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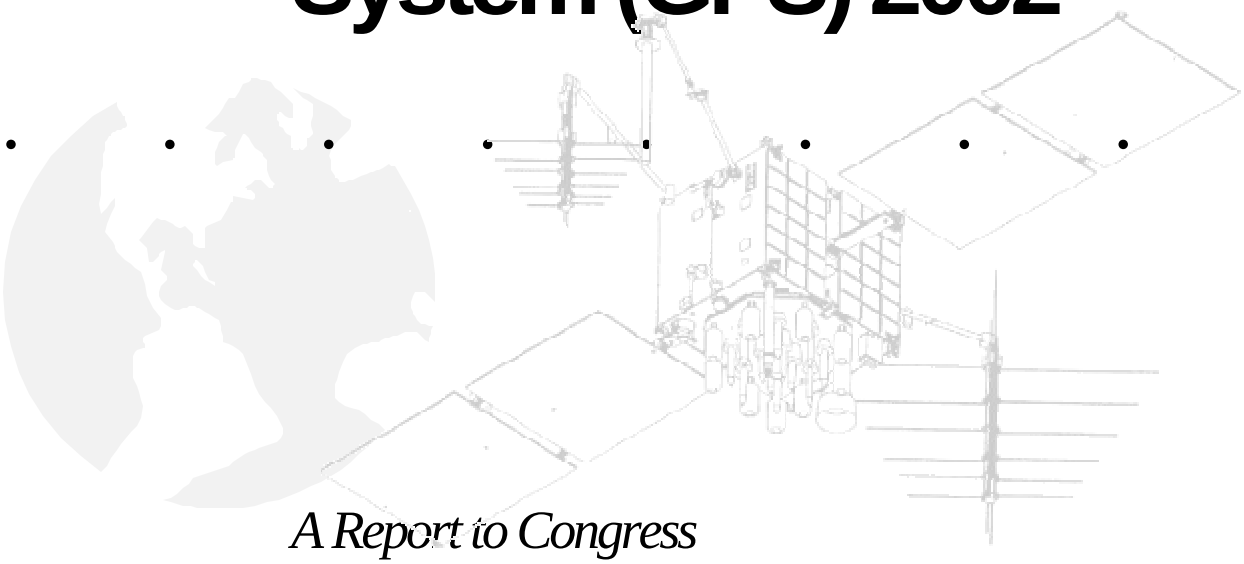
Department of Defense

Global Positioning System (GPS) 2002



A Report to Congress

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Global Positioning System (GPS) 2002

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Background

The National Defense Authorization Act for Fiscal Year 1998 (Public Law 105-85) established a requirement (10 U.S.C. 2281) for the Department of Defense, in consultation with the Departments of State, Commerce, and Transportation, to submit biennial reports to the Senate Committee on Armed Services and the House Committee on Armed Services on the status of specific elements of the Global Positioning System.

Reports were submitted in October 1998 and October 2000. This document constitutes the third in a continuing series of reports.

Operational Status

GPS continues to function at or above specified performance levels.

The Department of Defense is committed to ensuring a constellation of no fewer than 24 GPS satellites. Currently there are 27 operational satellites on orbit. The constellation is made up of three Block II, 18 Block IIA, and six Block IIR satellites. There are 14 IIR satellites awaiting launch. Within the current program, 8 of these 14 IIR satellites are planned to be modernized to add new civil and military signals. These modernized satellites, known as IIR-M, will be launched beginning in 2004. More details about the GPS Modernization Program will be addressed later in this report.

While the GPS constellation is healthy, as it ages, it becomes more fragile. Of the 28 currently on-orbit, 18 satellites are past their design life, 7 are past their revised mean mission duration (MMD), and 16 are single string, i.e., without redundancy, in either the navigation mission equipment or the satellite bus, or both. However, a sufficient number of satellites are available, in storage and ready for launch, to assure the U.S. meets its national commitment to keep the constellation healthy. Should the number of satellites fall below 24, users in some areas may experience reduced accuracy. Coverage could also be affected.

At least twelve Block IIF satellites are being procured to sustain the constellation, with the first Block IIF launch scheduled to occur in 2006.

The GPS Operational Control Segment (OCS), consists of the Master Control Station (MCS) at Schriever AFB, CO, and a Backup Master Control Station (BMCS) located at a contractor facility in Gaithersburg MD. The Alternate Master Control Station (AMCS) at the Vandenberg Tracking Station, CA (fully operational in FY05), as well as four remote Ground Antennas and five Monitor Stations worldwide.

Mission effectiveness of the OCS continues to exceed required performance levels, however, it, too, is aging. The ongoing Architecture Evolution Plan (AEP) will upgrade the control segment to replace some aging hardware and provide capabilities to support all future Block IIR and IIF GPS satellites.

