulk of U.S. exports of navigational

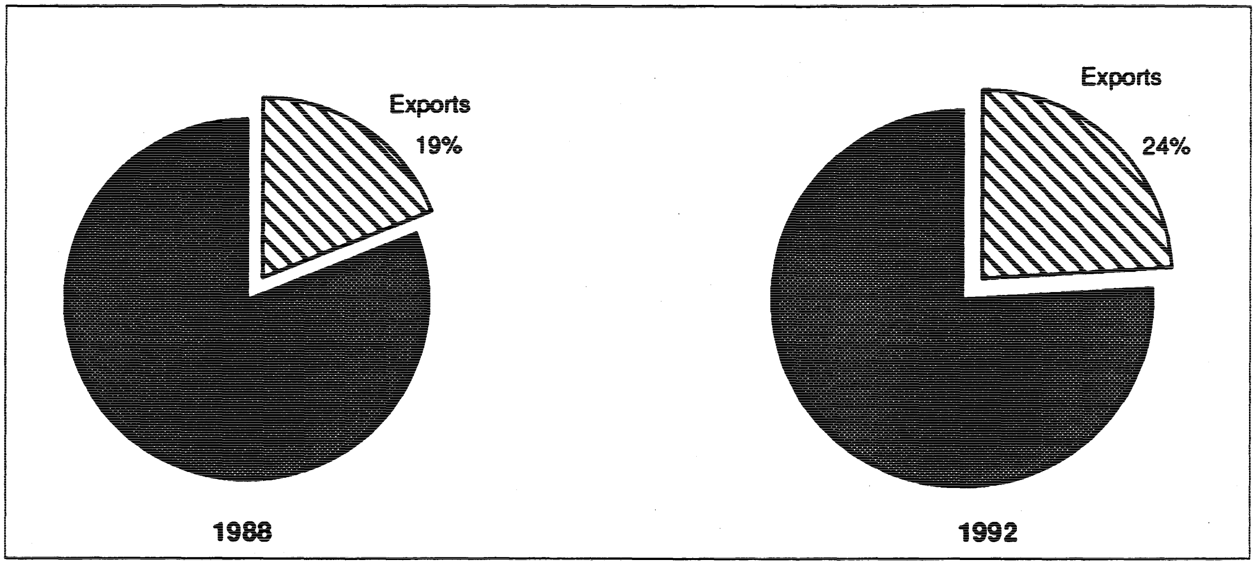
[73] Ibid. Upgrading the airplanes with new and high technology instruments is also common in European countries. Honeywell's Defense Avionics Systems Division will upgrade flight management systems of Belgian's C-130 fleet. *Defense News*, Feb. 3, 1992, p. 18.

[74] The newly independent Republic of Slovenia, formerly part of Yugoslavia, has awarded a contract to Siemens Air Management Division for equipping the country's national air transportation system. The contract covered a range of navigational aids to be used in the air transportation system (*Aerospace-world*, Apr., 1992, p. 39). Rockwell Collins of the United States is a prime contractor for avionics to Ilyushin of Russia for its westernized version of the Ilyushin 96 passenger jet (*Engineer*, Apr. 2, 1992, p. 7). Bendix air transport avionics division of Allied-Signal Aerospace of the United States has been delivering avionics to Yakovlev for installation on the first Yak-42A 120-seat airliner (*Flight International*, May 26, 1992, p. 10).

[75] Interview with officials of Litton Systems in Woodland Hills, CA, Aug. 18, 1992; Sperry Marine in Charlottesville, VA, July 30, 1992; and Interstate Electronics Corp. in Anaheim, CA, Aug. 19, 1992.

[76] Interview with officials of Trimble Navigation in Sunnyvale, CA, Aug. 20, 1992.

Figure 12
Navigational and surveying instruments: U.S. export share of domestic merchandise, 1988 and 1992



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

Table 20
Navigational and surveying instruments: U.S. exports in current and constant dollars, 1988-92

Year	U.S. exports: In current dollars	U.S. exports: In constant 1987 dollars[1]
	(Million dollars)	
1988	1,204	1,152
1989	1,411	1,284
1990	1,519	1,317
1991	1,734	1,433
1992	1,709	1,378
	Percent	
Average annual growth, 1988-92	9	5

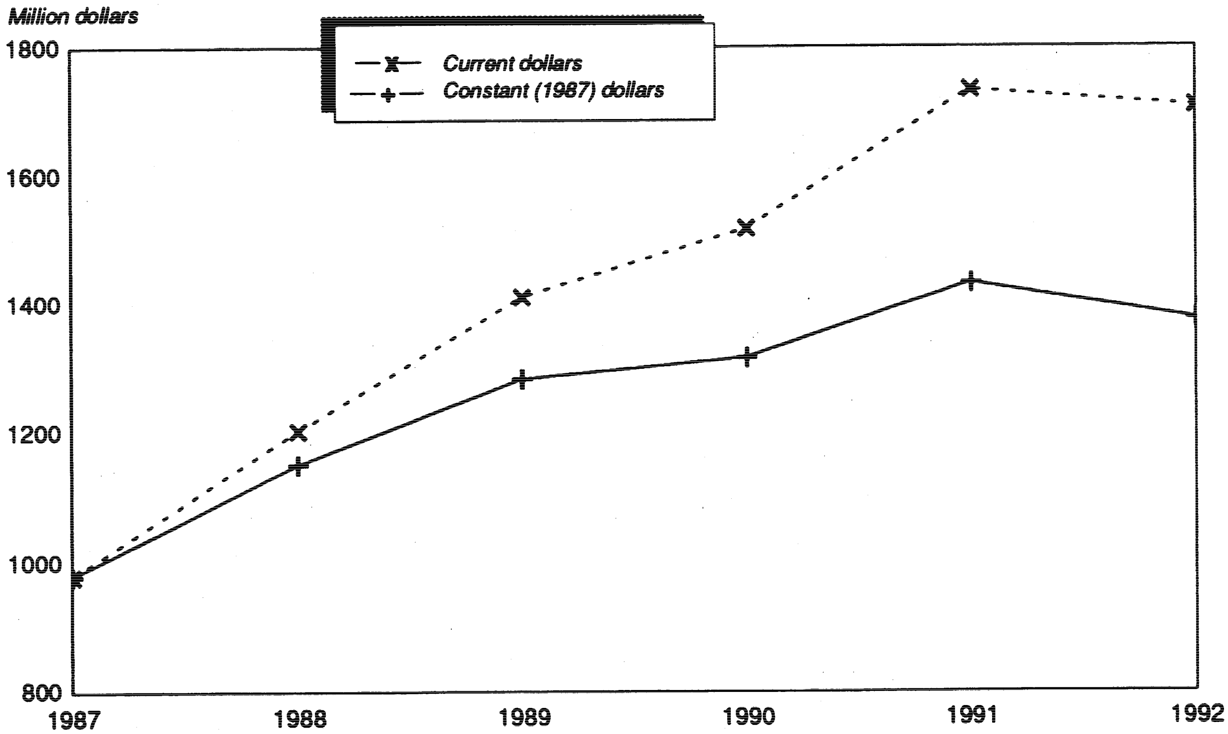
[1] Current dollar figures deflated by export price indexes for SIC 38.

