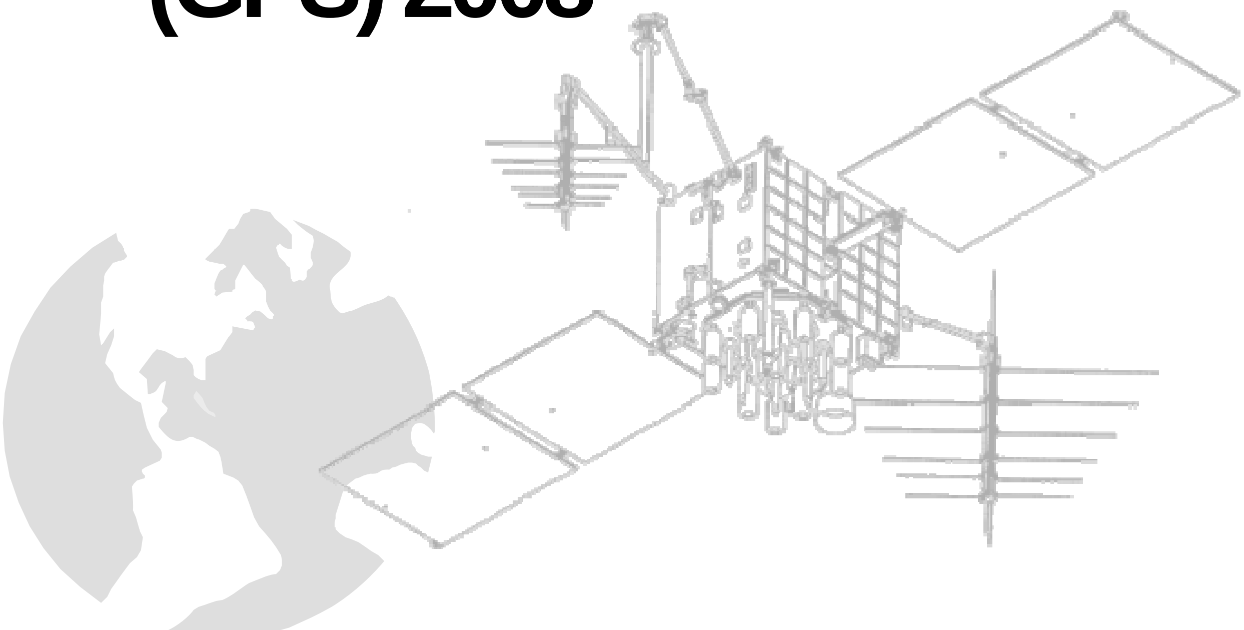
31 October 2008

Department of Defense

Global Positioning System (GPS) 2008



A Report to Congress

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ETWORKS AND INFORMATION
INTEGRATION

OCT 31 2008

FOREWORD

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.

The Secretary of Defense has delegated responsibility for this report to the Office of the Assistant Secretary of Defense for Networks and Information Integration.

The National Coordination Office for Space-Based Positioning, Navigation and Timing, established in 2005, provides the conduit for coordination of this report with appropriate USG departments and agencies.

This document is the sixth in a continuing series of reports. Previous DoD GPS Reports were submitted to Congress in October 1998, 2000, 2002, 2004, and 2006.

John G. Grimes

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Contents

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LIST OF ACRONYMS AND ABBREVIATIONS