Selective Availability

At the direction of the President, Selective Availability, the intentional degradation of the GPS signal, was set to zero at midnight on May 1, 2000. The President's decision was based upon a recommendation by the Secretary of Defense in coordination with the Departments of State, Transportation, and Commerce, the Director of Central Intelligence, and other Executive Branch Departments and Agencies. The decision acknowledged that worldwide transportation safety, scientific, and commercial interests could best be served by discontinuation of SA and was supported by DoD demonstrations of the ability to selectively deny GPS signals on a regional basis when U.S. national security is threatened.

Civilian users of GPS now receive position, velocity and time information with no accuracy degradation. Since SA was discontinued, horizontal position errors of less than 10 meters have routinely been observed. This accuracy represents a nearly ten-fold improvement over that available to civil users when SA was in place. Figure 1 demonstrates the performance improvement with SA turned off.

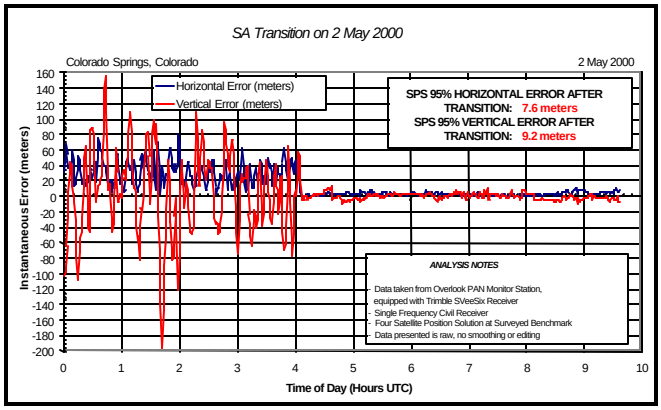

Figure 1-SA Transition

The new level of accuracy has encouraged the development of new products and resulted in accelerating the transition of GPS products and services into the mainstream:

- The Federal Communications Commission (FCC) is requiring wireless carriers to be able to identify the location of cell phone users (E-911). GPS has a potential role in this.

- GPS time data has improved to within 40 billionths of a second. This is useful for time-stamping financial transactions, managing electrical power grids, creating digital signatures for e-commerce, and synchronizing and managing telecommunications networks.

- Improvements in GPS tracking capabilities have allowed for improved package/cargo delivery tracking, fleet and asset management, emergency response, and theft recovery.

- Farmers can better use GPS to maximize the use of resources and minimize environmental impacts.

- Hikers who use hand-held recreational devices are able to find their way easier when hiking in unfamiliar areas.

- Boaters have an improved navigation tool and fishermen are better able to locate prime fishing spots.

- Other recreational uses for GPS include golf courses (distance ranging), ski resorts (tracking), and cycling. GPS was used for timing information during the 2002 Winter Olympic games. GPS has spawned new recreational activities such as geocaching and geodashing.

System Capabilities

A major goal of DOD and the Department of Transportation (DOT) is to select a mix of common-use (civil and military) radionavigation systems, that will include GPS, which meets diverse user requirements for accuracy, reliability, availability, integrity, coverage, operational utility, and cost; provides adequate capability for future growth; and eliminates unnecessary duplication of services. Selecting a future radionavigation systems mix is a complex task, since user requirements vary widely and change with time. While all users require services that are safe, readily available and easy to use, military requirements stress unique defense capabilities, such as performance under intentional interference, vehicle operations in high-dynamic situations, worldwide coverage, and operational capability in severe environmental conditions. Cost remains a major consideration that must be balanced with a needed operational capability.

Navigation requirements range from those for small single-engine aircraft or small vessels, which are cost-sensitive and may require only minimal capability, to those for highly sophisticated users, such as airlines, large vessel operators, or spacecraft, to whom accuracy, flexibility, and availability may be more important than initial cost. The emerging applications of land navigation will most likely cover the entire range of requirements.

The selection of an optimum radionavigation systems mix to satisfy user needs, while holding the number of systems and costs to a minimum, involves complex operational, technical, institutional, international and economic tradeoffs.

The DOT Positioning/Navigation (POS/NAV) Executive Committee is overseeing a Task Force that is nearing completion of a study to determine the best mix to satisfy the national need for navigation, positioning and timing services for the next 10 years. Systems still in R&D, such as GPS III and the European Galileo, are not being considered in this evaluation, but will be considered in future assessments, once their capabilities and implementation schedules are well defined. GPS Block II R-M and Block IIF satellites are currently being considered but may have an impact on future assessments if the implementation schedule to populate the constellation slips.