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

and surveying instruments. In 1992, Canada was the leading destination of U.S. exports at $196 million or 11 percent of total. The EU imported $601 million or 35 percent of total.[77] The major recipients of U.S. exports in the EU were the United Kingdom, France, Netherlands, Germany, and Italy, which together represented 91 percent of the EU total (table B-4 and B-5, figure 14). Norway and Switzerland were the other leading destinations of U.S. exports in Europe. Among Asian countries, Japan was the major recipient of U.S. exports at $133 million, followed by China ($86 million), Taiwan ($52 million), Singapore ($57 million), and Korea ($50 million) as shown in table B-4.

[77] Based on EU imports from the United States as reported in Eurostat data, the EU took $697 million or 40 percent of U.S. exports in 1991, compared with $616 million or 36 percent as reported by the Department of Commerce for 1991.

Figure 13
Navigational and surveying instruments: U.S. exports of domestic merchandise, 1987-92



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

Products exported

Geophysical instruments (including meteorological and hydrological) and nonelectrical instruments used in aeronautical and space navigation were the largest U.S. export items in 1992 at $369 million and $262 million, respectively (table 21). Other leading export categories were electrical items for aeronautical and space navigation ($166 million), instruments used in marine navigation ($145 million), and auto pilots ($92 million). Parts and accessories for navigation instruments totaled $230 million and that of surveying instruments totaled $235 million. Although most major export items grew during 1989-92, the growth has been especially rapid with respect to instruments used in marine navigation.

Because the U.S. industry producing surveying instruments is not competitive internationally, U.S. exports of surveying instruments were small during the period examined. The only significant instruments exported were levels ($39 million) and range finders ($31 million), as shown in table 21.

EU Trade with United States

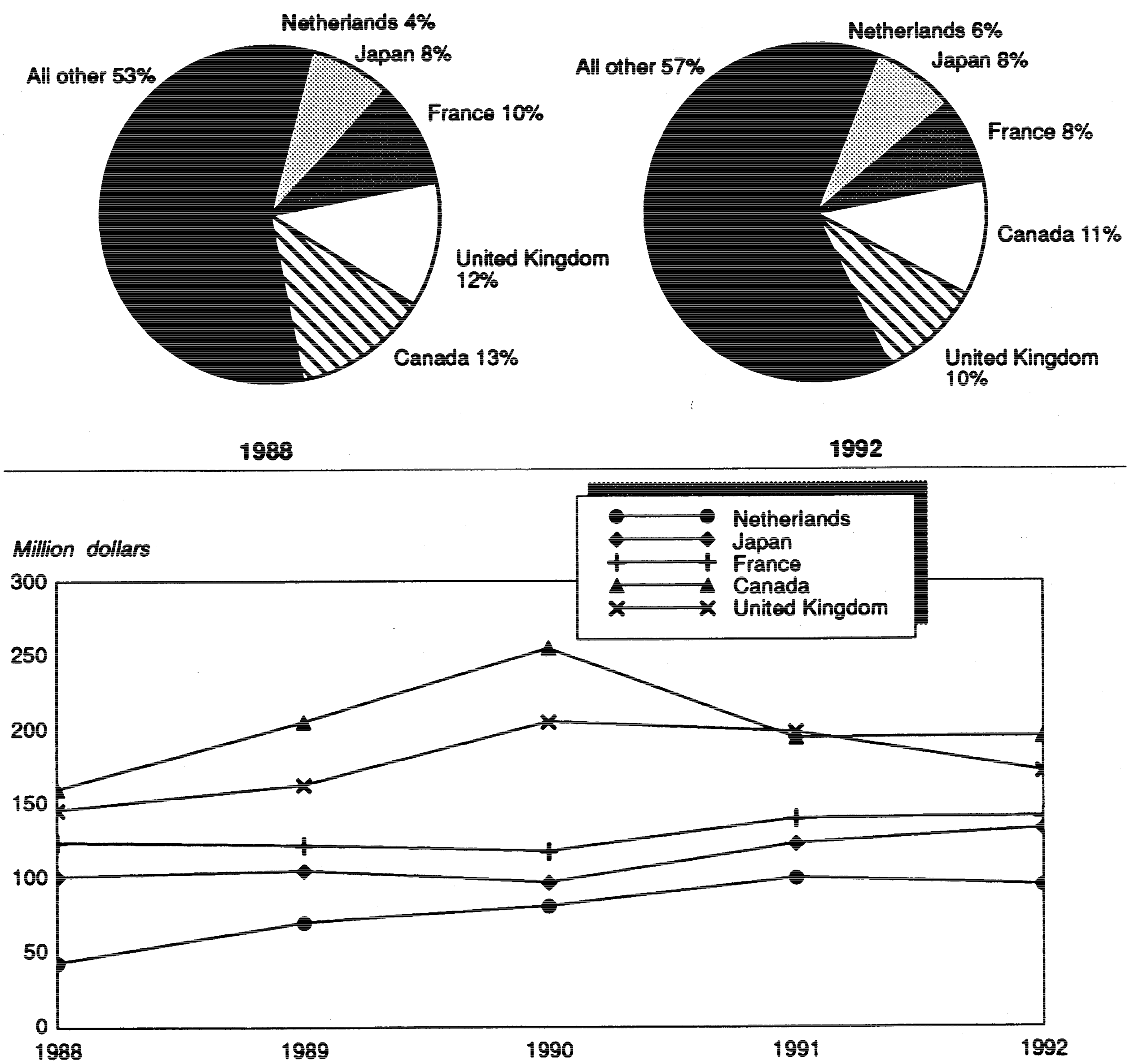
In 1991, EU imports of navigational and surveying instruments (excluding intra-EU trade) totaled $1,101 million. The United States supplied $697 million or 63 percent of the total (table 22). EU exports during the same year (excluding intra-EU trade) totaled $1,043 million, with the United States receiving $329 million or 32 percent of the total (table 22, figure 15).[78]

