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THE GLOBAL POSITIONING SYSTEM: GLOBAL DEVELOPMENTS AND OPPORTUNITIES

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EXECUTIVE SUMMARY

Background

- The Global Positioning System (GPS), which is the world's most accurate method of navigation, was conceived to enhance navigation accuracy for U.S. military forces during the early 1970s. Since 1984, the GPS has found application in a myriad of systems–from automotive monitors advising drivers of the locations of hotels and restaurants to guidance systems which allow bombs and missiles to make direct hits on targets. Of the two global satellite navigation systems currently operating, the GPS has gained preference in most international markets.

- The operation of the GPS relies on signals received from 24 NAVSTAR satellites, each of which orbit in space about 11,000 miles above the earth's surface. These satellites revolve around the earth twice a day (or once every 12 hours) and transmit signals to GPS receivers positioned on or above the earth's surface. GPS receivers, which process data emitted from GPS satellites, compare the time the satellite signal was transmitted with the time the signal reaches the receiver. The receiver is then able to determine its precise distance from the satellite.

U.S. Government Policies

- On March 29, 1996, the President of the United States approved a comprehensive national policy on the future management of the GPS and related U.S. Government augmentations. The policy seeks to enhance the country's productivity and economic competitiveness while protecting U.S. national security and foreign policy interests. Based on recommendations from the Departments of Defense, Transportation, and State, the policy requires the President to make annual determinations regarding certain GPS operational functions.

Global Industry and Markets

- Japan, followed by the United States, is the principal global supplier of GPS-related products. In 1998, Japan accounted for 47 percent ($2.0 billion) of the global GPS market, whereas the United States represented 32 percent ($1.4 billion). Eighteen percent ($784 million) of the remaining market share was largely accounted for by European countries. Although the United States and Japan are comparable with respect to GPS manufacturing technology, the United States is generally believed to enjoy a slight lead in higher value-added products with an advanced software content.

- Global demand for GPS products grew significantly during 1997-2001, with total global sales of such products increasing by 275 percent to $10.7 billion. Car navigation, which is the largest international market for the GPS, accounted for 34 percent ($3.6 billion) of total global GPS sales in 2001. The consumer sector, which is the second largest market, represented 22 percent ($2.4 billion) of such sales. The third largest market sector, surveying

and mapping, accounted for 16 percent ($1.7 billion) of global sales in 2001**.** Rising sales were recorded in all market sectors during 1997-2001, and are projected to continue upward during 2002-03.

Global Developments

- GPS receivers are available at a fraction of the price of a decade ago. Current prices of GPS receivers may range from approximately $100 for a small, one-hand operated 12 channel receiver to $2,000 for a deluxe color automobile GPS receiver capable of displaying routes and giving turn-by-turn directions and voice prompts to drivers. Prices of receivers designed for avionics, military equipment, and other sophisticated applications may by higher.

- Car navigation systems are continuing to grow in popularity in Asia, with Japan leading in output (about 2.2 million units shipped in 2001) and product innovation. While CD-ROMs have been an essential software for car navigation, DVD-ROMs are now being used extensively.

- Certain European countries, especially in Scandinavia, are taking a more entrepreneurial approach to GPS technology by focusing on immediate applications in land survey, vehicle tracking, geographic information systems, and coastal navigation. In some instances this has led to the acquisition of U.S. firms or technology, such as the transfer of the Magnavox's GPS product line to the Swiss firm Leica.

Forecast

- Rapidly expanding GPS technology will continue to provide both U.S. and foreign users with tremendous capabilities in consumer, commercial, industrial, and military applications. Worldwide sales of GPS products are projected to total nearly $16.5 billion by 2003, with U.S.-made products accounting for 30 percent ($4.9 billion) of those sales. The next generation of GPS satellites, which are scheduled to be launched by 2005, will have increased flexibility to accommodate new augmentations and auxiliary payloads, and larger processor and memory capacity.

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Introduction[1]

The Global Positioning System (GPS), which originated in the United States in the late 1970s, is widely recognized as the world's most accurate method of navigation. The GPS is also well known for precision time signals that synchronize global information network systems utilizing fiber optics, satellites, radio, coaxial cable, and copper wire.[2] Being an embedded technology, the GPS is not generally visible in personal computers, automobiles, surveying equipment, weather tracking systems, military munitions, electronic receivers, and other products incorporating the technology. Most individuals, for example, are unaware that data received from domestic and international financial institutions are dependent on the accurate synchronization of data streams provided by the GPS.[3]

Since its creation by the U.S. Department of Defense almost 25 years ago (at a cost of about $12 billion)[4] and its emergence into broader public awareness subsequent to becoming available for civilian use in 1984, the GPS has evolved into a wide range of technologies that have provided an enormous range of benefits for consumers. For example, numerous police, fire, and emergency medical services have incorporated the GPS into vehicles to ensure the quickest possible response in life-or-death situations. Automobile manufacturers offer GPS-aided map displays that give directions to drivers on display screens and through synthesized voice instruction. The GPS has proven to be invaluable to hikers, golfers, cyclists, and other recreational users by providing precise directions. The system is likely to be incorporated into cellular phones to pinpoint location in emergency situations. Aviation, mining,

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[1] The views expressed in this report are those of the author. They do not necessarily represent the views of the U.S. International Trade Commission as a whole or any individual Commissioner. Please direct all correspondence to James M. Brandon, International Trade Analyst, Office of Industries, U.S. International Trade Commission, 500 E Street, SW, Washington, DC 20436, telephone 202-205-3433, fax 202-205-2018, email: *brandon@usitc.gov*. The invaluable assistance provided by Monica Reed and Wanda Tolson during the preparation of the report is gratefully acknowledged.

[2] U.S. Department of Commerce, International Trade Administration (ITA), Office of Telecommunications, *Global Positioning System, Market Projections and Trends in the Newest Global Information Utility, Executive Summary,* p. 11.

[3] Ibid.

[4] GPS, *A Guide to the Next Utility,* "GPS - A Global Navigation System Everyone Can Use," Trimble Navigation, 1989, p. 7.

construction, and other commercial and industrial activities have been enhanced by the precise positioning provided by the GPS. Although privacy concerns could present a significant barrier regarding the monitoring of individual activities, the GPS can be used to determine shopping patterns and customer profiles to improve sales and inventory management.