Military Requirements

The military's experience with GPS to date has identified a number of operational limitations. These limitations are documented as operational needs in a Mission Needs Statement (MNS) titled *For the Operational Protection and Prevention of Global Space-Based Navigation Systems*. The MNS was validated by the Joint Requirements Oversight Council (JROC) in March 1996. The MNS specifies a need to develop and acquire "effective capabilities" to deny adversarial use of GPS without hindering US forces' ability to operate with the system and without disrupting civil use outside an area of military operations. In response to these operational requirements, the DoD initiated the Navigation Warfare (Navwar) program. One of the first products of the Navwar effort was an analysis of alternatives (AoA). In June 1999, the JROC validated an Operational Requirements Document (ORD) reflecting improved system performance and Navwar protection requirements. A Navwar ORD annex containing requirements for denying adversarial use of GPS was approved in May 2001. Requirements for detecting, locating, and negating adversarial efforts to deny the use of GPS are currently in review. The ORD with its annexes will form the basis for military GPS modernization activities to be conducted over the next several years. In April 2002, the JROC approved an evolutionary approach to GPS capability improvement over the next 30 years. The Senior Interagency Forum for Operational Requirements (IFOR) is conducting an initial requirements review and will present the results to the JROC this year. The Initial Requirements Set focuses on GPS III requirements and capabilities with threshold values needed for DoD and civil users to meet operational missions and required uses.

Federal Radionavigation Plan (FRP)

The FRP provides a consolidated statement of U.S. plans for federally provided radionavigation systems. As stated in the 2001 FRP, GPS will be the primary Federally-provided U.S. radionavigation system for the foreseeable future. Although GPS is the centerpiece of the U.S. Government's planned complement of radionavigation systems for the foreseeable future and GPS has the capacity to meet or exceed the accuracy and coverage of many other radionavigation systems, the FRP acknowledges that GPS is not intended to satisfy the requirements of all radionavigation system applications. Consequently, the FRP describes a number of augmentations to GPS to meet the stringent needs of particular civil user groups.

Aviation Requirements

Aircraft navigation is the process of piloting aircraft from one place to another and includes position determination, establishment of course and distance to the desired destination, and determination of deviation from the desired track. Requirements for navigational performance are dictated by the phase of flight and their relationship to terrain, to other aircraft, and to the air traffic control process.

The GPS Standard Positioning Service (SPS) meets the navigation requirements for oceanic en route and some remote regions of the National Airspace System (NAS); therefore, it has been approved as a primary means of navigation for these areas. GPS SPS does not meet the availability and integrity requirements as a primary system for NAS domestic en route navigation through non-precision approach and is approved only as a supplemental system. Augmented GPS SPS can meet FAA requirements for a primary navigation system in the NAS. The Wide Area Augmentation System (WAAS) being implemented by FAA should be able to meet the integrity, availability, and accuracy requirements, as specified in the 2001 FRP, for en route through Category I precision approach. The Local Area Augmentation System (LAAS) is also being implemented by FAA for Category I precision approaches. Installation of the first of 46 Federal systems is expected in 2003. LAAS for Category II and III is currently in research and development to determine whether it meets the requirements for Category II and III precision approach operations.

Maritime Requirements

Navigation requirements of a vessel depend upon its general type and size, the activity in which the ship is engaged and the geographic region in which it operates. Safety requirements for navigation performance are dictated by the physical constraints imposed by the environment and the vessel, and the need to avoid the hazards of collision, ramming, and grounding.

GPS SPS can meet the navigation requirements for the Open Ocean and Coastal phases of navigation, but does not meet the requirements for the Harbor Entrance and Approach phase without augmentations. The Maritime Differential GPS (DGPS) system, a Coast Guard-provided augmentation, does meet Harbor Entrance and Approach phase requirements. It provides service for coastal coverage of the continental U.S., the Great Lakes, Puerto Rico, portions of Alaska and Hawaii, and portions of the Mississippi River Basin with accuracy better than 10 meters (2 drms).

Land Application Requirements

In comparison with the air and marine communities, phases of land navigation are not well defined. Radionavigation requirements are more easily categorized in terms of applications. The land navigation applications fall into three basic categories; highway, transit, and rail applications:

- Highway accuracy requirements range from 10 centimeters for safety warning to 30 meters for vehicle monitoring. The GPS SPS can meet 10-30 meter accuracy requirements, but not integrity (the ability of a navigation system to warn users when the system should not be used). Augmentations are required to meet more stringent accuracy and integrity requirements.

- Rail accuracy requirements range from 1 meter for positive train control to 10-30 meters for position location. The GPS SPS can meet the 10-30 meter requirements, but augmentations are required to meet more stringent accuracy requirements.

