ASSISTANT SECRETARY OF DEFENSE
6000 DEFENSE PENTAGON
WASHINGTON, DC 20301-6000

NETWORKS AND INFORMATION
INTEGRATION

The Honorable John Warner
Chairman, Committee on Armed Services
United States Senate
Washington, DC 20510-6050

Dear Mr. Chairman:

I have enclosed the biennial report on the *Global Positioning System (GPS) 2004, A Report to Congress* as required by Section 2281 of Title 10 of the United States Code. This report outlines the current status of the system and the future direction that the United States Government is pursing to ensure that GPS remains an international standard for positioning, navigation and timing services.

A similar letter has been sent to the House Armed Services Committee; and the House and Senate Appropriations Committees, Subcommittees on Defense.

Sincerely,

Linton Wells II
Acting

Enclosure:
As stated

cc:
The Honorable Carl Levin
Ranking Member

ASSISTANT SECRETARY OF DEFENSE
6000 DEFENSE PENTAGON
WASHINGTON, DC 20301-6000

NETWORKS AND INFORMATION
INTEGRATION

NOV 9

The Honorable Ted Stevens
Chairman, Subcommittee on Defense
Committee on Appropriations
United States Senate
Washington, DC 20510-6028

Dear Mr. Chairman:

I have enclosed the biennial report on the *Global Positioning System (GPS) 2004, A Report to Congress* as required by Section 2281 of Title 10 of the United States Code. This report outlines the current status of the system and the future direction that the United States Government is pursing to ensure that GPS remains an international standard for positioning, navigation and timing services.

A similar letter has been sent to the House and Senate Armed Services Committee; and the House Appropriations Committee, Subcommittee on Defense.

Sincerely,

Linton Wells II
Acting

Enclosure:
As stated

cc:
The Honorable Daniel K. Inouye
Ranking Member

ASSISTANT SECRETARY OF DEFENSE
6000 DEFENSE PENTAGON
WASHINGTON, DC 20301-6000

NETWORKS AND INFORMATION
INTEGRATION

NOV 9

The Honorable Duncan L. Hunter
Chairman, Committee on Armed Services
United States House of Representatives
Washington, DC 20515-6035

Dear Mr. Chairman:

I have enclosed the biennial report on the *Global Positioning System (GPS) 2004, A Report to Congress* as required by Section 2281 of Title 10 of the United States Code. This report outlines the current status of the system and the future direction that the United States Government is pursing to ensure that GPS remains an international standard for positioning, navigation and timing services.

A similar letter has been sent to the Senate Armed Services Committee; and the House and Senate Appropriations Committees, Subcommittees on Defense.

Sincerely,

Linton Wells II
Acting

Enclosure:
As stated

cc:
The Honorable Ike Skelton
Ranking Member

ASSISTANT SECRETARY OF DEFENSE
6000 DEFENSE PENTAGON
WASHINGTON, DC 20301-6000

NETWORKS AND INFORMATION
INTEGRATION

The Honorable Jerry Lewis
Chairman, Subcommittee on Defense
Committee on Appropriations
United States House of Representatives
Washington, DC 20515-6018

Dear Mr. Chairman:

I have enclosed the biennial report on the *Global Positioning System (GPS) 2004, A Report to Congress* as required by Section 2281 of Title 10 of the United States Code. This report outlines the current status of the system and the future direction that the United States Government is pursing to ensure that GPS remains an international standard for positioning, navigation and timing services.

A similar letter has been sent to the House and Senate Armed Services Committees; and the Senate Appropriations Committee, Subcommittee on Defense.

Sincerely,

Linton Wells II
Acting

Enclosure:
As stated

cc:
The Honorable John P. Murtha
Ranking Member

October 2004

Department of Defense

Global Positioning System (GPS) 2004

A Report to Congress

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Global Positioning System (GPS) 2004

A Report to Congress

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 (DoD), 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, 2000, and 2002. This document constitutes the fourth in a continuing series of reports.

Operational Status

GPS continues to function at or above specified performance levels.

The DoD remains committed to ensuring a constellation of no fewer than 24 GPS satellites. In order to maintain a 95% probability that 24 satellites will be available on orbit, typically, the GPS constellation is made up of 28 or more satellites. Currently there are 29 operational satellites on orbit. The constellation consists of 2 Block II, 16 Block IIA, and 11 Block IIR satellites. There are 9 IIR satellites awaiting launch. Within the current program, up to 8 of these 9 IIR satellites will be modernized to add new civil and military signals. The GPS Modernization Program will be addressed in more detail later in this report.