Expanding use and popularity have caused the GPS to become an information technology that is part of the emerging global information infrastructure.[5] The Information Technology Agreement (ITA), which was finalized during meetings held in Singapore by the World Trade Organization in December 1996, requires signatory countries to eliminate tariffs on a specified list of information technology products by January 1, 2000. These products include computer hardware and peripherals, telecommunications equipment, computer software, semiconductor manufacturing equipment, analytical instruments, and semiconductors and other electronic components.[6] Although the GPS equipment is not included in the ITA when incorporated into information technology products that are in the Agreement, it will be duty free. Thus, demand for GPS is likely to benefit from increased demand for cellular phones, satellite network equipment, and other ITA products incorporating GPS technology.

Japan, followed by the United States, is the principal global supplier of GPS-related products. Although the United States and Japan are comparable with respect to GPS manufacturing technology, the United States enjoys a slight lead in higher value-added products with an advanced software content.[7] The remaining global market share was largely accounted for by European countries. Although the proliferation of hundreds of stand-alone GPS applications have had an enormous beneficial impact on the global economy, future economic benefits are virtually unlimited as new applications continue to be created.

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[5] Ibid.
[6] Found at *http://www.wto.org/english/tratop_e/inftec_e/itaintro_e.htm.,* retrieved Aug. 6, 2002.
[7] U.S. Department of Commerce, ITA, Office of Telecommunications, *Global Positioning System, Market Projections and Trends in the Newest Global Information Utility, Executive Summary,* p. 27.

This report provides a description of the evolution of the GPS; the operation process; U.S. policy addressing the GPS; the U.S. industry; global sales and principal markets; global developments and opportunities; other satellite navigation systems; and an outlook of GPS expansion during the next several years.

The Evolution of GPS

During the early 1960s the U.S. Department of Defense (DoD) determined that a global, all-weather navigation system based on accurate satellite positioning would be more effective than the radio-based navigation systems used during that period. Therefore, the U.S. Navy and Air Force were commissioned to investigate the possibility of placing high-frequency radio transmitters in space by use of satellites.[8] Through the combined efforts of these military departments, the first GPS satellite (Block 1) incorporating high-frequency radio transmitters was developed. This satellite was initially launched in 1978 and was followed by 9 additional Block 1 launchings for a total of 10 orbiting satellites by year-end 1988.[9]

Although Block 1 satellites (which were the first application of satellite navigation)[10] were developed under contracts with the DoD and used strictly for national defense, a steady rise in civil demand resulted in the GPS being made available for civilian use in 1984. Because the Block 1 satellites were incapable of handling the growing demand, which resulted from the proliferation of more affordable GPS receivers, 24 new GPS Block II satellites were developed and launched during 1989-94.

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[8] The genesis of satellite use began in 1957 when the former Soviet Union launched the Sputnik satellite.

[9] ENMG 604: Innovation and Technology Management: Desk Research - *The Evolution of Global Positioning System Technology*, Aaron J. McLeod, Master of Engineering Management, pp. 5-6.

[10] The former Soviet Union is the only other country to launched a satellite navigation system. That system, which is known as GLONASS and launched in 1982, is also intended for military and civilian use. Unlike the GPS which operates from 24 orbiting satellites, GLONASS receives signals from 10 satellites.

These GPS NAVSTAR[11] satellites are currently being used to provide 24-hour global coverage for both military and civil applications.[12]

The Operation Process

The operation of the GPS relies on signals received from the 24 NAVSTAR satellites, each of which orbit in space about 11,000 miles above the earth's surface. The satellites are positioned so that at least four satellites are always above the earth's horizon from every point on earth.[13] GPS satellites revolve around the earth twice a day (or once every 12 hours) and transmit signa1s to GPS receivers[14] positioned on or above the earth's surface. GPS receivers, which process data emitted from GPS satellites, compare the time the satellite signal was transmitted with the time the signal reaches the receiver. The receiver is then able to determine its precise distance from the satellite.

By determining the distances from three satellites (a method known as triangulation), the GPS receiver determines the user's position and reveals it on a display screen. A GPS receiver must use signals from at least three satellites to calculate two dimension positions (latitude and longitude) and track movement. By using signals of four or more satellites, a receiver can determine the user's three dimension position (latitude, longitude, and altitude). Once the user's two or three dimension position has been determined, other information such as speed, bearing, tracking, distance to destinations, and time of sunrise or sunset can be determined.[15]

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[11] NAVSTAR is an acronym for Navigation Satellite Timing and Ranging. The system is owned by the United States and managed by the Department of Defense.

[12] ENMG 604: Innovation and Technology Management: Desk Research - *The Evolution of Global Positioning System Technology*, Aaron J. McLeod, Master of Engineering Management, p. 6.

[13] U.S. Department of Commerce, ITA, Office of Telecommunications, *Global Positioning System, Market Projections and Trends in the Newest Global Information Utility,* p. 8.

[14] A GPS receiver consists of the following basic components: an antenna with an optional pre-amplifier; a radio-frequency and intermediate-frequency section; a signal tracker/coordinator section; and a microprocessor that controls the receiver, processes the signals, and computes the receiver's coordinates. The receiver also includes a power supply and memory devices for storing instructions and data. Found at *http://www.findarticles.com/cf_dls/m0BPW/4_11/62296969/plarticle.jhtml*, retrieved Aug. 12, 2002.

[15] GARMIN: What is GPS? Found at *http://www.garmin.com/about* GPS/, retrieved Sept. 4, 2002.

GPS satellites are built to last about 10 years,[16] after which they are replaced with new satellites. GPS satellites are powered by solar energy and are capable of operating from batteries if the solar energy fails because of an eclipse or malfunction related to solar power. Precise clocks are used to assure that satellites and GPS receivers are synchronized. Each satellite has four atomic clocks, while GPS receivers have traditional clocks. Even with atomic clocks some errors, such as orbital errors or ionospheric and tropospheric delays, are inevitable.[17] By using established models of the atmosphere, however, GPS receivers can minimize errors. A master control ground station located at Schriever Air Force Base in Colorado and ground monitoring stations located at Air Force bases in Hawaii (eastern Pacific Ocean), Diego Garcia (Indian Ocean), Kwajalein Atoll (western Pacific Ocean), and Ascension Island (central Atlantic Ocean are also essential components of the GPS operation.

The GPS provides two levels of service: (1) Precise Positioning Service (PPS) and (2) Standard Positioning Service (SPS).[18] The PPS is a restricted highly accurate positioning, velocity, and timing service designed primarily for the U.S. military/government and foreign allies. This service provides a positioning accuracy of at least 22 meters horizontally and 27.7 meters vertically, with a time transfer accuracy to the Universal Time Coordinated (UTC)[19] within 200 nanoseconds.[20] The SPS was originally designed to provide civil users with a less accurate positioning capability than PPS through the use of a technique known as Selective Availability (SA). The SPS provides a predictable positioning accuracy of 100 meters horizontally and 156 meters vertically. The SPS has a time transfer accuracy to the UTCwithin 340 nanoseconds.[21]

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[16] GARMIN: What is GPS? Found at *http://www.garmin.com/about* GPS/, retrieved Sept. 4, 2002.