Instruments and appliances for aeronautical and space navigation were the major products traded between the United States and EU during 1991. EU imports of these items totaled $423 million in 1991, of which the United States supplied $362 million, or 86 percent of the total (table 22). The United Kingdom was the largest recipient of such imports from the United States, at $182 million, or about one-half of the total (table 22). France ($109 million) accounted for most of the remainder. The United States was a major recipient of EU exports of instruments for aeronautical and space navigation, taking $182 million in 1991, or 48 percent of the EU total (table 22). Of the $182 million, the United Kingdom supplied $127 million; France supplied the bulk of the remainder ($37 million).

The United States has been highly competitive in the EU market with respect to most navigational instruments, capturing 79 percent of the EU import market in 1991. By contrast, the share provided by U.S. surveying and other instruments in the EU

[78] All of the statistics in this section is based on data reported by Eurostat, an official organ of the EU. These data from Eurostat differ from U.S. trade data published by the U.S. Department of Commerce. For example, Commerce data indicate U.S. exports of $616 million to EU and U.S. imports of $212 million from EU in 1991.

Figure 14
Navigational and surveying instruments: U.S. exports to leading markets, by share of total, 1988 and 1992, and by value, 1988-92



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

import market has been relatively much smaller, and in 1991, represented 34 percent. The majority of U.S. exports to the EU consisted of hydrographic, meteorological, and geophysical instruments and their parts. The products in which the United States was least competitive were theodolites and tachymeters. The United States supplied only 1 percent of total EU imports of theodolites and tachometers although it took about 6 percent of EU exports of these products, as seen in table 22.

In addition to the United States, other significant suppliers of navigational and surveying instruments to the EU were Norway ($82 million), Japan ($81 million), and Switzerland ($72 million). The major export markets for the EU, besides the United States were Norway ($98 million), China ($47 million), Singapore ($44 million), Canada ($36 million), and a number of countries in Europe and Asia.

Table 21
Navigational and surveying instruments: U.S. exports by major types, 1989 and 1992

(Million dollars)

Product type	1989	1992
Optical direction findings compasses	$38.4	$23.1
Gyroscopic compasses	44.8	27.0
Other direction finding compasses	9.3	7.3
Optical instruments for aeronautical and space navigation	33.1	23.1
Auto pilots	97.9	92.3
Other electrical instruments for aeronautical and space navigation	122.1	166.0
Nonelectrical instruments for use in civil aircraft and other aero and space navigation	219.3	261.8
Ships logs and depth sounding apparatus	40.0	46.8
Other marine and river navigation instruments	60.0	144.7
Parts and accessories for navigational instruments	247.3	230.0
Range finders	15.5	30.6
Theodolites and tachometers	1.4	2.7
Levels	29.4	38.7
Photogrammetrical surveying instruments	4.7	10.9
Geophysical, meteorological, and hydrological instruments	311.2	369.2
Parts and accessories for surveying instruments	136.7	235.0
Total	1,411.1	1,709.2

[1] Not available.

Source: U.S. Department of Commerce.

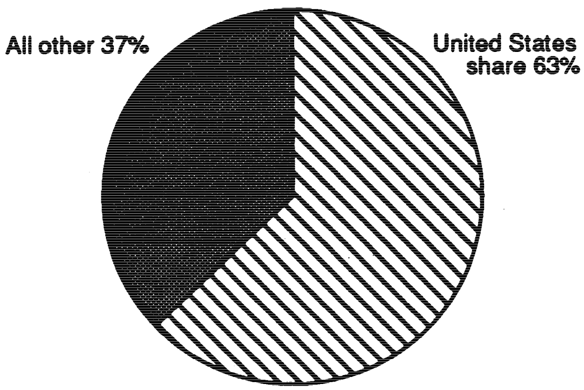
Table 22
Navigational and surveying instruments: EU exports and imports and U.S. share by major product type, 1991

Product type	Exports to: World	Exports to: United States	U.S. share	Imports from: World	Imports from: United States	U.S. share
	(Million dollars)		*(Percent)*	*(Million dollars)*		*(Percent)*
Direction finding compasses	$43.3	$10.3	24	$27.2	$15.0	55
Instruments for aeronautical and space navigation	383.0	182.3	48	422.7	362.4	86
Other instruments and appliances	78.8	20.2	26	92.9	53.9	58
Parts and accessories	132.9	38.5	29	173.8	136.6	79
Total navigational	638.0	251.3	39	716.6	567.9	79
Range finders	15.0	1.8	12	22.5	2.0	9
Theodolites and tachometers	14.3	0.8	6	48.3	0.4	1
Levels	5.1	0.2	4	36.4	15.7	43
Photogrammetrical surveying	19.0	8.3	44	5.5	2.3	42
Hydrographic, meteorological and geophysical instruments	221.5	31.4	14	164.9	78.1	47
Parts and accessories	129.8	34.8	27	106.5	30.2	28
Total surveying	404.7	77.3	19	384.1	128.7	34
Total navigational and surveying instruments	1,042.8	328.6	32	1,100.7	696.8	63

Note.—Individual sums may not add to totals due to rounding.

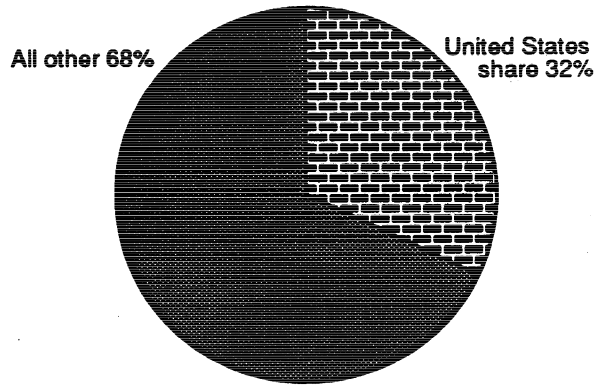
Source: Eurostat world imports and world exports (excluding intra EU trade).