While the GPS constellation is healthy, several satellites are approaching the end of their expected lifetime. Of the 29 currently on-orbit, 17 satellites are past their design life, and 17 are 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 ensure that the U.S. meets its national commitment to keep the constellation healthy. Should the number of satellites fall below 24, users in some areas will experience reduced accuracy. Coverage would also be affected.

The GPS Operational Control Segment (OCS) consists of the Master Control Station (MCS) at Schriever AFB, CO; 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 by the end of 2005); as well as four dedicated remote ground antennas and six monitor stations worldwide. GPS signal monitoring data from six National Geospatial-Intelligence Agency (NGA) monitor stations will be incorporated into the GPS OCS by the 1st quarter of FY05. These NGA monitor stations will provide improved accuracy to all users. The additional monitor stations will also provide 100% global monitoring to improved GPS signal integrity thereby minimizing the use of anomalous navigation signals. Additionally, since the performance of GPS civil signals is not monitored directly by the OCS today, an effort has been initiated to add this capability. This enhancement will result in complete and unambiguous performance monitoring of all GPS signals, military and civil, within a centrally focused GPS command and control operation.

The current OCS is aging and cannot support some capabilities of the satellites on orbit. The ongoing Architecture Evolution Plan (AEP) will upgrade the control segment to replace aging hardware and provide capabilities to support all future Block IIR and IIF GPS satellites.

System Capabilities

A major goal of the DoD and 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 trade-offs.

The Under Secretary of Transportation released the Radionavigation Capabilities Assessment Task Force Report on January 5, 2004, that recommends the best set of radionavigation mix options to satisfy the national need for positioning, navigation, and timing (PNT) services for the next ten years. The report also identifies several technical evaluations that need to be completed in order to determine if certain systems can meet cross-modal requirements and thus serve as a cost-effective radionavigation solution.

The Standard Positioning Service (SPS) Performance Standard, last updated and published by the DoD in 2001, establishes measures of performance that civil users can expect from GPS. Since it first became operational, GPS performance has continued to exceed performance specifications. As shown in the following table summarizing key performance parameters, over the entire year 2003, GPS performed well above specified levels.

2003 Specified and Observed Performance

Parameter	Specification	Observed
PDOP[1] Availability	6 or less 98% of time	99.98%
Horizontal Accuracy	36 m 99% of time	3.66m
Vertical Accuracy	77 m 99% of time	5.25m
User Range Error	6m or less	1.23m

Military Requirements

Collectively, recent operational experience, studies, and test activities have made a compelling case for improving the robustness and jam resistance of GPS. Current system limitations as well as statements of required capabilities to operate in the postulated threat environment are documented in Capability Development Documents, which are scheduled for validation by the Joint Requirements Oversight Council (JROC) early next year. These documents specify a need to develop and acquire effective capabilities to protect U.S. and Allied forces' ability to operate with the system and at the same time deny adversarial use of GPS without disrupting civil use outside an area of military operations. In response to an earlier statement of operational requirements, the DoD initiated Navigation Warfare (Navwar) activities, which remain a fundamental building block of the overall GPS modernization efforts to be conducted over the next several years. Once formally validated by the JROC, the CDDs will establish GPS III and modernized user equipment requirements and capabilities with threshold values needed for DoD and civil users to meet operational missions and required uses.

[1] **Position Dilution of Precision**. The geometrical effect on GPS three dimensional accuracy. The positions of GPS satellites in orbit determine the PDOP value for a given site at a given time. The higher the PDOP value, the less accurate the three dimensional position solution.

Federal Radionavigation Plan (FRP)

The FRP provides a consolidated statement of U.S. plans for federally-provided radionavigation systems. 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 specific user groups.

Aviation Requirements

Aircraft requirements for navigation performance are dictated by an aircraft's phase of flight and its relationship to terrain, other aircraft, and to the air traffic control process.

The GPS 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) operated by the FAA meets the integrity, availability, and accuracy requirements, as specified in the 2001 FRP, for en route through Category I[2] precision approach. The FAA commissioned WAAS for public use in September 2003. The Local Area Augmentation System (LAAS) is also undergoing research by the FAA for Category I precision approaches. Studies are currently underway to determine whether LAAS meets the requirements for Category II[3] and III[4] 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 Nationwide Differential GPS (NDGPS) 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

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[2] An instrument landing approach procedure that provides for approach to a height above touchdown of not less than 200 feet.