[17] Ionospheric and tropospheric delays reflect a slowdown of signals as they pass through the atmosphere. Orbital errors are known as ephemeris errors, which are inaccuracies of the satellite's reported location.

[18] NAVSTAR GPS Operations, GPS Capabilities, found at *http:tycho.usno.navy.mil/gpsinfo.html,* retrieved Sept. 4, 2002.

[19] Satellite images and weather maps generally show the date and time the data were recorded. Since these images and maps cover regions that span more than one time zone, an internationally agreed-upon time referred to as Universal Time Coordinated (formerly Greenwich Mean Time) was adopted.

[20] A nanosecond is one-billionth of a second.

[21] NAVSTAR GPS Operations, GPS Capabilities, found at *http:tycho.usno.navy.mil/gpsinfo.html*, retrieved Sept. 23, 2002.

U.S. Policy Addressing GPS[22]

On March 29, 1996, the President of the United States approved a comprehensive national policy on the future management of the GPS and related U.S. Government augmentations. The policy seeks to enhance the country's productivity and economic competitiveness while protecting U.S. national security and foreign policy interests. Certain Federal agencies have roles and responsibilities to encourage the acceptance and integration of GPS for peaceful purposes, persuade private sector investment, promote safety and efficiencies in transportation, mining, and other fields, and ensure the overall viability of the GPS. The roles and responsibilities of these agencies are shown in the following tabulation:

[22] *U.S. Global Positioning System Policy*, found at *http://www.ostp.gov/NSTC/html/pdd6.html,* retrieved Sept. 26, 2003.

U.S. Department of Defense
• Acquire, operate, and maintain the basic GPS function.
• Maintain a Standard Positioning Service (as defined in the Federal Radio Navigation Plan and the GPS Standard Positioning Service Signal Specification) that will be available on a continuous, worldwide basis.
• Maintain a Precise Positioning Service for use by the military and other authorized users.
• Cooperate with the Director of Central Intelligence, the Department of State, and other appropriate departments and agencies to assess the national security implications of the use of GPS, its augmentations, and alternative satellite-based positioning and navigation systems.
• Develop measures to prevent the hostile use of GPS and its augmentations to ensure that the United States retains a military advantage without unduly disrupting or degrading civilian uses.
U.S. Department of Transportation
• Serve as lead agency within the U.S. Government for all Federal civil GPS matters.
• Develop and implement U.S. Government augmentations to the basic GPS for transportation applications.
• In cooperation with the Departments of Commerce, Defense and State, take the lead in promoting commercial applications of GPS technologies and the acceptance of GPS and U.S. Government augmentations as standards in domestic and international transportation systems.
• In cooperation with other departments and agencies, coordinate U.S. Government-provided GPS civil augmentation systems to minimize cost and duplication of effort.
U.S. Department of State
• In cooperation with appropriate departments and agencies, consult with foreign governments and other international organizations to assess the feasibility of developing bilateral or multilateral guidelines on the provision and use of GPS services.
• Coordinate the interagency review of instructions to U.S. delegations to bilateral consultations and multilateral conferences related to the planning, operation, management, and use of GPS and related augmentation systems.
• Coordinate the interagency review of international agreements with foreign governments and international organizations concerning international use of GPS and related augmentation systems.

The Policy addressing the GPS requires the President is required to make annual determinations on the continued use of SA, beginning in 2000. To support these determinations, the Secretary of Defense, in cooperation with the Secretary of Transportation, the Director of the Central Intelligence Agency, and heads of other appropriate departments and agencies are to provide assessments and recommendations to the President. These recommendations are provided through the Assistant to the President for National Security Affairs and the Assistant to the President for Science and Technology.

On May 1, 2000, the President of the United States directed the U.S. Department of Defense (DOD) to discontinue the use of SA, thereby allowing civilian users to obtain satellite signals with PPS accuracy. Terminating SA, however, will not hamper the United States' efforts to thwart or guard against terrorism or subversive use of the GPS, since the DOD has the ability to deny or degrade signals on a regional basis when the country's national security is threatened.[23]

The U.S. Industry[24]

There were approximately 300 companies, including several foreign affiliated operations, manufacturing satellite-based GPS systems in the United States during 2001. These companies ranged in size from small operations specializing in a single or few GPS products to large, vertically integrated multinational corporations producing a diverse line of products. The industry is generally comprised of commercial electronics firms; aviation suppliers and manufacturers; military suppliers; automotive electronics suppliers; and various consumer product manufacturers (table 1). U.S. producers of GPS products generally supply domestic and international markets through retail outlets, distributors, affiliated international sales, and service network systems. In addition to their home-based operations, several large U.S. GPS producers maintain manufacturing facilities abroad.

[23] Ibid.

[24] The U.S. industry is largely comprised of companies manufacturing GPS receivers (both hand-held and stationary) and other products incorporating GPS technology.

Table 1
Major global producers of GPS products; markets served; and location of producers' headquarters

Producers	Markets[1]	Headquarters
Ashtech (Thales Navigation)	Marine; GIS[2]	Santa Clara, CA
Atomic GPS	Car navigation	Paola, KS
Furuno USA	Marine	Nishinomiya, Japan
Garmin International	Car navigation; marine; aviation; consumer	Cayman, Islands
Honeywell	Military; aviation	Minneapolis, MN
JRC Marine	Marine	Seattle, WA
Koden Electronics	Marine	Tokyo, Japan
Krupp Fordertechnik	Marine	Essen, Germany
Lieca Geosystems, Inc.	Surveying/mapping/GIS; military	Heerbrugg, Switzerland
Lowrance Electronics, Inc.	Marine; consumer	Tulsa, OK
Magellan Systems Corp.	Marine; consumer	San Dimas, CA
Motorola, Inc.	Car navigation	Schaumburg, IL
Raytheon	Marine; military	Lexington, MA
Rockwell Collins, Inc.	Military; aviation	Cedar Rapids, IA
Sperry Marine	Marine; military	Charlottesville, VA
STN Atlas Marine Electronics	Marine	Hamburg, Germany
Trimble Navigation Ltd.	Surveying/mapping/GIS; tracking/machine control	Sunnyvale, CA

[1] Markets shown may not represent all markets serviced by specified producer.
[2] Geographic Information System.