- Transit accuracy requirements range from 5 meters for data collection and automated voice bus stop annunciation, from 30-50 meters for vehicle command and control, and from 75-100 meters for Emergency Response. Unaugmented GPS SPS can meet the Emergency Response requirement and vehicle command and control, but not the applications requiring 5-meter accuracy.

The Nationwide DGPS system that DOT is now implementing with an expected completion date in 2007 will provide accuracies from 1-3 meters, which will meet most requirements. A High Accuracy-NDGPS project, a modification to the existing NDGPS service that maintains backward compatibility, is currently in a research phase. Early results show the potential for High-Accuracy NDGPS to produce navigation accuracies of 10 centimeters or better. More research and development is planned to determine if these accuracies can be achievable for nationwide coverage.

Space Navigation Requirements

NASA is currently using GPS to support earth-orbiting satellites conducting space and earth science missions and is essential to the mission success of the International Space Station.

GPS support of space applications falls into two basic categories:

1. Onboard spacecraft vehicle navigation support where GPS and GPS augmentations will be used in near real-time applications for navigation and attitude determination. In this role, onboard navigation and attitude accuracy requirements are:

    - Three-dimensional position error not to exceed 1 m (1 sigma).

    - Three-dimensional velocity error not to exceed 0.1 m/sec (1 sigma).

    - Attitude determination error not to exceed 0.1 degree in each axis (1 sigma).

    - Clock offset error between coordinated universal time (UTC) and onboard receiver time not to exceed 1 microsecond (1 sigma).

2. Scientific data analysis support where GPS will be used in a post-processing mode to accurately locate instrument position in space when measurements are taken. Current accuracy requirements are to determine three-dimensional position within 5 cm. However, more accurate positioning in the 1 to 2 cm range may be required in the future for some earth observation instruments.

Non-Navigation Requirements

The use of radionavigation systems, especially GPS, for non-navigation is very large and quite diverse. They include surveying and mapping, geophysical applications, meteorology, and timing. Accuracy requirements range from a few centimeters to several meters and could be real-time or employ post-processing. Augmented GPS SPS is currently needed to meet most of these requirements. Unaugmented GPS SPS will meet some resource management requirements in the 10-meter accuracy range.

Other users who require even more accurate, centimeter-level positioning are able to use a nationwide network of GPS Continuously Operating Reference Stations, known as the National CORS. CORS is a GPS augmentation established by the National Geodetic Survey that supports non-navigation, post-processing applications. This network is managed by the Department of Commerce's National Oceanic and Atmospheric Administration (NOAA), and provides local users with ties to the NOAA managed National Spatial Reference System, for accurate, 3-dimensional, post-mission positioning. Typical uses of National CORS are for land management, coastal monitoring, civil engineering, boundary determination, mapping, and geographical information systems, and both geophysical and infrastructure monitoring as well as future improvements to weather predicting and climate monitoring. NOAA is modernizing the height dimension by the use of the 301 CORS sites and CORS is growing at a rate of 5 sites per month. The CORS system is a multi-purpose cooperative endeavor involving many government, academic, and private organizations. In particular, it contains all existing NDGPS/DGPS sites and will soon include all existing FAA WAAS sites.

GPS Modernization

The Administration plans a significant investment over the next several years to modernize GPS to enhance its ability to meet both military and civil needs for the next 30 years.

The FRP summarizes the objectives of the GPS Modernization effort as improving position and timing accuracy, availability, integrity monitoring support capability, and enhancing the GPS ground control system to ensure a robust, highly dependable navigation and timing source for all users.

The currently planned GPS modernization program will add new military signals (known as the M-Code) to Block IIR and IIF satellites, a second civil signal on IIR satellites, and a third civil signal (L5) on IIF satellites. Also, in response to emerging and known threats, the program will include a Flexible Power capability which will allow satellite power to be "swapped" between military signals to provide increased protection in an interference (jamming) environment.

Under the current plan, the DoD will add the M-Code to 8 block IIR satellites along with the new civil signal and Flexible Power. This new civil signal will operate at the same frequency as the existing second military signal known as L2. The first launch of a satellite with these expanded capabilities is planned to occur in 2004.

In addition to the M-Code, second civil signal and Flexible Power, the Block IIF satellites will transmit a third civil signal, L-5, to support civil safety of life operations. Corresponding improvements to the GPS ground control supporting

infrastructure will also be implemented. The first launch of the Block IIF satellites is currently planned for 2006.