[3] An instrument landing approach procedure that provides for approach to a height above touchdown of not less than 100 feet.

[4] An instrument landing approach procedure that provides for approach without a minimum height above touchdown.

portions of the Mississippi River Basin with accuracy better than 10 meters, an availability of 99.9%, and integrity broadcasts when the system should not be used for navigation.

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, rail, and transit 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 NDGPS system that is currently under development and in initial operations will ultimately provide accuracies from 1 – 3 meters. This system, when complete in 2008 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 Requirements

The GPS signals from space are key enablers in the National Aeronautics and Space Administration's (NASA) mission to better understand and protect our home planet and to explore the universe.

From an engineering perspective, NASA is exploiting GPS signals for the full spectrum of research missions including the International Space Station, the Space Shuttle, Earth and Space Science satellites, research balloons, Unpiloted Air Vehicles (UAVs), and NASA's research aircraft. Capabilities include precise navigation (to centimeter level), attitude determination and control, unprecedented timing measurements, and space and air vehicle formation flying. These capabilities allow NASA and other spaceflight developers to engineer systems that are lower in cost and much higher in performance than without GPS.

NASA is also investigating the use of GPS above the GPS constellation. Among other things, this work will allow closer spacing of communications satellites in Geostationary orbits—providing a more dense satellite population over crucial areas of the world. It will also improve space vehicle autonomy, thereby reducing mission costs. NASA also hopes that this weak signal GPS research, coupled with the future advancements of GPS, will pave the way for the use of GPS and GPS-like augmentations as NASA ventures back to the Moon with humans. And as part of NASA's new exploration initiative, it is hoped that GPS technology and its augmentations go along with our future space explorers as we venture out to Mars and into the far recesses of space.

Non-Navigation Requirements

The use of GPS for non-navigation activities is large and diverse. Such activities include surveying and mapping, positioning, tracking, geophysical applications, meteorology, and timing. Real-time accuracy requirements range from several meters to a few centimeters. Post-processed accuracy requirements extend to the sub-centimeter level. Augmented GPS SPS is currently needed to meet many of these requirements. Unaugmented GPS SPS meets requirements in the 10-meter accuracy range.

Users who require centimeter-level positioning are able to use a nationwide cooperative network of GPS Continuously Operating Reference Stations, known as the National CORS. CORS is a GPS augmentation managed by the Department of Commerce's National Oceanic and Atmospheric Administration (NOAA) that supports non-navigation, post-processing applications. This network 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 include 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's Height Modernization program is currently making it more affordable to determine precise heights by using the 487 sites in the National CORS network. Moreover, this network is growing at a rate of about 8 sites per month. The CORS program is a multi-purpose cooperative endeavor involving more than 130 government, academic, and private organizations–each of which operates at least 1 site. In particular, it includes all existing NDGPS/DGPS sites and all existing FAA WAAS sites.

New GPS-based Earth science investigations are improving our knowledge of the Earth and its environment. For example, Earth science atmospheric and ionospheric limb soundings and ocean reflection measurements using GPS are improving our understanding of atmospheric makeup, ionosphere structure and dynamics, and sea surface winds, all crucial to better understand the environment in which we live. GPS has also enabled Earth scientists to better understand the geodetic nature of the Earth to much greater precision. For example, subtleties in the Earth rotation and polar motion, deformation of the Earth's crust, and a better understanding of the shape of the Earth represent key measurements that are routinely probed using GPS.

NASA has developed a high accuracy GPS augmentation system to support the demanding real-time positioning, timing, and orbit determination requirements of its science missions. The Global Differential GPS (GDGPS) System enables 10-20 cm real-time positioning accuracy for users with dual frequency GPS receivers anywhere in the world, on the ground, in the air, and in space. NASA is presently developing the TDRSS Augmentation Service for Satellite (TASS) to disseminate the GDGPS real-time differential correction message to earth satellites, enabling precise autonomous orbit determination, science processing, and planning operations in Earth orbit. NASA is working with the Air Force and the Aerospace Corporation to exploit the unique GPS monitoring capability of the GDGPS System.

Progress in Modernizing GPS

The DoD has begun a significant investment that will continue 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. Incorporation of six additional NGA monitor stations, scheduled for 2005, is a significant step toward these objectives and provides benefits for all blocks of GPS satellites.