Source: U.S. Department of Commerce, The International Trade Administration, Office of Telecommunications, Global Positioning System, Market projections and Trends in the Newest Global Information Utility, p. 19 and information obtained from the Internet and trade journals.

The U.S. GPS industry is a global leader in terms of advanced technology, product design, and levels of production. The industry leadership largely reflects a significant level of capital investment expended by U.S. producers on research and product development,[25] coupled with ongoing U.S. advancements in complementary products (i.e., wireless communication systems, semiconductors, and space communications).

Another enhancement of the global competitiveness of the U.S. industry stems from the concerted efforts of U.S. Federal agencies to establish programs designed to improve and maintain effective navigation systems. Intense competition exists between U.S. and foreign GPS producers, most of whom have invested heavily in product research and development. Regardless of the product origin, however, a producer's competitiveness is generally influenced by the ease at which products can be used, physical

[25] Industry sources indicate that research and development expenditures totaled an estimated $150 million in 2001.

characteristics (including size, weight, and power consumption), product reliability, price, vendor reputation, and other factors.

Global Demand, Sales, and Principal Markets

There are basically two factors driving the growing demand for GPS application development.[26] First, the continuing decline in the cost and size of electronics hardware, which is especially important in the consumer (retail) market. In 1983, for example, the first commercial GPS receiver cost over $150,000 and weighed more than 100 pounds. The following year, a portable receiver was introduced that weighed 40 pounds and cost about $40,000. Current prices of GPS receivers may range from approximately $100 for a small, one-hand operated 12 channel receiver to $2,000 for a deluxe color automobile GPS receiver capable of displaying routes and giving turn-by-turn directions and voice prompts to drivers.[27] Prices of receivers designed for avionics, military equipment, and other sophisticated applications are generally higher. The second factor involves the software embedded in GPS applications. The ultimate value of the GPS is in the information recovered from GPS signals. In commercial markets, increased software content is the fundamental driver that enhances sales and stimulates product research. In the consumer market, however, software content is less of a cost factor which results in reduced prices at the retail levels.[28]

Global demand for GPS products grew significantly during 1997-2001, with total global sales of such products increasing by 275 percent to $10.7 billion (table 2) despite significant declines in unit

[26] U.S. Department of Commerce, ITA, Office of Telecommunications, *Global Positioning System, Market Projections and Trends in the Newest Global Information Utility,* p. 40.
[27] GPS Receivers, found at *http://GPSNow.com/,* retrieved Oct. 3, 2002.
[28] U.S. Department of Commerce, ITA, Office of Telecommunications, *Global Positioning System, Market Projections and Trends in the Newest Global Information Utility,* p. 41.

Table 2
Global GPS Sales by Market Segment, 1997-2001, and projected sales, 2002-2003

Market Segment	1997	1998	1999	2000	2001	2002	2003
				Million dollars			
Car navigation	900	1,600	2,300	2,900	3,600	4,200	4,700
Consumer	560	850	1,200	1,800	2,400	3,100	3,800
Survey/mapping/GIS	530	735	960	1,300	1,740	2,320	3,120
Tracking/machine control	280	450	720	1,100	1,650	2,300	3,000
Aviation	160	220	300	380	500	600	710
Military	90	100	110	130	145	160	185
Other[1]	330	400	475	565	660	765	900
Total	2,850	4,355	6,065	8,175	10,695	13,445	16,415

[1] Include OEM and marine.

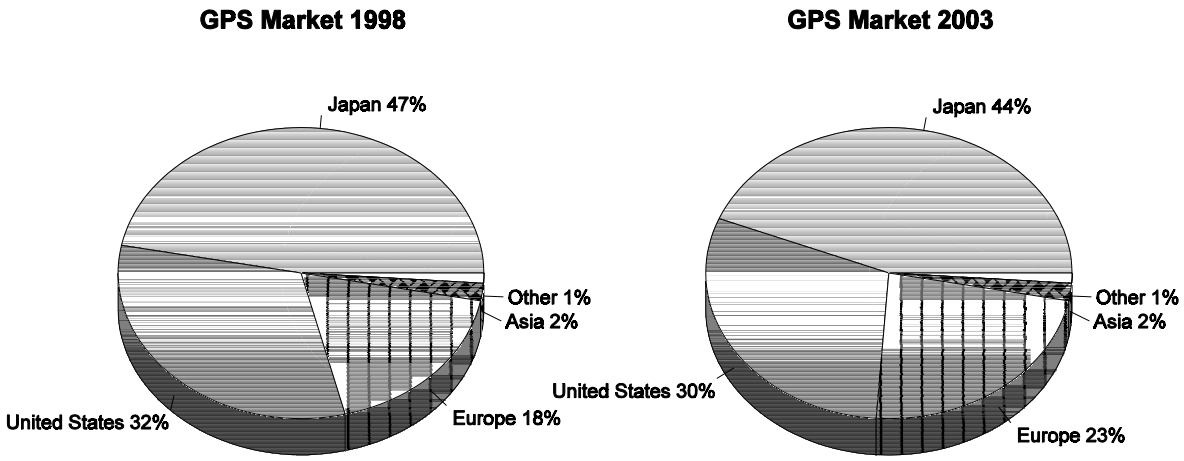
Source: U.S. Department of Commerce, The International Trade Administration, Office of Telecommunications publication, *Global Positioning System, Market Projections and Trends in the Newest Global Information Utility,* p. 23.

prices. Rising sales, which were recorded in all market sectors, are projected to continue upward during 2002-03. The growth rate of GPS sales during 1997-2001 was far greater than the growth rates recorded by the automotive and consumer electronics industries, which reflects a higher level of demand for the increasingly popular GPS related products. The automotive and consumer electronics industries experienced rises in sales of 13 percent and 28 percent, respectively during 1997-2001.

As shown in figure 1, Japan, followed by the United States, is the principal global supplier of GPS-related products. In 1998, Japan accounted for 47 percent ($2.0 billion) of the global GPS market, whereas the United States represented 32 percent ($1.4 billion). The bulk, 18 percent ($784 million), of the remaining market share was accounted for by European countries.

Since a relatively large volume of the GPS products supplied by Japan and the United States during 1997-2001 met the increasing home-market demand for car navigation systems (a demand that softened during the latter part of the period), a saturation in the market segment has increased and is expected to cause Japan and the United States to lose market share to Europe by 2003.