Figure 15
Navigational and surveying instruments: U.S. share of EU imports and U.S. share of EU exports, 1991



EU imports
1991
(million dollars)

EU imports, total	1,101
U.S. supplied	697
U.S. share	63%



EU exports
1991
(million dollars)

EU exports, total	1,043
U.S. took	329
U.S. share	32%

Source: Euro stat world imports and world exports (excluding intra-EU trade), 1991.

The United Kingdom ($335 million) was by far the largest consumer of U.S. navigational and surveying instruments, accounting for 48 percent of total EU imports from the United States (table 23). France was the second-largest recipient at $156 million (22 percent), followed by Germany and Netherlands. The leading items imported by the EU from the United States were instruments for aeronautical and space navigation. The United Kingdom took just over one-half of the total and France took 30 percent. Hydrological, meteorological, and geophysical instruments were the next largest category of instruments imported from the United States; the United Kingdom took 49 percent of the total.

U.S. TRADE BALANCE

The U.S. trade surplus in navigational and surveying instruments grew from $716 million in 1988, to $1.1 billion in 1992 (table B-5, figure 16). The improvement in the trade surplus was largely the result of increased U.S. exports, which grew by 9 percent annually, increasing from $1.2 billion in 1988, to $1.7 billion in 1992. Imports showed a much smaller gain, increasing an average 4 percent annually from $488 million to $562 million during the period.

The U.S. trade surplus increased with all major regions of the world. The U.S. trade surplus with the EU, which accounted for nearly 30 percent of the U.S. trade surplus with the world, increased by 48 percent between 1988 and 1991 before declining by 18 percent to $332 million in 1992. The U.S. trade surplus with other trading partners, although relatively small, increased rapidly.

Table 23
Navigational and surveying instruments: Major EU importers of U.S. instruments, by type, 1991

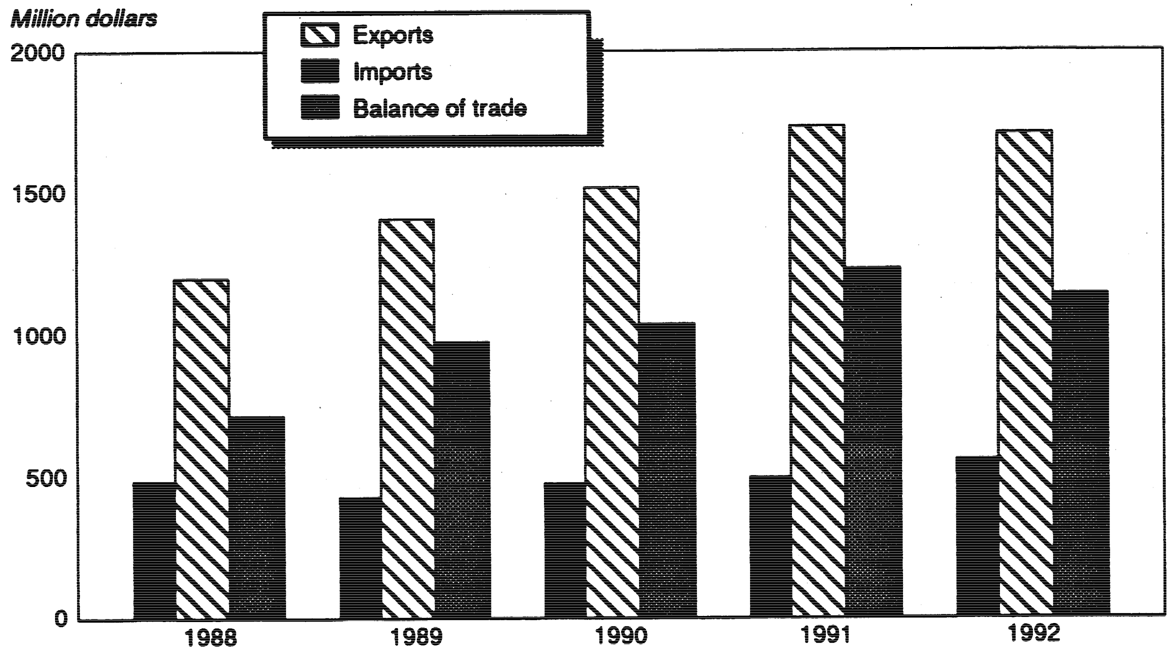
(1,000 dollars)

	Major EC importers					
Products	United Kingdom	France	Nether-lands	Germany	Other	Total
Direction finding compasses	$8,364	$1,173	$913	$2,591	$1,914	$14,955
Instruments for aeronautical and space navigation	181,860	109,437	17,685	18,475	35,020	362,477
Other navigational instruments	19,336	6,177	3,611	10,087	[1]14,687	53,898
Parts and accessories for navigational instruments	73,902	25,006	12,914	4,155	[2]20,652	136,629
Range finders	196	62	126	1,173	[2]475	2,032
Theodolites and tachometers	185	([3])	([3])	89	[4]141	415
Levels	1,068	2,418	1,137	10,479	645	15,747
Photogrammetrical surveying instruments	318	236	118	104	[5]1,528	2,304
Other surveying instruments	37,937	8,474	6,761	9,029	[6]15,871	78,072
Parts and accessories for surveying instruments	1,718	3,327	2,472	10,019	2,704	30,240
Total navigational and surveying instruments	334,884	156,309	45,737	66,201	93,638	696,769

[1] Italy took $11.3 million.
[2] Italy took $13.4 million.
[3] Less than $5,000.
[4] Italy totaled $120,000.
[5] Spain took $1.3 million.
[6] Italy took $5.6 million and Spain, $5 million.

Source: Eurostat world imports and exports (excluding intra EU trade).