The next generation GPS III system will provide improved anti-jam capability, accuracy, availability, and integrity. GPS III is intended to satisfy both military and civil requirements. GPS III system architecture and requirements definition efforts were completed in November 2001. Three industry teams analyzed future GPS needs and explored system architecture concepts to determine the feasibility and cost associated with achieving varying levels of improved performance. Currently, the industry teams are building on these results to further refine GPS III requirements and concept of operations. The Interagency Forum for Operational Requirements (IFOR) is conducting an initial requirements review and will present the results to the JROC this year. The Initial Requirements Set focuses on GPS III requirements and capabilities with threshold values needed for DoD and civil users to meet operational missions and required uses. The DoD plans to award the contract for the continued concept definition and design of the new series of satellites by 2006.

International Cooperative Efforts

Civil, Commercial, and Scientific Activities

Among the goals of the Presidential Decision Directive (PDD) on GPS is to encourage acceptance and integration of GPS into peaceful civil, commercial and scientific applications worldwide and to promote international cooperation in using GPS for peaceful purposes. The Departments and agencies are working with their respective international counterparts to achieve these goals. International discussions focus on establishing GPS as a core component of any future Global Navigation Satellite System (GNSS) and the necessary infrastructure to support a global seamless architecture. Political, institutional, and technical issues are being addressed and must be resolved before this architecture is realized. The US continues to be an active initiator, participant, and facilitator internationally in defining the future GNSS architecture.

Since the 2000 report, the U.S. State Department has led three negotiation sessions with the European Community on GPS-Galileo cooperation. It has also led additional rounds of regular consultations with Japan on GPS cooperation.

Recently, the State Department and the United Nations sponsored regional GNSS Workshops in Malaysia in August 2001 for the benefit of countries in Asia and the Pacific; Austria in November 2001 for countries in Eastern Europe; Chile in April 2002 for countries in Latin America and the Caribbean; and Zambia in July 2002 for countries in Africa and the Middle East. The purpose of these workshops was to follow up on the Third United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE III) recommendation that the social and economic benefits of GNSS such as GPS be better articulated and stressed, particularly in developing countries. Each of these workshops focused upon two things. First, bringing the benefits of the availability and use of GPS and other GNSS to the awareness of decision-makers and technical personnel from potential user institutions and service providers in the private sector. Second, identifying actions to be taken and partnerships to be established for building capacity in the use of GPS in various areas of application where the system can offer cost-effective solutions to pursue

economic growth while protecting the environment and promoting sustainable development. A final workshop to consolidate the findings of each regional workshop will take place in Vienna in November 2002.

International Standards

Radionavigation services and systems should consider the needs of diverse international groups. The goals of performance, standardization, and cost minimization of user equipment influence the search for an international consensus on a selection of radionavigation systems. One of the policy guidelines of the PDD on GPS is advocating the acceptance of GPS and U.S. Government augmentations as standards for international use. For civil aviation, the International Civil Aviation Organization (ICAO) establishes standards for international use of radionavigation systems. For the international maritime community, a similar role is played by the International Maritime Organization (IMO). The FAA and Coast Guard have offered the basic GPS to ICAO and IMO respectively as a candidate for the future Global Navigation Satellite System (GNSS) that is envisioned to create a seamless navigation, positioning, and timing system for all civil users around the world. ICAO and IMO have accepted these offers.

The FAA took a leadership role in organizing the ICAO GNSS Panel in 1993. As a result, the GPS is a GNSS standard and the Space-Based and Ground-based Augmentation Systems (SBAS and GBAS) standards conform to the U.S. Wide Area Augmentation System (WAAS) and the Local Area Augmentation System (LAAS) specifications, respectively. Furthermore, after lengthy coordination, the European Geostationary Navigation Overlay Service (EGNOS) and MTSAT (Multi-functional Transport Satellite) Satellite Based Augmentation System (MSAS) developed by Europe and Japan are perfectly compatible with WAAS. Additionally, the FAA has been actively involved in a variety of cooperative activities with other nations including Brazil, Canada, China, India, and Mexico to promote and assist in the implementation of GPS and its augmentations; as well as regional initiatives and working groups in South America and Southeast Asia.

Similarly, the USCG continues to be a driving force in IMO activities. The Coast Guard Differential GPS system for maritime users, which uses the RTCM SC 104 format, has been adopted by more than 40 countries as the standard to meet their maritime navigation and positioning needs. It is being considered by IMO as the world standard for local area augmentations for GPS to meet maritime needs. Regarding land transportation and other uses of GPS, there are no international regulatory organizations such as ICAO and IMO that deal with these applications. They are currently being discussed in the State Department led activities with the European Union, Japan, and Russia. Discussions on the US approach to High Accuracy-NDGPS have occurred between DOT and representatives of several nations (South Korea, United Kingdom, and others) during open meetings.