Figure 1
Global GPS market share projections



Source: U.S. Department of Commerce, The International Trade Administration, Office of Telecommunications, *Global Positioning System, Market Projections and Trends in the Newest Global Information Utility, p. 26.*

Car Navigation

Car navigation, which is the largest international market for the GPS, accounted for 34 percent ($3.6 billion) of total global GPS sales in 2001and is expected to make up 29 percent ($4.7 billion) of global sales in 2003 (table 2). This increasingly popular navigation system utilizes a combination of the following: (1) highly detailed CD-ROM database, which includes an electronic map and directory of potential travel destinations; (2) GPS receiver that continuously receives GPS satellite signals as the car travels; (3) monitor that displays electronic maps, a system menu, and other useful information; (4) CD-ROM drive that reads the database and electronic map features stored on the CD-ROM; and (5) central processing unit that ingests information received from each navigation component to determine locations, calculates routes, and displays the car's position on the monitor.[29]

Although the United States is the world leader in the development and application of total GPS technology, Japan leads in the sales of navigation systems for automobiles. In Japan, 15 to 20 percent of the new car buyers purchase cars with GPS technology and about 5 to 10 percent of buyers in Europe purchase cars with navigation capabilities.[30] Only 2 percent of the new car buyers in the United States purchase automobiles with car navigation capabilities. With respect to price, the typical car navigation system in the United States lists for approximately $1,500 to $2,000. Prices of car navigation systems in Japan and Europe, however, are lower.[31]

Innovations in electronics, especially wireless systems, have generated significant interest in the GPS-driven intelligent highway system. Data acquisition for this system, which is under the authority of the Intelligent Transportation System (ITS) of the U.S. Department of Transportation, will be used in

[29] *What is GPS*, found at *http://www.zenrin.com/gps_body.html*, retrieved Oct. 15, 2002.
[30] Scientific American: *Getting There*, Vol. 286, Issue 5, May 2002.
[31] Ibid.

different types of sensors to detect, among other things, weather conditions and the presence and quantity of traffic.[32] Control centers would then develop the wireless messages for transmission to display signs or to supply adaptive control measures to traffic signals, ramp meters, and to individual vehicles. Currently, induction loop detectors and video cameras are widely used to control traffic and adherence to traffic signals along highways and at intersections. These devices will remain in effect, but other types of information gathering devices will be used to effect an intelligent highway system.[33] An essential component of the intelligent transportation system will be the GPS receiver, which will supply location information transmitted by cellular telephone.

Consumer

The consumer/recreation sector is the second largest market for GPS applications, with sales of GPS receivers used in this sector accounting for 22 percent ($2.4 billion) of total global GPS sales in 2001. Global sales in this sector are expected to account for 23 percent ($3.8 billion) in 2003. In the United States there are an estimated 40 million users of consumer GPS equipment.[34] Among these users are fishermen, campers and hikers, hunters, boaters, and other outdoor recreational participants. The consumer market is characterized by high demand elasticity.[35] Retail prices of GPS receivers in this market have declined from about $150 to $100 since 1997. These price declines have resulted in increased sales and economy of scale for producers of GPS receivers.

The use of GPS technology in the consumer market has generated numerous benefits for users, especially recreational users. Golf carts equipped with GPS monitors allow golf course managers to monitor activity on the golf course and golfers to improve play performance by minimizing guess-

[32] Electronic Design: *An Evolving ITS Paves the Way for Intelligent Highways*, Vol. 49, Issue 1, Jan. 8, 2001.
[33] Ibid.
[34] Ibid.
[35] Ibid.

work.[36] Golfers see a layout of a specific hole with details or tips on how to best play the hole. The GPS monitor also provides electronic information regarding yardage to the hole for particular shots.[37] Since golf cart rentals typically generate about 40 percent of the revenue of a golf course, the premium charged for GPS-equipped golf carts has a positive impact on the financial status of operations.

Another example of consumer GPS is its use in the enhancement of realistic computer games such as Microsoft's Precision Racing Indy Car Simulator. GPS survey equipment was used to map major U.S. automobile racetracks, including features such as pavement, curbs, fence lines, and pits. These data were incorporated into game software to recreate each course in three-dimensional simulations, which are accurate to a few centimeters.

Survey/mapping/GIS

The survey/mapping/GIS market, which accounted for 16 percent ($1.7 billion) of total sales in 2001 and an expected 19 percent ($3.1 billion) of such sales in 2003, has traditionally relied upon a variety of surveying equipment and methods (compass/chain and theodolites/EDMs) to create maps and to mark and locate land ownership boundaries.[38] With the introduction of the GPS, however, the practice of surveying and mapping has been revolutionized. Prior to the GPS, for example, surveying was limited to measurements that were accurate to 1:1 million,[39] a measurement that required a formidable effort.[40] With the GPS, surveying measurement accuracy can exceed 1:1 billion.[41] In addition to greater accuracy afforded by the GPS, the system allows smaller teams to survey and map larger areas in a more detailed manner, all of which enhance productivity, lower costs, and provide safer and more effective surveying

[36] *Nemacolin Woodland Resort & Spar*, found at *http://www.nwir.com/golf.htm*.
[37] Ibid.
[38] *Real-Time Kinematic GPS for Cadastral Surveys,* Carl W. Sumpter and Gregory W. Asher, USDA Forest Service, found at *http://wwwsgi.ursus.maine.edu/gisweb/spatdb/acsm/ac94105.html,* retrieved Oct. 22, 2002.
[39] A measurement accuracy of 1:1 million indicates that only one part of a million parts would be inaccurate.
[40] Surveying and Mapping Manual: *The Global Positioning System - Introduction*: Minnesota Highway Department, Department of Transportation, p. 2-6.
[41] Ibid.

techniques.[42] Of the numerous GPS surveying techniques, real-time kinematic[43] GPS provides surveyors with immediate, centimeter-level accuracy. This technology is the fastest growing sector of the GPS survey market.[44]

As with land surveying, the GPS reduces the cost of surveys conducted on and under water. Accurate surveys of coastal and harbor measurements are needed to support dredging operations and other activities to ensure safe and effective handling of ships. GPS coastal and harbor surveys provide accuracies better than 3 meters, and GPS deep-water surveys provide accuracies of approximately 15 meters.[45] The precise positioning of large mobile structures, such as oil rigs, undersea cables, and other fixed objects are enhanced with GPS use.[46]

Tracking

As the price of GPS receivers declined, demand for tracking systems responded by rising at a phenomenal rate. Global sales of GPS tracking applications rose by 489 percent during 1997-2001, and accounted for 15 percent ($1.7 billion) of total GPS sales in 2001. It is anticipated that tracking applications will account for 18 percent ($3.0 billion of global sales in 2003. GPS tracking technology allows users to monitor movements of people, motor vehicles, airplanes, ships, trains, packages, and other products. Tracking enhances efficient management of goods and services and reduces loss stemming from accidents, theft, malfunctions, or improper operation. GPS tracking also reduces response times and enables more efficient utilization of vehicles used by police departments, fire officials, search and rescue missions, and other emergency services.[47] Law enforcement and wireless communications industries are considering placing GPS technology in cellular telephones and other information systems to facilitate

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[42] U.S. Department of Commerce, ITA, Office of Telecommunications, *Global Positioning System, Market projections and Trends in the Newest Global Information Utility*, p. 38.