AEP	Architecture Evolution Plan
AFB	Air Force Base
AFSPC	Air Force Space Command
AMCS	Alternate Master Control Station
ARNS	Aeronautical Radionavigation Service
ASD	Assistant Secretary of Defense
AT&L	Acquisition, Technology and Logistics
BDA	Burst Detector Analyzer (NDS)
BDP	Burst Detector Processor (NDS)
BMCS	Backup Master Control Station
CDD	Capability Development Document
CENTCOM	Central Command
CHAMP	Challenging Minisatellite Payload (EU Satellite w/ JPL GPS receiver)
CJCS	Chairman of the Joints Chiefs of Staff
cm	centimeter(s)
CNS/ATM	Communications, Navigation, Surveillance/Air Traffic Management
COCOM	Combatant Command
CONOPS	Concept of Operations
CORS	Continuously Operating Reference Stations
COSMIC	Constellation Observing System for Meteorology, Ionosphere, and Climate (NASA)
CXD	Combined X-ray and Dosimeter (NDS sensor)
DASS	Distress Alerting Satellite System
DGPS	Differential GPS
DHS	Department of Homeland Security
DoD	Department of Defense
DOC	Department of Commerce
DOT	Department of Transportation
DSB	Defense Science Board
DSP	Defense Support (satellite) Program
eLoran	Enhanced Long-Range Air Navigation (System)
EMI	Electro-Magnetic Interference
EMP	Electro-Magnetic Pulse
EP	Electronic Protection (Navwar)
EU	European Union
EXCOM	The National Executive Committee for Space-Based Positioning, Navigation and Timing
FAA	Federal Aviation Administration
FCC	Federal Communications Commission
FRP	Federal Radionavigation Plan
FHWA	Federal Highway Administration
GAGAN	GPS Aided GEO Augmented Navigation (India)
GANS	Global Air Navigation System
GBAS	Ground-Based Augmentation System (e.g., NDGPS)
GDGPS	Global Differential GPS (Service)

GETS	GPS Enhanced Theater Support
GLONASS	Global Navigation Satellite System (Russian)
GPS	Global Positioning System
GPS-MT	GPS Metric Tracking (System)
GNSS	Global Navigation Satellite System
GRACE	Gravity Recovery and Climate Experiment (NASA)
HA-NDGPS	High Accuracy National Differential GPS
IALA	International Association (of Marine Aids to Navigation) and Lighthouse Authorities
ICAO	International Civil Aviation Organization
ICG	International Committee on GNSS
iGPS	Proposed Combination of GPS and Iridium Services
ILS	Instrument Landing System
IMO	International Maritime Organization
INS	Inertial Navigation System
IRNSS	Indian Regional Navigation Satellite System
ISS	International Space Station
ITU	International Telecommunications Union
JLOC	GPS Jammer Location
JNWC	Joint Navigation Warfare Center
JPALS	Joint Precision Approach and Landing System
JPO	Joint Program Office
JPL	Jet Propulsion Lab (NASA)
JROC	Joint Requirements Oversight Council
LAAS	Local Area Augmentation System
LPTV	Low Power Television
MAGR	Miniaturized Airborne GPS Receiver
M-Code	Military Code
MGUE	Military GPS UE
MCS	Master Control Station
MILSPEC	Military Specifications
MOA	Memorandum of Agreement
MOU	Memorandum of Understanding
MGUE	Military GPS User Equipment
NAS	National Airspace System or National Air Space
NASA	National Aeronautics and Space Administration
NATO	North Atlantic Treaty Organization
Navwar	Navigation Warfare
NCO	National Coordination Office for Space-Based PNT
NDGPS	National Differential GPS
NDS	NUDET Detection System
NextGen	Next Generation Air Transportation System
NGA	National Geospatial-Intelligence Agency
NII	Networks and Information Integration
NIST	National Institute of Standards and Technology
NOAA	National Oceanic and Atmospheric Administration
NSA	National Security Agency
NSPD	National Security Presidential Directive
NSTC	National Science and Technology Council