Progress in Protecting GPS from Interference

Unintentional and Intentional Interference

In September 2001, the DOT's Volpe National Transportation Systems Center released a study indicating that GPS is susceptible to unintentional disruption from such causes as atmospheric effects, signal blockage from buildings, and interference from communications equipment, as well as to potential deliberate disruption. The Volpe study contained a number of recommendations to address the possibility of disruption and ensure the safety of the national transportation infrastructure.

Each transportation mode has critical applications that must be backed up. Whether it is navigation and air traffic control for aviation, navigating harbors and restricted waterways for maritime, timing and frequency for critical communications infrastructure, or emergency response across all modes. Safety-critical transportation applications that use GPS currently have adequate backups in place. In looking to the future however, the radionavigation system mix may need to change in response to new uses or changing threats. For example, additional actions will be required to build redundancy into critical transportation systems under development such as Intelligent Transportation Systems and ensure essential radionavigation services continue.

DOT has formally endorsed the Volpe report, noting that safety-critical transportation applications that use GPS currently have adequate backups in case of GPS disruptions and that future actions will be necessary to build redundancy into critical transportation systems under development and ensure essential radionavigation services continue.

Infrastructure protection is an ongoing concern within DOT operating administrations continually assess the adequacy of backup systems for vital transportation functions that rely on GPS. The DOT action plan will ensure that the vulnerabilities identified in the Volpe report do not affect the safety and security of our transportation system as we work to ensure that GPS fulfills its potential as a key element of the nation's transportation infrastructure. Back-up systems for safety-critical uses of GPS may also serve security functions such as container tracking. Innovative products based on GPS technology will substantially improve the way we track container shipments. However, appropriate backup systems to GPS should also be employed.

The DOT is implementing an action plan based on the Volpe report recommendations including the following initiatives for maintaining the viability of the transportation infrastructure:

- Ensure that adequate backup systems are maintained.
- Maintain the partnership with the Department of Defense to continue modernizing GPS with the implementation of new civil signals.
- Facilitate transfer of appropriate anti-jam technology from the military for civil use.
- Conduct industry outreach to develop receiver performance standards.

- Emphasize and promote education programs with state and local departments of transportation that advise users about GPS vulnerabilities.

- Complete an assessment of radionavigation capabilities across all the modes of transportation to identify the most appropriate mix of systems, from both a capabilities and cost perspective, for the next 10 years and beyond. This will include completing the evaluation of the long-term need for the continuation of the Loran-C.

The DOT Positioning/Navigation Executive Committee will oversee the implementation of the report recommendations and the associated work plan over the next year. Implementation of the report recommendations will be integrated into future editions of the Federal Radionavigation Plan.

The DoD is also concerned with disruption and interference. As discussed above, the DoD's plans to modernize GPS include the addition of new, higher power military signals providing more robust anti-jam (AJ) capability as well as spectral separation from the civil signals.

Spectrum Management

Potential interference to GPS signals and subsequent service disruption must also be addressed through the appropriate regulation of the radio frequency spectrum used by GPS. To this end, the GPS community was insistent on appropriate emissions limits to protect GPS users from potentially harmful interference from Ultra-wideband transmission systems. Under rules recently approved by the Federal Communications Commission in consultation with the National Telecommunications and Information Administration, non-licensed UWB devices will be allowed to intentionally emit in the radionavigation satellite service bands used by GPS. The emissions of theses devices will be limited to levels that should provide adequate protection. However, if these emissions limits are immediately relaxed, as some have advocated, progress in protecting GPS from interference will be hampered despite the modernization efforts of the DoD and the plans of DOT mentioned above.

The electromagnetic spectrum that enables both commercial and government services is a finite and already crowded resource. Approximately ninety-three percent of spectrum use is in less than 1 percent of the spectrum (the spectrum below 3 GHz). That 1 percent is popular in part because of the favorable technical characteristics of that spectrum and its related suitability for various kinds of services. As a result, the defense of this portion of the spectrum used for Radionavigation Satellite Service (RNSS) systems such as GPS is of critical importance to both existing GPS as well as planned modernization to the system. In the forthcoming World Radiocommunication Conference 2003 (WRC-03), Agenda Item 1.15 is the biggest challenge for GPS. The US objective is to oppose any unnecessary power limits for RNSS systems operating in the 1215-1260 MHz band (used by the GPS L2 signal) while still protecting other government services that also operate in this band. For the 1164-1215 MHz band (where the planned GPS L5 signal will reside), the US has acknowledged the need for criteria to protect existing Aeronautical Radionavigation Service, but also insists that there is no need for elaborate ITU regulatory processes to facilitate RNSS - ARNS sharing.