[43] A procedure that allows position corrections to be transmitted in real time from a reference station to the users roving GPS receiver.

[44] *GPS Survey Market Healthy and Set to Grow*, Global Positioning & Navigation News; Potomac, Oct 20, 1999.

[45] U.S. Department of Commerce, ITA, Office of Telecommunications, *Global Positioning System, Market Projections and Trends in the Newest Global Information Utility*, p. 38.

[46] Ibid.

[47] Ibid, p. 37.

apprehension of criminals and the location of cellular telephones in the possession of individuals trapped in collapsed buildings, snow storms, and other catastrophes.

Aviation

Commercial pilots and aviation officials are relying upon the GPS to improve the current aircraft instrument landing system (ILS).[48] The Federal Aviation Administration's (FAA) Wide Area Augmentation System (WAAS)[49] is of particular interest since it is designed to provide a more precise landing system within North America by utilizing GPS technology. Implementation of the WAAS will result in significant benefits to the Federal Government and commercial and private aircraft operators.[50] The government will benefit because the costs associated with maintaining the enormous network of existing ground-based navigational aids will be reduced significantly. Benefits to aircraft operators would result from having a more efficient landing capability which will reduce costs related to accidents, deaths, injury, and property damage.[51]

The GPS will also play an essential role in Free-Flight, a concept that will allow pilots more freedom in selecting routes to destinations. Under Free-Flight the pilot will be able to select the most direct route to a destination as well as the desired speed and altitude after seeking and being granted approval by the traffic controller. The benefits of Free-Flight include the elimination of various flight restrictions, fuel savings, reductions in flight delays, time savings to destinations, and more efficient use of available runways.[52]

Military

Although the military market for GPS applications is relatively small, the importance of GPS for

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[48] *Coming Soon: Jets That Land Themselves,* Business Week; New York, Oct. 22, 2001, p. 66.

[49] WAAS is a GPS-based navigation and landing system that will provide precision guidance to aircraft at thousands of airports and airstrips where there is currently no precision landing capability.

[50] *National Airspace System: Observations on the Wide Area Augmentation Syatem (Testimony, 10/01/97, GAO/T-RCED-98-12)*, found at *http://www.fas.org/spp/military/gao/rced98012.htm.,* retrieved Nov. 11, 2002.

[51] Ibid.

[52] *About Free Flight*, found at *http://ffpl1.faa.gov/about/about.asp,* retrieved Nov. 14, 2002.

military operations and weapons systems is crucial. The role of the GPS during hostilities was illustrated during Operation Desert Storm, when U.S. and coalition forces used more than 9,000 portable GPS receivers to assist in navigating featureless expanses of the desert.[53] GPS receivers were attached to motor vehicles, helicopters, and other aircraft. In 2002, Rockwell Collins was selected by the GPS Joint Program Office to develop and deliver a limited quantity of Defense Advanced GPS Receivers (DAGR) to the military.[54] The DAGR will become the standard for GPS position and navigation and will be used primarily by the U.S. army.[55]

GPS technology is also embedded in bombs and missiles, which allows these weapons to make precise hits on targets. If a weapon loses contact with GPS signals emitted by the satellites, an Inertial Navigation System (INS) based on fiber-optic gyroscopes or solid-state accelerometer sensors is used to ensure accuracy. Most "smart weapons" developed in the 1990s featured GPS-INS guidance systems. The GPS is required on virtually all U.S. military vehicles.[56] Typically the cost of incorporating GPS technology is greater than the cost of the equipment itself.[57]

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[53] *Military Uses for GPS*, found at *http://www.aero.org/publications/GPSPRIMER/MltryUse.html,* retrieved Nov. 14, 2002.

[54] See Rockwell Collins Financial News, found at *wysiwyg://http://biz.yahoo.com/bw/021030/302193_1.html*, retrieved Nov. 14, 2002.

[55] Ibid.

[56] U.S. Department of Commerce, ITA, Office of Telecommunications, *Global Positioning System, Market Projections and Trends in the Newest Global Information Utility*, p. 34

[57] Ibid.

U.S. Production and Trade

Official U.S. production and trade data for GPS products are not separately reported.[58] However, estimates of both U.S. exports and imports are believed to represent roughly 45 percent and 10 percent of U.S. production, respectively. U.S. production of GPS products totaled an estimated $935 million in 1997. Therefore, U.S. exports are believed to have totaled about $420 million and U.S. imports totaled about $94 million during the period. With an estimated annual growth rate of 25 to 30 percent for U.S. GPS production during 1997-2001, both U.S. exports and imports of such products are believed to have recorded significant increases during the 5-year period. Japan, Europe, and Canada were the principal sources of U.S. imports–Japan, Taiwan, China, and Europe were the principal U.S. export markets.

Global Developments and Opportunities

North America

A growing number of companies in North America (mainly the United States) that are engaged in construction, mining, military, and mobile management operations have realized the importance of the GPS in enhancing productivity and other business operations. Benefits of the GPS have encouraged the restructuring of these operations through business consolidations, joint ventures, mergers, and acquisitions. For example, in 2001Trimble Navigation and Caterpillar formed a joint venture for the purpose of improving productivity and further modernizing their respective construction and mining activities.[59] Trimble (a global leader in producing GPS applications) supplied GPS technology, laser, wireless communications, computer, and software capabilities whereas Caterpillar (a major manufacturer of construction equipment) contributed the construction and engineering expertise.

With respect to the military, a myriad of GPS advancements in weaponry, mapping, weather forecasting, and troop and vehicle deployment have also encouraged business alliances in North America.

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[58] Certain GPS equipment is included within the North American Industry Classification System (NAICS) 334511: Search, Detection, Navigation, Guidance, Aeronautical, and Nautical System and Instrument Manufacturing. Since the GPS heritage can originate from a diverse line of product applications, however, GPS products may be included within other NAICS classifications.