Further, the ongoing GPS Modernization Program will add new military signals (known as the M-Code) and a second civil signal (known as L2C) to as many as 8 Block IIR (redesignated as IIR-M) satellites. GPS IIF satellites will incorporate the same improvements as well as an additional civil signal (known as L5) for safety of life applications. 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. Corresponding improvements to the GPS ground control supporting infrastructure will also be implemented.

The first IIR-M satellite with these expanded capabilities is planned for launch in mid 2005. The first Block IIF satellite is planned for launch in mid 2006.

The final stage of the currently planned GPS Modernization includes the development and fielding of the next generation GPS system, GPS III. GPS III will provide improved anti-jam capability, accuracy, availability, and integrity and is intended to satisfy both military and civil requirements. Contracts were awarded for a second phase of GPS III system architecture and requirements definition study efforts in January 2004. Two industry teams are analyzing future GPS needs and expanding system architecture concepts to determine the feasibility and cost associated with achieving varying levels of improved performance. Currently, the industry teams are focusing on presenting the results of their study efforts at a System Requirements Review in 2005. Plans call for award of a contract for a risk reduction/design development phase in the fourth quarter of 2005. Target date for launch of the first GPS III satellite is 2012.

An initial civil-military requirements review has resulted in the generation of a GPS III Capability Development Document (CDD). The CDD is currently in the final stages of review and is scheduled to be presented to the JROC for validation early next year. The CDD focuses on GPS III capabilities with threshold values needed for DoD and civil users to meet operational mission needs and required uses.

The civil community is continuing to refine its future GPS needs and is currently conducting an Analysis of Alternatives (AoA) of civil space-based positioning, navigation, and timing requirements. AoA results will be reflected in future updates to the CDD or in a Capability Production Document (CPD).

NASA, in cooperation with the USAF GPS Joint Program Office and Sandia National Laboratories, has embarked on a proof-of-concept initiative called the Distress Alerting Satellite System (DASS) to GPS IIR and IIF satellites. The DASS proof-of-concept adds a bent-pipe repeater of the 406 MHz distress beacon onboard GPS satellites to demonstrate improved future search and rescue capability. Pending the successful completion of the proof-of-concept (POC) program, the formal validation of the DASS requirement, and future budgetary authority, DASS would involve the placement of 406 MHz distress beacon repeaters onboard future GPS satellites.

International Cooperative Efforts

Defense Activities

The DoD has entered into agreements with 37 friendly nations whereby these nations have agreed to adopt GPS as the source of military position, navigation, and timing (PNT) information. In addition, NATO has adopted GPS as its PNT standard. These agreements will significantly contribute to improved interoperability and situational awareness as these nations join with U.S. forces in future coalition military operations.

Civil, Commercial, and Scientific Activities

To achieve the goals of encouraging acceptance and integration of GPS into peaceful civil, commercial and scientific applications worldwide and promote international cooperation in using GPS for peaceful purposes, federal departments and agencies are working with their respective international counterparts. 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 U.S. continues to be an active initiator, participant, and facilitator internationally in defining the future GNSS architecture.

On June 26, 2004, the U.S. and European Community and its 25 Member States signed a cooperation agreement for GPS and the European satellite navigation system known as Galileo. After many years of intensive negotiations, the U.S. has reached an agreement that protects our national security interests related to the use of GPS M-code signals in a Navwar environment. In addition, per the agreement, all parties agreed to pursue nondiscriminatory approaches to trade in the provision of civil services. The agreement also lays the foundation for a common civil signal to be broadcast by both Galileo and the GPS III constellation.

The U.S. and Japan continue to enjoy an excellent working relationship with respect to GPS cooperation. In addition to plenary discussions, U.S. and Japanese experts have engaged in technical discussions to ensure that the proposed Japanese Quasi Zenith Satellite System is compatible and interoperable with GPS.

A final workshop in a series of regional sessions, co-sponsored by the U.S. and the United Nations, took place in Vienna in November 2002 to consolidate the findings of each previous regional workshop and make recommendations for future steps. These recommendations include the establishment of an International Committee on GNSS, potential future workshops, and pilot projects to incorporate GPS into the infrastructure of developing countries.

Many federal agencies (NASA, NOAA, NGA, NRL, USNO, NSF) and universities participate in the International GPS Service (IGS), a multinational consortium of government agencies, universities, and other organizations that provides GPS-derived data and products in support of Earth science research, multidisciplinary applications, and education. The IGS now comprises more than 200 contributing organizations in more than 80 countries, and the IGS cooperative global tracking network has grown to over 350 stations. NASA sponsors the office that manages and coordinates the IGS.