Figure 16
Navigational and surveying instruments: Imports, exports, and balance of trade, 1988-92



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

APPENDIX A
EXPLANATION OF TARIFF AND TRADE AGREEMENT TERMS

APPENDIX A
TARIFF AND TRADE AGREEMENT TERMS

The ***Harmonized Tariff Schedule of the United States*** (HTS) replaced the *Tariff Schedules of the United States* (TSUS) effective January 1, 1989. Chapters 1 through 97 are based upon the internationally adopted Harmonized Commodity Description and Coding System through the 6-digit level of product description, with additional U.S. product subdivisions at the 8-digit level. Chapters 98 and 99 contain special U.S. classification provisions and temporary rate provisions, respectively.

Rates of duty in the ***general*** subcolumn of HTS column 1 are most-favored-nation (MFN) rates; for the most part, they represent the final concession rate from the Tokyo Round of Multilateral Trade Negotiations. Column 1-general duty rates are applicable to imported goods from all nonembargoed countries except those enumerated in general note 3(b) to the HTS plus Serbia and Montenegro, whose products are dutied at the rates set forth in ***column 2***. Goods from Albania, Armenia, Belarus, Bulgaria, the People's Republic of China, the Czech Republic, Estonia, Georgia, Hungary, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Moldova, Mongolia, Poland, Romania, Russia, Slovakia, Turkmenistan, and Ukraine are currently eligible for MFN treatment, as are the other republics of the former Socialist Federal Republic of Yugoslavia. Among articles dutiable at column 1-general rates, particular products of enumerated countries may be eligible for reduced rates of duty or for duty-free entry under one or more preferential tariff programs. Such tariff treatment is set forth in the ***special*** subcolumn of HTS column 1. Where eligibility for special tariff treatment is not claimed or established, goods are dutiable at column 1-general rates.

The ***Generalized System of Preferences*** (GSP) affords nonreciprocal tariff preferences to developing countries to aid their economic development and to diversify and expand their production and exports. The U.S. GSP, enacted in title V of the Trade Act of 1974 and renewed in the Trade and Tariff Act of 1984, applies to merchandise imported on or after January 1, 1976 and before September 30, 1994. Indicated by the symbol "A" or "A*" in the special subcolumn of column 1, the GSP provides duty-free entry to eligible articles the product of and imported directly from designated beneficiary developing countries, as set forth in general note 4 to the HTS.

The ***Caribbean Basin Economic Recovery Act*** (CBERA) affords nonreciprocal tariff preferences to developing countries in the Caribbean Basin area to aid their economic development and to diversify and expand their production and exports. The CBERA, enacted in title II of Public Law 98-67, implemented by Presidential Proclamation 5133 of November 30, 1983, and amended by the Customs and Trade Act of 1990, applies to merchandise entered, or withdrawn from warehouse for consumption, on or after January 1, 1984; this tariff preference program has no expiration date. Indicated by the symbol "E" or "E*" in the special subcolumn of column 1, the CBERA provides duty-free entry to eligible articles, and reduced-duty treatment to certain other articles, which are the product of and imported directly from designated countries, as set forth in general note 7 to the HTS.

Preferential rates of duty in the special subcolumn of column 1 followed by the symbol "IL" are applicable to products of Israel under the ***United States-Israel Free Trade Area Implementation Act*** of 1985 (IFTA), as provided in general note 8 to the HTS. Where no rate of duty is provided for products of Israel in the special subcolumn for a particular provision, the rate of duty in the general subcolumn of column 1 applies.

Preferential nonreciprocal duty-free or reduced-duty treatment in the special subcolumn of column 1 followed by the symbol "J" or "J*" in parentheses is afforded to eligible articles the product of designated beneficiary countries under the ***Andean Trade Preference Act*** (ATPA), enacted in title II of Public Law 102-182 and implemented by Presidential Proclamation 6455 of July 2, 1992 (effective July 22, 1992), as set forth in general note 11 to the HTS.

Preferential rates of duty in the special subcolumn of column 1 followed by the symbol "CA" are applicable to eligible goods of Canada, and those followed by the symbol "MX" are applicable to eligible goods of Mexico, under the ***North Ameri-***

can Free Trade Agreement, as provided in general note 12 to the HTS, effective January 1, 1994.

Other special tariff treatment applies to particular ***products of insular possessions*** (general note 3(a)(iv)), goods covered by the ***Automotive Products Trade Act*** (APTA) (general note 5) and the ***Agreement on Trade in Civil Aircraft*** (ATCA) (general note 6), and ***articles imported from freely associated states*** (general note 10).

The ***General Agreement on Tariffs and Trade*** (GATT) (61 Stat. (pt. 5) A58; 8 UST (pt. 2) 1786) is a multilateral agreement setting forth basic principles governing international trade among its signatories. The GATT's main obligations relate to most-favored-nation treatment, the maintenance of scheduled concession rates of duty, and national (nondiscriminatory) treatment for imported products; the GATT also provides the legal framework for customs valuation standards, "escape clause" (emergency) actions, antidumping and countervailing duties, and other measures. Results of GATT-sponsored multilateral tariff negotiations are set forth by way of separate schedules of concessions for each participating contracting party, with the U.S. schedule designated as Schedule XX.

Officially known as "The Arrangement Regarding International Trade in Textiles," the ***Multifiber Arrangement*** (MFA) provides a framework for the negotiation of bilateral agreements between importing and producing countries, or for unilateral action by importing countries in the absence of an agreement. These bilateral agreements establish quantitative limits on imports of textiles and apparel, of cotton and other vegetable fibers, wool, man-made fibers and silk blends, in order to prevent market disruption in the importing countries—restrictions that would otherwise be a departure from GATT provisions. The United States has bilateral agreements with many supplying countries, including the four largest suppliers: China, Hong Kong, the Republic of Korea, and Taiwan.