NTIA	National Telecommunications and Information Administration
NSP	Navigation Systems Panel
NUDET	Nuclear Detonation
OCS	GPS Operational Control System (or Segment)
OCX	Next Generation GPS Operational Control System
OIF	Operation Iraqi Freedom
ORD	Operational Requirements Documents
PDD	Presidential Decision Directive
PNT	Positioning, Navigation and Timing
PPS	Precise Positioning Service
RTCM	Radio Technical Commission for Maritime (services)
QZSS	Quasi-Zenith Satellite System (Japan)
RNSS	Radio-Navigation Satellite Service
SA	Selective Availability
SAASM	Selective Availability / Anti-Spoofing Module
SAC-C	Satelite de Aplicanciones Cientificas-C (NASA international collaborative satellite)
SAR	Search And Rescue
SBAS	Space-Based Augmentation System (e.g., WAAS)
SC	Special Committee
SIGI	Space Integrated GPS/INS
SORD	System(s) Operational Requirements Document
SPS	Standard Positioning Service
SSV	Space Service Volume
STRATCOM	Strategic Command
TACAN	Tactical Air Navigation (system)
TASS	TDRSS Augmentation Service for Satellites
TDRSS	Tracking and Data Relay Satellite System
TTPs	Tactics, Techniques and Procedures
UAV	Unmanned Aerial Vehicle
UE	User Equipment (also known as “GPS receivers”)
UHF	Ultra-High Frequency
US/U.S.	United States
USD	Under Secretary of Defense
USCENTCOM	United States Central Command
USCG	United States Coast Guard
USG	United States Government
USNO	United States Naval Observatory
USSTRATCOM	United States Strategic Command
UTC	Coordinated Universal Time
UWB	Ultra-Wide Band
WAAS	Wide Area Augmentation System
WRC	World Radiocommunication Conference

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EXECUTIVE SUMMARY

A National Security Presidential Directive (NSPD) for Space-Based Positioning, Navigation and Timing (PNT) was signed by the President in December 2004. The policy provided guidance on the procurement, management, and protection of the GPS segments, and created a The National Executive Committee for Space-Based Positioning, Navigation and Timing (EXCOM) to advise and coordinate among federal agencies on policies, issues, and initiatives pertaining to GPS and related space-based PNT systems. The fundamental goal of the policy is to ensure that the United States maintains space-based positioning, navigation, and timing services, augmentation, back-up, and service denial capabilities that: (1) provide uninterrupted availability of positioning, navigation, and timing services; (2) meet growing national, homeland, economic security, and civil requirements, and scientific and commercial demands; (3) remain the pre-eminent military space-based positioning, navigation, and timing service; (4) continue to provide civil services that exceed or are competitive with foreign civil space-based positioning, navigation, and timing services and augmentation systems; (5) remain essential components of internationally accepted positioning, navigation, and timing services; and (6) promote U.S. technological leadership in applications involving space-based positioning, navigation, and timing services. Various U.S. Government (USG) departments and agencies are using this national policy to develop and deliver more specific directives and instructions for military and civil GPS developers and users.

The DoD remains committed to ensuring a healthy and robust satellite constellation. In the face of fiscal, technical, and programmatic challenges, GPS continues to function at or above specified performance levels. Currently, there are 31 operational satellites on orbit. Two additional satellites are awaiting launch and 12 are in production before the next generation of GPS satellites is anticipated to be ready. Should delivery and launch of the next generation space and control segments be delayed, sustainment of the GPS constellation will be difficult, and the constellation population could fall below the 24 satellites necessary to meet published performance standards. Despite these challenges, great efforts are being made to prolong satellite life and provide other enhancements to increase GPS performance, accuracy, and availability for military and civil users worldwide. In 2007, the control system that monitors the satellite constellation and maintains its precise time and position determination features was converted from a legacy mainframe configuration to a more modern distributed processing environment. The change was thoroughly tested in advance of the transition, and the change was accomplished without disruption to GPS positioning and timing services. Also in 2007, a procurement action was initiated for the next generation control capability, called OCX, which will enable full operation of signal features and capabilities on current and future GPS satellite blocks. The operational capabilities afforded by OCX will be phased in over time beginning in 2011. Finally, in May 2008 a contract was awarded for the next generation of GPS satellites, designated as GPS III, planned for launch beginning in 2014.

In anticipation of the pending GPS III procurement activity, an important announcement regarding future GPS civil service was issued in September 2007. On the recommendation of the DoD, the President approved permanent elimination of the intentional accuracy degradation feature called Selective Availability that had been a part of GPS operational capabilities since the 1980s, though it had been disabled (set to zero) since 2000.

The 2004 NSPD highlighted key space-based PNT goals for the DoD: 1) ensure uninterrupted PNT capability; 2) modernize and improve all GPS segments; and 3) eliminate or mitigate emerging threats. These DoD goals support the overall U.S. interagency goal to deliver a mix of common-use radionavigation systems that will include GPS to: 1) meet diverse PNT user requirements; 2) maintain current services and performance while providing for future growth; and 3) preclude unnecessary duplication of PNT services.