[59] Found at *http://www.trimble.com/news/031502a.htm,* retrieved Nov. 25, 2002.

In October 1997, the U.S. Department of Justice approved a merger of Raytheon Company and Hughes Defense, creating one of the largest industrial corporations in the United States.[60] A significant result of the merger was the formation of the Raytheon Systems Company, which enhanced the company's global competitive position in the various military and government operations. In 1996, Boeing bought Rockwell Collins' aerospace and defense business (which builds the GPS Block IIF satellites) for $3.1 billion.

In the consumer sector there are rapidly growing synergies with automotive and communication products. In 1997, Rockwell's Driver Information Systems unit was sold to Orbital Sciences Corporation (OSC). The product sold to OSC was the PathMaster car navigation system, which is widely available on Hertz rental cars. Also in 1997 OSC merged Ashtech with Magellan. Ashtech was a leading supplier of high-precision GPS survey equipment, including combined GPS/GLONASS[61] receivers.

In 1998, Motorola created a new "Telematics Information System (TIS)" business to integrate its GPS, cellular, wireless messaging, and microprocessor design and production capabilities. A principal role of TIS is to provide efficient information to operators of motor vehicles by combining wireless voice and data communications with location information, emergency roadside assistance, and entertainment–all from a central service center. Emergency road assistance using GPS and other options are currently being offered on luxury cars in the United States, Japan, and Europe. Emergency road assistance is expected to improve significantly response times to accidents, especially in rural areas.

[60] News Release, *Raytheon Completes Merger With Hughes Aircraft, Announces Creation of Raytheon Systems Company,* found at *http://www.sec.gov/Archives/edgar/data/82267/0000950130-97-005628.txt*, retrieved Nov. 25, 2002.

[61] For information on GLONASS see section GLONASS and Galileo, p. 24.

Asia-Pacific

Car navigation systems are continuing to grow in popularity in Asia, with Japan leading in output (about 2.2 million units shipped in 2001) and product innovation.[62] While CD-ROMs have been an essential software for car navigation, DVD-ROMs are now being adopted extensively. Although DVD-ROMs are relatively expensive, they are present in about 60 percent of the car navigation systems sold in Japan. In addition, many portable GPS receivers from Japan are equipped with larger monitors, with one model having a 7-inch screen and supporting a digital audio and a surround sound system.[63] The combined use of car navigation and the mobile phone is also becoming popular. Japan offers car navigation systems that permit communication via mobile phone, access to the Internet, e-mail, and a system that provides various traffic information services. Although research and product development has not been as significant in Taiwan, GPS manufacturers in that country are increasing their output of GPS receivers, antennas, and modules for car navigation.

China has displayed a significant interest in GPS applications for vehicle tracking, surveying, mapping, navigation, railway management, marine, aeronautical, and electric power systems. Chinese companies are manufacturing GPS-related systems that incorporate GPS receivers obtained from Rockwell, Motorola, Garmin, Trimble, and other U.S. sources.[64] With more than 200,000 fishing vessels in China, the market for GPS applications in marine navigation is substantial. As the number of Chinese companies with capabilities to design and develop integrated GPS systems grows, a wider range of GPS products and applications will become more readily available for commercial use.[65]

Other countries in the Asia-Pacific region have made use of GPS in specialized areas.[66] For example, the Civil Aviation Authority of Fiji relies on GPS to provide all air navigation services around

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[62] Global Sources, *Advanced Models Boast Faster Search Speed, Use With Ias*, found at *http://www.globalsources.com.,* retrieved Nov. 25, 2002.

[63] Ibid.

[64] ATIP97.049: GPS (Global Positioning System) in China, found at *http://www.cs.arizona.edu/japan/ww...c/atip.reports.97.049r.html*, retrieved Nov. 25, 2002.

[65] Ibid.

[66] U.S. Department of Commerce, ITA, Office of Telecommunications, *Global Positioning System, Market Projections and Trends in the Newest Global Information Utility*, pp. 29-30.

the island and for a large area of the Southern Pacific. In Singapore, a taxi service has added an innovative method of obtaining taxicab service. Callers use an automated system that sends a message to the closest cab. GPS is used to constantly update a cab's location and the nearest vehicle is routed to the caller. GPS-based automatic vehicle location systems in Singapore also improve scheduling and management of bus fleets, subways, monorails and other public transportation systems.[67]

Europe

The European GPS equipment market is largely supplied by U.S. and Canadian firms.[68] Within Europe there continues to be a debate on the relative importance of GPS satellite technology and GPS receiver technology. Some argue that Europe has the necessary technical capabilities to produce competitive receiver equipment, while others maintain that a stronger European position in space systems is necessary. This debate occurs against the backdrop of continuing efforts to restructure and privatize European aerospace and defense industries in which new satellite construction contracts are being sought.[69]

Smaller European countries, especially in Scandinavia, appear to be taking a more entrepreneurial approach to GPS technology by focusing on commercial applications in land survey, vehicle tracking, geographic information systems, and coastal navigation.[70] In some instances this has led to the acquisition of U.S. firms such as the transfer of the Magnavox's GPS product line to the Swiss firm Leica. Europe's market position is expected to continue expanding as a result of its current strong participation in GPS applications in oil exploration and recovery in the North Sea. For example, GPS receivers provide constant subsidence rate measurements to engineers on drilling platforms in the North Sea oil field. GPS is also being combined with communications services by European firms. Racal Instruments of the United

[67] Ibid, p. 30.
[68] Ibid.
[69] Ibid.
[70] Ibid, p. 31.

Kingdom and Fugro of Holland are presently the leading successful commercial models for the use of GPS space-based augmentations in the oil exploration industry.[71]

Differential GPS (DGPS)[72] services are crucial to marine survey for helicopter logistics support to the North Sea oil fields. The economic importance of this GPS application is significant given that North Sea oil accounts for about 3 percent of the GDP of the United Kingdom. Rapid buildup of GPS applications in Europe is expected to occur in the London-Milan crescent, where about 70 percent of Western European population and industry is located. GPS is particularly useful for the "multi-modal" shipment of cargo from sea ports and air ports to trains and trucks. These transportation networks can be expected to expand into Eastern Europe as those economies develop. Poland and the Czech Republic are in the process of using GPS to create standardized geodetic networks. The full potential of these developments is not expected to be seen until after 2003.[73]

Other Regions

In Latin America, Africa, and the Middle East, aviation applications should be the dominant GPS market through 2003.[74] Aviation uses of GPS are linked to broader transportation and shipping infrastructures. In Dubai (United Arab Emirates), GPS-based systems are used to schedule delivery and loading of containers at one of the busiest ports in the world. The ability of commercial GPS firms to provide solutions to environmental management, infrastructure development, and other critical local needs will determine the market leaders of 2000 and beyond.[75]

In Latin America, GPS has been found to be useful in regional environmental management.