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. 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). Consistent with the goal of advocating the acceptance of GPS and U.S. Government augmentations as standards for international use, the FAA and Coast Guard have offered the GPS Standard Positioning Service 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 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.

The U.S. Coast Guard (USCG) continues to be a driving force in two international forums, the International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA) and the International Maritime Organization (IMO). The Coast Guard's Differential GPS (DGPS) system has been adopted by more than 40 countries as the standard to meet their maritime navigation and positioning needs. The USCG has supported IALA in establishing technical workshops for maritime nations interested in establishing DGPS systems. Last year an agreement was signed with the Canadian Coast Guard to establish a "seamless DGPS service" between our common borders. This service combines the two nations' systems as one system from the user perspective. It increases signal availability by scheduling off-air maintenance between providers and giving the users the status of all available signals, not just the ones operated by either nation. This agreement is being duplicated through the efforts of IALA for use by other neighboring countries providing like services.

Progress in Protecting GPS from Interference

Unintentional and Intentional Interference

The DoD clearly recognizes the need to protect GPS from disruption and interference. Indeed, one of the three primary goals of the Department's Navwar activities is to enhance the robustness and jam resistance of GPS through a combination of increased power from space, investment in modernized user equipment (UE), and selectively upgrading high-priority platforms with additional anti-jam (AJ) features. (Other Navwar goals include preventing adversary exploitation of GPS and preserving peaceful use of GPS outside an area of military operations.) As discussed above, the DoD's program to modernize GPS with the addition of higher power military signals providing more robust AJ capability as well as spectral separation from the civil signals is underway.

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. DOT and DHS operating administrations continually assess the adequacy of backup systems for vital transportation functions that rely on GPS. The DOT action plan ensures 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.

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 approved by the Federal Communications Commission in consultation with the National Telecommunications and Information Administration, non-licensed certain UWB devices, e.g., ground-penetrating radars, will be allowed to emit in the radionavigation satellite service bands used by GPS. The emissions of these devices will be limited to levels that should provide adequate protection. However, if these emission limits are 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.

Even with the UWB emission limits at the present level, new services such as Mobile Satellite Services Ancillary Terrestrial Components (MSS ATC) and Digital Low Power TV (D-LPTV) may add emissions into the radionavigation satellite service bands. The current emission limits for UWB, plus the proposed emission limits for other services, could jointly add up to a level that further reduces the signal margin for current GPS satellites, which cannot be modified, and whose signals are already being affected by electromagnetic noise. The electromagnetic spectrum that enables both commercial and government services is a finite and already crowded resource. Approximately 93 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.

At the World Radiocommunication Conference 2003 (WRC-03), the U.S. opposed unnecessary power limits for RNSS systems operating in the 1215-1260 MHz band (used by the GPS L2 signal) and the relevant resolution was suppressed without the need for further study. For the 1164-1215 MHz band (where the planned GPS L5 signal will reside), the U.S. acknowledged the need for criteria to protect existing Aeronautical Radionavigation Service (ARNS), but insisted that there was no need for elaborate International Telecommunications Union (ITU) regulatory processes to facilitate RNSS - ARNS sharing. WRC-03 subsequently adopted Resolution 609 whereby consultation meetings between administrations operating or planning to operate ARNS and RNSS systems are held on a regular basis to achieve the necessary level of protection for ARNS systems.

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, not only in this country, but 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, U.S. national and regional security objectives will be maintained. Until then, U.S. interests are increasingly at risk.

GPS continues to enhance military operations globally. In Operation Iraqi Freedom (OIF), the U.S. military used 19,948 precision munitions (approximately 68%) versus 9,251 unguided munitions. Of those, approximately 57% were GPS-aided munitions, including those used to accomplish the time-sensitive targeting of Iraqi leadership and other critical targets. To enhance GPS performance to users in the Iraqi theater, the 2nd Space Operations Squadron (2 SOPS) at Schriever AFB, CO, implemented a tactic known as GPS Enhanced Theater Support (GETS). By providing satellites with their orbit and clock updates immediately prior to entering the theater, 2 SOPS guaranteed that performance significantly exceeded specifications, and users even experienced an increase in accuracy.