APPENDIX B
STATISTICAL TABLES

Table B-1
Navigational and surveying instruments: Harmonized Tariff Schedule subheading; description; U.S. col. 1 rate of duty as of Jan. 1, 1993; U.S. exports, 1992; and U.S. imports, 1992

HTS subheading	Description	Col. 1 rate of duty As of Jan. 1, 1993 General	Special[1]	U.S. exports 1992	U.S. imports 1992
				Thousand dollars	
9014.10.10	Optical direction finding compasses	7.9%	Free (A,C,E,IL,J) 3.9% (CA)	23,064	639
9014.10.60	Gyroscopic direction finding compasses, other than electrical	3.9%	Free (A,C,E,IL,J) 1.9% (CA)	3,872	3,208
9014.10.70	Electrical direction finding compasses	4.9%	Free (A,C,E,IL,J) 2.4% (CA)	23,327	4,730
9014.10.90	Direction finding compasses, other than optical	5.7%	Free (A,C,E,IL,J) 2.8% (CA)	7,279	5,932
9014.20.20	Optical instruments and appliances (other than compasses) for aeronautical or space navigation	5.6%	Free (A,C,E,IL,J) 2.8% (CA)	23,071	13,456
9014.20.40	Automatic pilots for aeronautical or space navigation	4.2%	Free (A,C,E,IL,J) 2.1% (CA)	92,292	17,437
9014.20.60	Electrical instruments and appliances (other than auto pilots) for aeronautical or space navigation	4.9%	Free (A,C,E,IL,J) 2.4% (CA)	166,042	13,351
9014.20.80	Nonelectrical instruments and appliances (other than auto pilots) for aeronautical or space navigation	Free		261,833	130,933
9014.80.10	Optical navigational instruments, nesi	5.6%	Free (A,E,IL,J) 2.8% (CA)	28,942	4,798
9014.80.20	Ships' logs and depth-sounding apparatus	4.8%	Free (A,E,IL,J) 2.4% (CA)	46,751	6,792
9014.80.40	Electrical navigational instruments, nesi	4.9%	Free (A,CA,E,IL,J)	65,120	40,954
9014.80.50	Nonelectrical navigational instruments, nesi	Free		50,649	4,571
9014.90.10	Parts and accessories of automatic pilots for aeronautical or space navigation	4.2%	Free (A,C,E,IL,J) 2.1% (CA)	46,008	15,366
9014.90.20	Parts and accessories of nonelectrical instruments for aeronautical or space navigation	Free		69,013	30,002
9014.90.40	Parts and accessories of nonelectrical instruments, nesi	Free		23,005	5,414
9014.90.60	Parts and accessories of navigational instruments, other nesi	4.9%	Free (A,C,E,IL,J) 2.4% (CA)	92,018	118,607

See footnotes at end of table.

Table B-1—*Continued*

Navigational and surveying instruments: Harmonized Tariff Schedule subheading; description; U.S. col. 1 rate of duty as of Jan. 1, 1993; U.S. exports, 1992; and U.S. imports, 1992

HTS subheading	Description	Col. 1 rate of duty As of Jan. 1, 1993 General	Special[1]	U.S. exports 1992	U.S. imports 1992
				Thousand dollars	
9015.10.40	Electrical rangefinders	4.9%	Free (A,E,IL,J) 2.4% (CA)	25,979	662
9015.10.80	Rangefinders, other than electrical	5.6%	Free (A,E,IL,J) 2.8% (CA)	4,585	2,569
9015.20.40	Electrical theodolites and tachymeters	4.9%	Free (A,E,IL,J) 2.4% (CA)	2,332	27,171
9015.20.80	Theodolites and tachymeters, other than electrical	5.6%	Free (A,E,IL,J) 2.8% (CA)	412	1,000
9015.30.40	Electrical levels	4.9%	Free (A,CA,E,IL,J)	7,750	4,556
9015.30.80	Levels, other than electrical	5.6%	Free (A,CA,E,IL,J)	30,998	6,359
9015.40.40	Electrical photogrammetrical surveying instruments	4.9%	Free (A,E,IL,J) 2.4% (CA)	9,801	10,658
9015.40.80	Photogrammetrical surveying instruments, nonelectrical	6%	Free (A,E,IL,J) 3% (CA)	1,089	479
9015.80.20	Optical surveying, hydrographic, oceanographic, hydrological, meteorological or geophysical instruments	5.6%	Free (A,E,IL,J) 2.8% (CA)	19,076	2,859
9015.80.60	Seismographs	4.9%	Free (A,CA,E,IL,J)	5,553	3,121
9015.80.80	Surveying, hydrographic, oceanographic, hydrological, meteorological or geophysical instruments, nesi	4.9%	Free (A,E,IL,J) 2.4% (CA)	344,538	46,460
9015.90.00	Parts and accessories for surveying, hydrological, oceanographic, hydrological, meteorological, or geophysical instruments	[1]	Free (A,E,IL,J) [1] (CA)	235,048	40,061

[1] The rate applicable to the article of which it is a part or accessory.

Source: U.S. exports and imports compiled from data of the U.S. Department of Commerce.

Table B-2
Navigational and surveying instruments: U.S. producers' shipments, exports of domestic merchandise, imports for consumption, and apparent U.S. consumption, 1988-92

Year	Producers' shipments[1]	Exports	Imports	Apparent consumption	Ratio of imports to consumption
	Millions of current dollars				*Percent*
1988	6,404	1,204	488	5,688	9
1989	6,966	1,411	432	5,987	7
1990	7,213	1,519	479	6,173	8
1991	7,299	1,734	499	6,064	8
1992	7,200	1,709	562	6,053	9
	Millions of constant (1987) dollars[2]				*Percent*
1988	6,181	1,152	471	5,500	9
1989	6,498	1,284	421	5,635	7
1990	6,463	1,317	444	5,590	8
1991	6,325	1,433	455	5,347	9
1992	6,035	1,378	497	5,154	10

[1] Estimated by the USITC staff.
[2] Constant dollar values were computed by the USITC staff by deflating shipments by producer price index for engineering and scientific instruments (BLS commodity code 1185), and exports and imports by their respective export and import price indexes for instruments (SIC 38).
Source: Compiled from official statistics of the U.S. Departments of Commerce and Labor, except as noted.

Table B-3
Navigational and surveying instruments: U.S. imports for consumption, by principal sources, 1988-92

Source	1988	1989	1990	1991	1992
			1,000 dollars		
France	59,819	43,258	50,670	73,781	117,980
United Kingdom	94,994	85,365	105,846	105,165	115,013
Canada	118,026	104,600	93,453	86,970	82,429
Japan	76,820	63,409	69,653	60,499	65,603
Israel	39,312	49,861	53,753	55,266	50,638
Germany	22,977	16,425	22,227	21,817	24,119
Switzerland	16,908	14,968	14,243	18,362	21,910
Korea, South	3,389	839	9,347	10,526	18,277
Mexico	12,195	14,798	16,077	14,573	15,732
Finland	7,657	5,813	5,795	6,893	8,000
Norway	3,060	5,722	7,170	7,641	7,616
Taiwan	9,628	3,903	4,641	11,228	6,380
Netherlands	3,734	1,641	2,845	5,774	3,708
Sweden	5,730	6,211	8,066	5,617	3,137
All other	14,031	15,455	14,870	14,922	21,605
Total	488,281	432,266	478,658	499,036	562,147

Note.—Data before 1989 are estimated.
Source: Compiled from official statistics of the U.S. Department of Commerce, except as noted.