GPS users continue to expand the number of PNT applications for national and economic infrastructures, military operations, and many scientific and commercial efforts. The USG departments and agencies, via the EXCOM, continue to establish GPS as an integral component of the 21st century global marketplace and work to maintain U.S. preeminence in satellite PNT technologies and services. Since the last report, the EXCOM has expanded to include participation by the Department of Agriculture and Department of the Interior. Continued strong support from senior leadership across the USG remains necessary to ensure GPS remains the world's "gold standard" for space-based PNT. In support of this objective, an interagency effort has been underway for the last two years to produce a National PNT Architecture that will guide future investment decisions not only to maintain GPS preeminence but also to determine the best mix of augmentations and complementary technologies to accompany GPS in creating a robust, economical and efficient PNT system of systems for the next 20 years and beyond.

GPS represents the standard for space-based PNT around the world; however, several foreign satellite navigation systems are in active development or becoming closer to operation. As those evolve, the U.S. is making every effort to ensure the foreign PNT systems are compatible or interoperable with GPS. A significant achievement since the last report was the initiation of an International Committee on Global Navigation Satellite Systems (ICG) to serve as a forum to encourage creation of GNSS applications by the developing world. At the urging of the United States, an ICG Provider's Forum was established under the auspices of the ICG to provide a forum for multilateral discussion among the GNSS service providers.

While GPS currently enjoys unprecedented acceptance, new threats to it continue to emerge. In addition to providing affordable modernized space and control segments in a timely manner, one of our greatest challenges is supplying the warfighter with affordable advanced military user equipment and protecting them from jamming, deception jamming, and unintentional interference. The DoD is pursuing an incremental and systematic upgrade to a number of space, control, and user features through the GPS Modernization Program. Maintaining GPS at the forefront of the world's space-based PNT technology can only be achieved through a continued national commitment accompanied by adequate and stable funding throughout the lifecycle of the program.

Global Positioning System (GPS) 2008

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. Since that time, the National Aeronautics and Space Administration (NASA) and the Department of Homeland Security (DHS) have also been included as consulting agencies.

This document constitutes the sixth in a continuing series of reports. Previous DoD GPS Reports were submitted to Congress in October 1998, 2000, 2002, 2004, and 2006.

OPERATIONAL STATUS

The GPS constellation continues to age, but continues to function at or above U.S. Government (USG) published levels of performance.

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 to support PNT users, the GPS constellation is typically maintained by the Air Force at more than 24 satellites. Currently, there are 31 operational satellites on orbit. The constellation consists of 13 GPS Block IIA, 12 Block IIR, and 6 IIR-Modified (or IIR-M) satellites. There are 2 IIR-M satellites awaiting launch. The GPS Modernization Program (which includes IIR-M satellites, as well as future GPS IIF and GPS III satellites) is addressed in more detail later in this report.

Air Force Space Command's (AFSPC) 2nd Space Operations Squadron operates the GPS satellite constellation from Schriever Air Force Base (AFB), Colorado, under the operational command of United States Strategic Command (USSTRATCOM), headquartered at Offutt AFB, Nebraska, exercised through the Joint Forces Component Commander for Space at Vandenberg AFB, California.

While the GPS constellation is healthy, many satellites are approaching or beyond the end of their design life. Of the 31 GPS satellites currently on orbit, 20 are past their design life, and 19 are without redundancy in either the navigation mission equipment or the satellite bus, or both. However, a sufficient number of satellites are available for launch to ensure that the U.S. meets its national and international commitment to maintain constellation health for the near-term. Should GPS IIF launches be delayed, sustainment of the GPS constellation will be difficult, and the USG could fail to meet performance levels prescribed in published federal plans and standards.