System Effectiveness

GPS Effects on National and Regional Security

GPS continues to be a major factor in the modernization and upgrade of weapon and support systems throughout the world. At the same time, the scientific, economic, and industrial base of the U.S. and friendly nations is becoming increasingly reliant on GPS. As a result, the protection, sustainment, and modernization of GPS become increasingly critical issues within national security policy development and implementation. In addition, the continued exploitation of GPS for military modernization globally by potential adversaries necessitates the development and employment of capabilities to counter this threat. The DoD is currently working to address this situation in its Navwar activities. Once Navwar is fully implemented, US national and regional security objectives will be maintained. Until then, US interests are increasingly at risk.

The United States continues to enhance and strengthen its national and regional security through the employment of GPS related technology. Development and increased use of GPS technology within the defense and transportation sectors are the two major areas providing improvements to U.S. security. Following the terrorist attacks on the United States on September 11, 2001, the Department of Defense planned and initiated GPS-enabled combat operations against terrorist activities in Afghanistan. During Operation Enduring Freedom, the principle weapon used against the terrorists and their supporting infrastructure was the Joint Direct Attack Munition (JDAM). JDAM, a precision-guided weapon using GPS for targeting, was used in over 4,600 attacks against the enemy. Supported by U.S. Special Forces ground troops using GPS range finders, Navy and Air Force pilots were able to surgically employ JDAMS against terrorist targets and minimize civilian collateral damage. Additionally, the high degree of accuracy resulting from the use of GPS for weapon guidance enabled the U.S. to scale back the number of attack platforms necessary to deliver weapons. This resulted in the ability to provide around the clock coverage of the battlespace without overtasking critical resources. The 24/7 air coverage afforded by the use of GPS-guided weapons substantially accelerated US successes in Afghanistan.

Economic Competitiveness of U.S. Industry

The GPS industry segment has experienced healthy growth over the last few years and will continue to grow rapidly over the next few years, as "GPS" becomes an increasingly familiar term for the general population. Overall, the GPS market is expanding in terms of dollars spent by customers and revenues earned by manufacturers. Intensifying competition has led to several mergers and acquisitions in recent years as companies attempt to diversify their overall product lines, grow their market share, and increase bottom-line revenues. Manufacturers tend to continue producing their own specialized, niche products; thus, the GPS industry remains sharply segmented with product applications extending from recreational to military and prices ranging from approximately two hundred dollars to thousands of dollars. However, there are partnerships emerging between GPS manufacturers and other industry manufacturers. Telecommunications and transportation are examples, as GPS products become more integrated into high value-added products ranging from cell phones to car navigation to flight management systems.

Revenue Growth

The Department of Commerce Office of Space Commercialization's *Trends in Space Commerce*, released in June 2001, determined that global sales of GPS equipment reached $7.34 billion in 2000 with $9.5 billion in equipment sales projected for 2002. These values do not include value-added services or any business related to the GPS space and ground control segments. Double-digit growth is anticipated through 2008. Total revenues from aviation, land, marine, military, and timing segments could surpass $10 billion through 2008. Approximately 4 million commercial GPS units were sold in 2000. Breakdown by market sector of these sales is shown in the figure below.

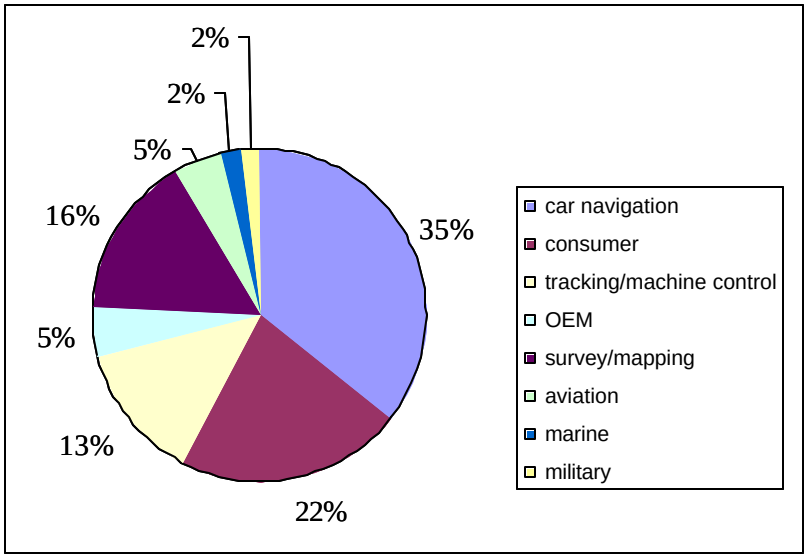

Figure 2. -Distribution of GPS units sold by market component in 2000

Source: Trends in Space Commerce

According to *Trends in Space Commerce*, over the course of 1999, the North American aviation market for GPS products grew about 10%, the land market grew just over 24%, the marine market grew 11%, and the military and timing markets each grew just under 25%. The land market comprised almost 62% percent of the total North American GPS revenues in 1999 and continue to make up the majority of industry revenues as recreational and car navigation systems gain popularity and as GPS timing products make their way into e-commerce and other Internet applications.