Operation Iraqi Freedom also saw the introduction of antispace countermeasures, as Iraqi forces tried to jam GPS signals. From the onset of coalition air strikes until U.S. forces entered Baghdad, the Iraqis executed a concept of operations aimed at interfering with GPS signals. While the Iraqi jamming techniques were not overly detrimental to the conduct of military operations, they emphasized the fact that the overall jamming threat must be viewed with concern. New and improved jammers and employment concepts will almost surely emerge as potential adversaries come to recognize and appreciate the asymmetric advantage U.S. and coalition forces now enjoy through the use of GPS.

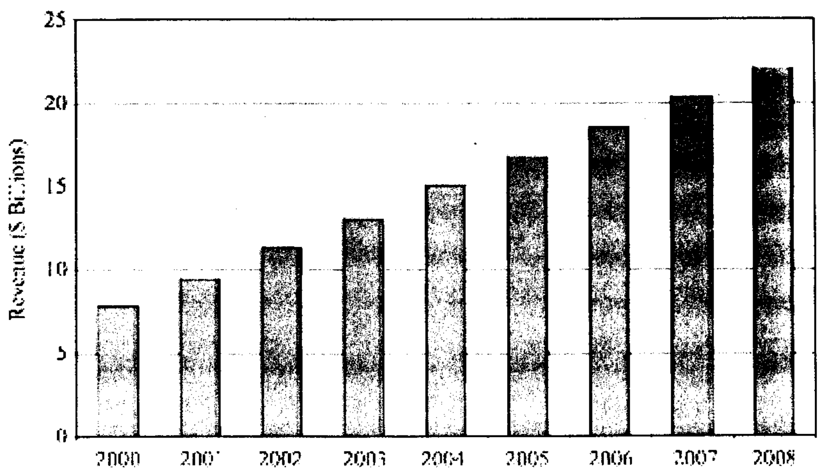
Economic Competitiveness of U.S. Industry

The GPS industry continues to experience the same healthy growth that has characterized this industry for the past several years. GPS has become more of a household name among the general population, as evidenced by the proliferation of television and print advertisements touting it as a feature in new cars, telephones, and even soft drink cans.

The government's most recent study, the Department of Commerce's 2001 report on Trends in Space Commerce, conservatively estimated double digit market growth in global sales of GPS equipment to drive the market to nearly $10 billion by 2008.

More recent studies by commercial technology market research firms have reflected an even more robust picture of market growth. One New York firm with extensive experience in market research and technology intelligence on the wireless, automotive, electronics, and broadband and energy industries recently projected a worldwide GPS market worth over $22 billion by 2008[5].

GPS Equipment Revenue, World Market, Moderate Forecast: 2000 to 2008
(Source: Allied Business Intelligence Inc)



[5] Allied Business Intelligence, Inc., *GPS World Markets: Opportunities for Equipment and IC Suppliers*. Oyster Bay, NY, 2003

Today, roughly half of the worldwide market consists of sales of automotive and asset-tracking equipment. These segments are expected to continue to grow faster than the overall, broader market for GPS equipment. In addition to the strength of these markets, new segments are constantly emerging for GPS applications and are projected to continue to drive demand for gear as diverse as people-tracking devices and GPS golf systems.

U.S. companies excel at integrating GPS receivers into innovative form factors. Novel applications are likely in an ever-increasing range of devices.

While total GPS revenues will continue to grow, per unit revenue is not expected to be as strong as unit growth, due mainly to pricing pressure. Growing sales, particularly in consumer application products such as car navigation and recreational handhelds, are expected to enable GPS manufacturers to remain profitable for the next several years. In the more distant future, continued product innovation should enable U.S. manufacturers to maintain profitability as the accuracy and capabilities of GPS products improve.

Summary

Since the most recent report to the Congress in 2002, GPS has become even more vital to the success of future U.S. military operations as well as an increasing number of scientific and commercial endeavors. Both traditional and nontraditional applications of GPS continue to materialize.

The Transportation, Homeland Security, State, and Commerce Departments continue to lead the way in establishing GPS as an integral component of the 21st century global marketplace and maintaining U.S. preeminence in satellite PNT 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. To date, the DoD's Navwar activities have demonstrated that capabilities exist to meet the challenge. Effective implementation of these features remains a DoD priority.

While GPS currently enjoys unprecedented acceptance throughout the world, the prospect of foreign satellite navigation systems looms on the horizon. The DoD is well on the way to 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, navigation, and timing technology can only be achieved through a continued national commitment accompanied by adequate and stable requirements and funding throughout the life of the system.