The GPS Operational Control System (OCS) consists of the Master Control Station (MCS) at Schriever AFB, CO; the Alternate Master Control Station (AMCS) at Vandenberg AFB, CA; four dedicated (and one shared) remote Ground Antennas, and six dedicated Monitor Stations worldwide. GPS tracking data from ten National Geospatial-Intelligence Agency (NGA) monitor stations are now included in the GPS OCS. The NGA monitor stations enable the OCS to provide improved accuracy to all users. This combined Air Force/NGA monitor station network is designed to provide 100% global monitoring capability to improve GPS signal quality, which in the event of satellite problems will minimize the time anomalous navigation signals are visible to users.

The current OCS is being upgraded, as it cannot presently support some capabilities of the newer satellites on orbit. The ongoing Architecture Evolution Plan (AEP) upgrade is replacing aging hardware and software and, when complete, will provide full legacy functionality for the GPS IIR, IIR-M, and IIF satellites and will also provide full Selective Availability/Anti-Spoofing Module (SAASM) functionality. An AEP transition from legacy mainframe computers to a more modern distributed processing capability was accomplished in September 2007 without disruption to GPS timing or positioning services. The next generation control segment upgrade called OCX (which is now in development by two contractor teams, with plans to select a single team in 2009) will follow AEP as soon as possible to support full modernized capabilities for the IIR-M and GPS IIF, and provide the foundation for GPS III. OCX will also support existing and new interfaces, and together with GPS III and modernized Military GPS User Equipment (MGUE), will eliminate or mitigate existing shortfalls in the current GPS architecture.

The Nuclear Detonation (NUDET) Detection System (NDS) is a secondary mission aboard all GPS satellites. NDS is designed to detect, locate, and report NUDETs in near real-time anywhere on or above the earth's surface. The system supports nuclear force management, integrated tactical warning and attack assessment, space control, and test ban treaty monitoring. Various NUDET detection payloads (or sensors) are hosted on GPS satellites and Defense Support Program (DSP) satellites. NDS employs both fixed site and mobile ground processing to process and report information to various NDS users and senior decision makers. More detailed descriptions of sensors hosted on GPS satellites are provided later.

U.S. NATIONAL SPACE-BASED PNT POLICY

A National Security Presidential Directive (NSPD) for Space-Based PNT was signed by the President in December 2004. This policy provides the departments of the USG guidance on the procurement, management, and protection of the GPS space, control, and user segments. The NSPD stresses that GPS is a national system with international implications that serves military and civilian/commercial needs. It also stresses the importance of compatibility with other space-based PNT systems. These include the existing Russian Global Navigation Satellite System (GLONASS), and the planned Japanese Quasi-Zenith Satellite System (QZSS) and European Union (EU) sponsored Galileo satellite constellation, as well as recently announced systems planned by India and China. Lastly it established the EXCOM, an interagency advisory body co-chaired by the Deputy Secretaries of Defense and Transportation.

The NSPD also established a National Coordination Office (NCO) for Space-Based PNT to provide the EXCOM with subject matter expertise, secretariat support, and to prepare a Five-Year National Space-Based PNT Plan addressing strategies, plans and program implementation for U.S. space-based PNT systems and related systems. The NCO is hosted by the Department of Commerce in its Washington headquarters and is headed by a Director selected by the co-chairs of the EXCOM.

The 2004 NSPD provides six USG goals for maintaining space-based positioning, navigation, and timing services, augmentation, back-up, and service denial capabilities that: 1) Provide uninterrupted availability of positioning, navigation, and timing services; 2) Meet growing national, homeland, economic security, and civil requirements, and scientific and commercial demands; 3) Remain the pre-eminent military space-based positioning, navigation, and timing service; 4) Continue to provide civil services that exceed or are competitive with foreign civil space-based positioning, navigation, and timing services and augmentation systems; 5) Remain essential components of internationally accepted positioning, navigation, and timing services; and 6) Promote U.S. technological leadership in applications involving space-based positioning, navigation, and timing services.