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[71] Ibid.

[72] DGPS is a method of increasing the accuracy of positions shown on GPS receivers. With DGPS receivers, position accuracy is improved from 30 meters to 10 meters or better. Found at *http://www.ccg-gcc.gc.ca/dgps/guide_4_e.htm,* retrieved Nov. 25, 2002.

[73] U.S. Department of Commerce, ITA, Office of Telecommunications, *Global Positioning System, Market Projections and Trends in the Newest Global Information Utility*, p. 30.

[74] Ibid, p. 31.

[75] Ibid.

In Argentina, Paraguay, and Bolivia, natural canals have been detected and accurately mapped using GPS. In transportation infrastructure, trucking fleets in Mexico, Brazil, and other Latin American countries use GPS to achieve efficient routing and scheduling. In addition, trucks carrying dangerous or high-value cargo can be tracked to protect against hijacking. This helps lower theft losses and insurance premiums.[76]

In sub-Saharan Africa, GPS is being used to improve air safety in a region where air traffic management is very poor. GPS is also useful in addressing local health problems. For example, malaria causes the deaths of more than 1.5 million children annually in sub-Saharan Africa. GPS is being used to create a Geographic Information System (GIS) locating mosquito breeding sites, local health clinics, and permanent and seasonal rivers. Entomology and childhood mortality databases are linked to the GIS so that researchers can study the relationships between disease data and geographic factors. This enables local health officials to more efficiently target limited resources to reduce the incidence of malaria. GPS tracking is used to manage game parks and track endangered species. Aside from ecological benefits, better game management helps promote international tourism, an important factor for many economies in the region.[77]

GLONASS and Galileo

In 1982, the former Soviet Union launched an alternative Global Navigation Satellite System known as GLONASS. The characteristics of this system are similar to those of the GPS in terms of the satellite constellation, orbits, and signal structure. Both systems are government owned and operated by their respective defense departments and they offer precise, global, continuous position-fixing capabilities. In addition, the signals provided by both systems are available for civil use without cost to users.[78]

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[76] Ibid.
[77] Ibid, p. 32.
[78] GLONASS - Global Navigation Satellite System, found at *http://gnssindustry.com,* retrieved Nov. 29, 2002.

The satellites used by GLONASS are larger and heavier than those comprising the GPS, which is believed to result from using older and more robust solutions instead of high-tech, state of the art techniques employed by the United States.[79] Other differences between these systems involve the orbits in which they are launched. The six orbital planes of the GPS provide better coverage of latitudes closer to the equator, whereas the three orbital planes used by GLONASS yield better satellite availability at higher latitudes. One of the principal differences between GLONASS and the GPS was eliminated on May 1, 2000, when the United States discontinued the use of SA. Prior to that date, GLONASS had been the only system that did not intentionally degrade satellite signals.

When GLONASS reached its full orbital configuration in 1995, there was only one experimental GPS/GLONASS receiver which met Western standards.[80] At present, there are at least three companies manufacturing GPS/GLONASS dual purpose receivers.[81] Given the technological advancements of GPS products, however, the GPS has become the internationally preferred system. Conversely, Russia has not been able to maintain the full configuration of GLONASS during recent years because of deteriorating economic conditions in that country.

In 1998, The European Space Agency (ESA) and the European Commission (EC) instituted comprehensive studies regarding development of a satellite navigation system known as GALILEO. As a result of the studies and recommendations of the ESA and the EC, a sum of $745 million was allocated to begin design and implementation of the GALILEO navigation system.[82] Galileo, which will enable users to determine positioning in three dimensions, time, and velocity, is expected to eliminate certain shortcomings of the GPS and GLONASS , such as poor availability in urban areas and high latitudes, temporary gaps in coverage, and single points of failure.[83] Galileo, which is being touted as an efficient alternative to the GPS and GLONASS, is expected to be operating by 2008.

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[79] *GLONASS Contributions to Space Geodesy*, Jorgen Borjesson, Department of Radio and Space Science, Chalmers University of Technology, Goteborg, Sweden, 2000.
[80] *Positioning and Navigation in the 3rd Millennium*, Gunther W. Hein, Survey Ireland - Winter 1999.
[81] Ibid.
[82] *Greater Than The Sum of Its Parts*, SATNAV, Helicopter World, June 2002, p. 11.
[83] Galileo, found at *http://www.gnssindustry.com,* retrieved Dec. 5, 2002.

Outlook

Rapidly expanding GPS technology will continue to provide both U.S. and foreign users of the system with tremendous capabilities in consumer, commercial, industrial, and military applications. Growing worldwide acceptance, coupled with the proliferation of GPS receivers and price reductions, will place GPS technology within reach of millions of consumers. Worldwide sales of GPS products are projected to totaled nearly $16.5 billion by 2003, with U.S.-made products accounting for 30 percent ($4.9 billion) of those sales. The 2003 global market for car navigation is expected to total 5 times the 1997 level and account for approximately 30 percent of global demand for all GPS products. With worldwide ownership totaling 768 million automobiles in 2001, car navigation will continue to represent one of the most lucrative markets for GPS applications. In addition, demand for GPS applications used in aviation, pleasure boating, marine navigation, surveying, recreation, cellular communications, military operations, and other areas will continue to increase well beyond 2003.

Expanding international acceptance of the GPS will have a positive impact of both the U.S. trade balance and employment by increasing significantly U.S. exports of GPS products. It is projected that by the year 2003, exports will have increased from the 1997 estimated level of $420 million to $1.4 billion, while new manufacturing positions created from GPS applications will total an estimated 130,000 jobs.

The next generation of GPS satellites (GPSIIF) is currently being developed by Boeing.[84] These satellites, which are scheduled to be launched by 2005, will have an increased flexibility to accommodate new augmentations and auxiliary payloads, and a larger margin for processor and memory capacity. Both military and civilian users of the GPSIIF will benefit from improved coverage and availability (up to thirty-three satellites), improved frequencies, timely warning of degraded signal integrity, and advanced signal development.[85]

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[84] *From GPS and GLONASS via EGNOS to Galileo Positioning and Navigation in the 3rd Millennium*, Gunter W. Hein, Institute of Geodesy and Navigation, University of Munich, p. 8.

[85] Ibid.