Table B-4
Navigational and surveying instruments: U.S. exports of domestic merchandise, by principal markets, 1988-92

Market	1988	1989	1990	1991	1992
			1,000 dollars		
Canada	159,535	206,231	255,258	195,111	195,925
United Kingdom	146,053	163,368	205,691	198,638	172,473
France	124,073	122,032	117,537	140,360	141,626
Japan	101,453	105,494	96,933	123,417	132,917
Netherlands	43,386	69,927	81,098	100,460	95,178
China	37,426	66,458	44,122	72,013	86,079
Germany	58,292	71,717	60,470	75,852	62,175
Australia	26,722	35,212	37,841	41,087	54,633
Taiwan	14,031	27,070	20,591	47,376	51,559
Singapore	29,331	25,762	42,827	57,028	45,703
Italy	50,781	56,488	48,122	46,390	41,502
Norway	19,051	16,465	20,405	77,996	37,862
Switzerland	29,536	30,692	32,569	43,828	35,321
Korea, South	26,549	29,271	55,776	49,500	31,437
All other	337,725	384,953	399,349	465,274	524,827
Total	1,203,944	1,411,142	1,518,589	1,734,328	1,709,217

Note.—Data before 1989 are estimated.

Source: Compiled from official statistics of the U.S. Department of Commerce, excepted as noted.

Table 5
Surveying and navigational instruments: U.S. exports of domestic merchandise, imports for consumption, and merchandise trade balance, by selected countries and country groups, 1988-92[1]
(Million dollars)

Item	1988	1989	1990	1991	1992
U.S. exports of domestic merchandise:					
United Kingdom	146	163	206	199	172
Canada	160	206	255	195	196
France	124	122	118	140	141
Japan	101	105	97	123	133
Netherlands	43	70	81	100	95
China	37	66	44	72	86
Germany	58	72	60	76	62
Israel	10	16	21	25	27
Mexico	19	6	16	32	57
Taiwan	14	27	21	47	52
All other	491	557	600	724	689
Total	1,204	1,411	1,519	1,734	1,709
EU-12	462	540	568	616	601
OPEC	63	61	78	117	94
ASEAN	43	47	68	88	77
CBERA	13	10	18	21	13
Eastern Europe	7	5	6	10	18
U.S. imports for consumption:					
United Kingdom	95	85	106	105	115
Canada	118	105	93	87	82
France	60	43	51	74	118
Japan.	77	63	70	60	66
Netherlands	4	2	3	6	4
China	1	2	3	3	5
Germany	23	16	22	22	24
Israel	39	50	54	55	51
Mexico	12	15	16	15	16
Taiwan	10	4	5	11	6
All other	50	47	57	61	76
Total	488	432	479	499	562
EU-12	189	154	186	212	269
OPEC	0	0	0	0	0
ASEAN	2	3	2	4	4
CBERA	0	0	0	0	0
Eastern Europe	0	0	0	0	0
U.S. merchandise trade balance:					
United Kingdom	51	78	100	94	57
Canada	42	101	162	108	114
France	64	79	67	66	23
Japan	24	42	27	63	67
Netherlands	39	68	78	94	91
China	36	64	41	69	81
Germany	35	56	38	54	38
Israel	-29	-34	-33	-30	-24
Mexico	7	-9	0	17	41
Taiwan	4	23	16	36	46
All other	441	510	543	663	613
Total	716	979	1,040	1,235	1,147
EU-12	273	386	382	404	332
OPEC	63	61	78	117	94
ASEAN	41	44	66	84	73
CBERA	13	10	18	21	13
Eastern Europe	7	5	6	10	18

[1] Import values are based on customs value; export values are based on f.a.s. value, U.S. port of export. U.S. trade with East Germany is included in "Germany" but not "Eastern Europe".

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

APPENDIX C
GLOSSARY OF TERMS

Accelerometers: Instruments that are used to determine the maximum limit of inert forces produced by acceleration during high speed evolutions.

Acceleration indicator: A fundamental measurement required for the operation of the inertial navigator.

Air position indicator: An airborne computing system, which presents a continuous indication of the aircraft position on the basis of aircraft heading, airspeed, and elapsed time.

Air speed head: An instrument or device, usually a pilot tube mounted on an aircraft for receiving the static and dynamic pressure of air used by the airspeed indicator.

Air speed indicator instrument: An instrument that computes and displays the speed of an aircraft relative to the air mass in which the aircraft is flying.

Aircraft flight instruments: Electronic, gyroscopic and other instruments for detecting, measuring, recording, telemetering, processing, or analyzing different values or quantities (aircraft's speed, altitude, attitude, heading, conditions, etc.) in the flight of an aircraft.

Alidades: A topographic surveying and mapping instrument with a telescope and graduated vertical angle that gives the direction of objects from a plane-table station.

Altimeter: An instrument used to determine the altitude of an object with respect to a fixed level, such as sea level.

Anemograph: An instrument used for recording a continuous log of time variation of wind.

Anemometer: An instrument used for indicating and measuring wind speed.

Attitude: The position of orientation of an aircraft, spacecraft and so on, either in motion or at rest as determined by the relationship between its axes and some reference line or plane or some fixed system of reference axis.

Attitude control: A device or system that automatically regulates and corrects attitude, especially of a pilotless vehicle.

Automatic pilot: Also called autopilot, this system temporarily replaces the pilot by controlling the equilibrium and flight of the aircraft in accordance with a pre-established setting. It consists chiefly of direct-operated or servo-motor controls (usually hydraulic motors which replace the pilot's movements) and an automatic acting apparatus (high speed gyroscopes) that coordinate instrument readings and the action of the servo-motors. Autopilot, in marine navigation, controls a ship's rudder in relation to the readings of a gyroscopic compass.