Supporting these goals are other important policy documents produced by various federal departments. These include the DoD GPS Security Policy, the Chairman of the Joint Chiefs of Staff (CJCS) Master Positioning, Navigation and Timing Plan, and the Federal Radionavigation Plan (FRP). These documents provide policy and planning direction to U.S and allied military users of GPS, as well as civil and commercial users. They identify the capabilities, directives, and restrictions of the two primary GPS services: the open Standard Positioning Service (SPS) and the secure Precise Positioning Service (PPS). They also provide information regarding the ongoing transformation of PNT services from a mix of land, sea, and space-based PNT systems to a more prevalent use of space-based systems. These documents also provide policy on navigation aids, as well as wide-area and local-area augmentation systems which can deliver significantly improved position accuracies in comparison to basic GPS service alone. Lastly, they establish guidelines for civil/military and U.S./foreign cooperation to ensure the various existing and planned PNT systems “do no harm” to one another.

SYSTEM CAPABILITIES AND REQUIREMENTS

The major space-based PNT goals of the DoD are: 1) sustain and improve the functionality of the current GPS space, control, and user segments; 2) acquire the necessary modernized space-based PNT capabilities to meet ever growing user requirements; and 3) mitigate emerging threats. To meet these goals efficiently and effectively, the DoD and Department of Transportation (DOT) recommend the delivery of a mix of radionavigation systems (including GPS) to: 1) meet diverse user requirements for accuracy, reliability, availability, integrity, coverage, operational utility, and cost; 2) maintain current services and performance while providing for future growth; and 3) eliminate unnecessary duplication of services.

Selecting a future radionavigation systems mix is a complex task because user requirements vary widely and change with time. While all users require PNT services that are safe, readily available, and easy to use, military requirements add unique defensive, offensive, and security capabilities (e.g., use in electronically and environmentally stressed conditions). Cost remains a major consideration that must be balanced against operational capabilities required by users.

In order to more systematically address this situation, the Assistant Secretary of Defense for Networks and Information Integration (ASD/NII) and the DOT Under Secretary of Transportation Policy (UST/P) jointly sponsored a National Positioning, Navigation, and Timing (PNT) Architecture Study. The study was initiated in early 2006 in response to Department of Defense (DoD) and Civil Agency recommendations to develop a comprehensive National PNT Architecture as a framework for developing future PNT capabilities and supporting infrastructure. Its purpose is to provide more effective and efficient PNT capabilities focused on the 2025 timeframe and an evolutionary path for government-provided systems and services. Initial Architecture development was completed in late 2007 with an enterprise-level version, including vectors and recommendations for assessment of future alternatives. With final approval of the way ahead by the co-sponsors in 2008, transition planning activities are now underway with nearly 30 military and civil departments and agencies participating.

The "Standard Positioning Service Performance Standard" was updated and published by the DoD in September 2008. It documents measures of minimum performance that civil users can expect from GPS. Since GPS first became operational, its performance has continued to improve and exceed performance standard requirements.

One single action that ensures continued high fidelity performance for civil GPS users was the permanent removal of Selective Availability (SA)[1] from future GPS

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[1] Selective Availability, or SA, involved the purposeful degradation of (civil) GPS SPS to deliver SPS accuracy and performance significantly worse than that provided to authorized (military) PPS users. " SA was ordered "set to
(footnote continued)

elements. On September 14, 2007, the Deputy Secretary of Defense issued a memorandum stating, "Pursuant to meeting the requirements set forth in NSPD Number 39, U.S. Space-based Positioning, Navigation and Timing Policy, of December 15, 2004, the DoD will permanently remove the accuracy degradation feature known as Selective Availability from future generations of GPS satellites and military user equipment. In this regard, the Department has initiated a Navigation Warfare program to mitigate potential threats to GPS position, navigation and timing services, thus eliminating the need for the Selective Availability feature." The action to permanently remove SA will eliminate a source of uncertainty in GPS performance that has been of concern to civil GPS users worldwide for some time. While this action does not materially improve the performance of the system, it does reflect the strong US commitment to users that this global utility can be counted on to support peaceful civil applications around the globe. A public announcement of the change was also issued by the Secretary of Transportation at a meeting of the International Civil Aviation Organization in September 2007.