In 2000, U.S. producers generated 52% of worldwide GPS equipment sale revenues ($3.82B). Estimates for 2002 suggest a slight decline to 50% of total revenues ($4.73B). Domestic annual growth rate in equipment sales has averaged 14% since 1996.

While U.S. producers earn a majority of the total world GPS revenues, U.S. consumers comprise only about one-third of their customer base. Between 1996 and 2002, U.S. customers accounted for 31% of total worldwide GPS related sales. In 2002, US customer expenditures were $2.93B. By 2003 this market share is

projected to decline slightly to 30%. The figure below shows the projected 2003 worldwide breakdown of GPS customer expenditures.

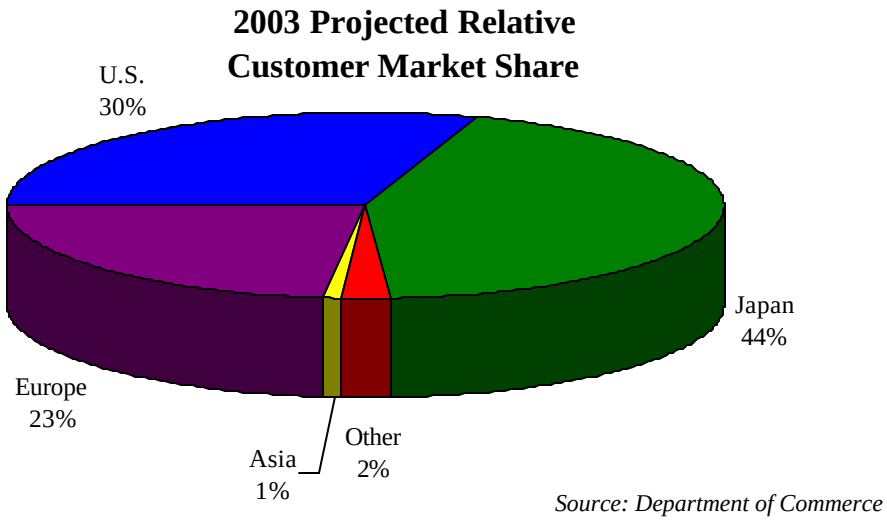

Figure 3 – 2003 Projected Market Share

Total GPS revenues will continue to grow in the near term, although revenues per unit received by producers worldwide are decreasing. Total revenues for world GPS producers are growing faster than revenues for U.S. GPS producers. U.S. GPS manufacturers historically have enjoyed profit margins in the 30 to 40 percent range, but in the next few years, falling prices will lead to profits dropping by 10 to 15 percent. However, due to growing sales, particularly in consumer application products such as car navigation and recreational handhelds, GPS manufacturers will continue to see a growing GPS market, remaining profitable in the next few years. In the future, manufacturers may have the market power to maintain prices as the accuracy and capabilities of GPS products improve.

Summary

Since the first report to the Congress in 1998, GPS has become even more vital to both the success of future US military operations and an increasing number of scientific and commercial endeavors. Both traditional and nontraditional applications of GPS continue to materialize. The discontinuation of Selective Availability in May 2000 has helped fuel the continued growth of GPS applications throughout the world.

The Transportation, State, and Commerce Departments continue to lead the way in establishing GPS as an integral component of the 21st century global marketplace and maintaining US preeminence in satellite navigation and positioning technologies and services.

The continued acceptance and widespread application of GPS will present new challenges to the DoD's ability to maintain a decisive competitive edge in the

battlespace of the future in the absence of SA. To date, the DoD's Navwar efforts have demonstrated that capabilities exist to meet the challenge. Rapid implementation of these features remains a DoD priority.

While GPS enjoys unprecedented acceptance throughout the world, now is not the time for the DoD or the U.S. to rest on its laurels. As good as GPS performs, there remain a number of areas in which the system can be further improved and enhanced. The DoD has put in place plans for a systematic upgrade to a number of features of the system through the GPS Modernization Program. Maintaining GPS at the forefront of the world's satellite positioning and navigation technology can only be achieved through a national commitment accompanied by adequate and stable funding throughout the life of the system.