Ceilometer: Used for automatically measuring and recording cloud height.

Climbing and diving speed indicator: Shows the vertical speed of descent or ascent of an aircraft by means of a differential pressure gauge.

Course recording or directional finder kit: Provides an accurate record of the course and distance traveled during a ship's journey.

Direction finding compass: Consists of all types of compasses, from magnetic to gyroscopic, and from simple types used by hikers and cyclists to those specialized for use in mining and navigation.

Driftmeter: An instrument for measuring drift angle. Drift is defined as deviation of an aircraft, spacecraft, or marinecraft from a planned course especially as a result of wind, ocean current, or other disturbance in the medium of travel.

Echo Sounding equipment: A device, which determines the depth of the water by measuring the time interval between emission, sonic or ultrasonic signal, and the return of its echo from the sea bottom.

Geodesy: The science dealing with the determination of the shape, size area, and curvature of the earth, with the precise mapping of continents or other large tracts.

Geophones: An electronic receiver designed to pick-up seismic vibrations.

Geophysics: The physics of geologic phenomena, including fields such as meteorology, oceanography, geodesy, and seismology.

Global Positioning System (GPS): GPS was developed by the U.S. Department of Defense to simplify accurate navigation. GPS uses satellites and computers to compute positions anywhere on earth. GPS receivers have a wide range of military and commercial applications. The uniquely designed multi-channel receivers, integrated with inertial reference units, guarantee optimum accuracy for high performance aircraft. Translator-based systems continue to prove their value in missile tracking. The commercial applications of GPS cover surveying, mapping, photogrammetry, resource management, and related areas. Accurate information is provided on a full range of display types in spaceborne, airborne, shipboard, and land-based applications.

Gravimeter: A highly sensitive weighing device used for relative measurement of the force of gravity by detecting small weight differences of a constant mass at different points of the earth.

Gyrocompass: A north-seeking form of gyroscope used as a vehicle's or craft's directional reference. Also called a gyroscopic compass.

Gyropilot: A trade name for a type of autopilot used in guided missiles.

Gyroscope: An instrument that maintains an angular reference direction by virtue of a rapidly spinning heavy mass; all applications of the gyroscope depend on a special form of Newton's second law, which states that a massive, rapidly spinning body rigidly resists being disturbed and tends to react to a disturbing torque by precessing (rotating slowly) in a direction at right angles to the direction of torque. Also known as gyro.

Hydraulics: The branch of science and technology concerned with the mechanics of fluids, especially liquids.

Hydrometer: A direct-reading instrument for indicating the density, specific gravity, or some similar characteristics of liquids.

Inclinometer: An instrument showing the inclination of an aircraft or ship relative to the horizontal.

Inertia: The tendency of a body at rest to remain at rest or of a body in motion to stay in motion in a straight line unless disturbed by an external force.

Inertial guidance: Guidance by the use of inertial navigation system; guidance by means of self-contained automatically controlling devices that respond to inertial forces; guidance in which gyroscopic and accelerometer data are used by a computer to maintain a predetermined course.

Inertial Navigation System (INS): Considered the heart of the modern aircraft, INS completely controls navigation, providing steering signals to the autopilot and pilot instruments. The INS does this without reference to radio signals from the ground, and can navigate over water to the remotest parts of the world.

Integrated circuit: A circuit in which many elements are fabricated and interconnected by a single process, as opposed to a nonintegrated circuit in which transistors, diodes, resistors, etc, are fabricated separately and then assembled.

Levels: Used to ascertain whether a surface is horizontal, which when equipped with a telescope is used in surveying to compute the difference in elevation between two points.

Logs: An instrument for measuring the speed or distance or both traveled by a vessel.

Machmeter: An instrument used to measure the ratio between the air speed and the local speed of sound.

Magnetometer: An instrument for measuring magnitude of a magnetic field, such as the earth, and is used in prospecting for ores, oil, and so forth.

Marine navigation: The process of directing the movement of watercraft from one point to another.

Meteorology: The science concerned with the atmosphere and its phenomena; the meteorologist observes the atmosphere's temperature, density, winds, clouds, precipitation, and other characteristics and aims to account for its observed structure and evolution (weather, in part) in terms of external influence and the basic law of physics.

Navigating sextant: A double reflecting instrument used in navigation, for measuring angles, primarily altitudes of celestial bodies; differs from hydrographic sextant.

Nephoscope: An instrument used for determining the direction of cloud motion.

Photogrammetry: The science of making reliable measurements by the use of photographs and especially aerial photographs (as in surveying).

Rain gauge: Used for measuring precipitation.

Range finder: An instrument used to determine the distance between the instrument and a given object.

Seismograph: An instrument used for recording vibration in the earth.

Seismometer: An instrument used for detecting movement in the earth.

Solid-state electronics: Designation used to describe devices and circuits fabricated from solid materials such as semiconductors, ferrites, or films, as distinct from devices and circuits making use of electron tube technology.

Sounding leads: Determines the depth of the water and the nature of the sea bed.

Sunshine recorder: Used for recording duration of sunshine without regard to intensity.

Surveying: A branch of applied mathematics that teaches the art of determining the areas of any portion of the earth's surface, the length and direction of the bounding lines, and the contour of the surface and of accurately delineating the whole on paper.

Tachometer: An instrument used to determine speed, especially the rotational speed of a shaft.

Tachymeter: Similar to a theodolite (incorporating a range finder), which measures distances, angles, and differences of elevation from any given point by telescopic observation.

Theodolite: An instrument elctronically operated which measures horizontal and vertical angles with a small telescope that can move in horizontal or vertical planes.

Transit: An instrument similar to a theodolite, but is mechanically operated and therefore less accurate, and is used in all types of construction and engineering surveys (transits equipped with precision optics are used for more accurate results).

Turning and banking indicator: An instrument which works on gyroscopic principles, the former indicating the angle of the aircraft by reference to the transversal or longitudinal axis and the latter by reference to the vertical axis.

Ultrasonic sounding or detecting equipment: For example asdic, sonar or the like, used for normal sounding operations, for mapping the sea bed, for detecting submarines, wrecks, shoals of fish etc.

Wind transmitter: An instrument used for sensing wind velocity.