Military Requirements

Broad military requirements and directives are published in the DoD GPS Security Policy, and the CJCS Instruction 6130.01D.[2] More specific statements of required capabilities to operate in stressed environments (including system limitations) are documented in two Capability Development Documents (CDDs). A CDD for GPS III (Block A) and OCX was validated by the DoD Joint Requirements Oversight Council (JROC) on 23 July 2007, and the CDD for Military GPS User Equipment (MGUE) is in coordination for submission to the JROC. Future updates to the GPS III CDD are planned in 2012 to support OCX Milestone B and GPS III Milestone C, as well as GPS III (Block B). These documents define requirements for development and acquisition of effective space, control, and user segment capabilities to ensure U.S. and allied ability to utilize GPS in support of DoD and national security missions.

To fulfill validated requirements regarding preservation of operational military PNT preeminence, the DoD continues to pursue diverse Navigation Warfare (Navwar) activities, which remain a fundamental building block of the overall GPS modernization efforts. The GPS III and MGUE CDDs will document the capabilities-based requirements with threshold and objective values needed to support DoD missions.

Precise Positioning Service (PPS)

Authorized U.S., allied, and federal government users of GPS rely primarily on the PPS. The Air Force designs, develops, and funds GPS Modernization activities through the Global Positioning Systems Wing (formerly known as the GPS Joint Program Office) which also includes Army, Navy, NGA, and Civil personnel. The PPS is based on stringent military requirements and advanced

zero" by the President in May 2000. Since then, SPS users in benign environments have enjoyed virtually the same performance and accuracy as PPS users.

[2] Chairman of the Joint Chiefs of Staff instruction (CJCSI) 6130.01D is also known as the Master Positioning, Navigation and Timing Plan.

cryptography developed by the National Security Agency (NSA) and the Air Force. These ensure the PPS UE continues to operate under harsh electronic and environmental conditions. The cryptography ensures only authorized users get the most secure and robust GPS service. Although more secure and robust than commercial SPS receivers, the legacy PPS devices rely on older security modules and must be keyed with bulky key-loaders or classified crypto paper tapes. Many military GPS users chose to either not key their PPS receivers or forego using PPS receivers altogether in favor of smaller/lighter commercial SPS receivers. Such actions unfortunately increase military user vulnerability to signal disruption from interference or deception.

In the mid-1990s, to improve functionality and security of PPS UE, the Joint Staff directed the Air Force, the National Security Agency (NSA) and trusted vendors to develop the SAASM security architecture. SAASM UE operates with unclassified keying material, lessening the probability of classified compromise. SAASM security, coupled with state of the art physical design, allows UE that is smaller, lighter, longer lasting, and more capable than legacy UE. Once the OCS AEP upgrade is complete, SAASM will enable the operations crews at Air Force Space Command to deliver crypto keying material "over-the-air" to SAASM users around the globe, greatly reducing the need to fabricate, account for, and deliver paper key tapes. There are currently hundreds of thousands of SAASM receivers in the field, with many thousands more on order by the Services and allies for air, land, sea, and space applications. Lastly, SAASM provides a secure bridge from legacy GPS capability to even greater flexibility, functionality, and security with the delivery of Military Code (M-code) signals, MGUE, and GPS III satellites.

Similar to the SPS Performance Standard, the DoD published a "Precise Positioning Service (PPS) Performance Standard" on 27 February 2007. This PPS Performance Standard clearly identifies the minimum performance levels that the U.S./allied military user communities can expect from secure GPS.

Nuclear Detonation (NUDET) Detection System (NDS)

The U.S. NDS mission is shared by the Defense Support (satellite) Program (DSP) and GPS, each with its own supporting ground segment. NDS payloads are hosted on each GPS IIA, IIR, and IIR-M satellite. These payloads consist of optical, particle, EMP, and X-ray sensors, and associated on-board communications and processors. Collectively, these sensors detect, locate, and report NUDET events, and provide clarification regarding less critical non-NUDET events.

Similar to satellite navigation payload components, NDS equipment is subject to aging, damage, and degradation. As a result, not all NDS payloads are fully mission capable. Although NDS is considered secondary to the PNT mission, the NDS community is queried by AFSPC before launch decisions are made (and prior to any constellation configuration changes) to ensure the best possible global NDS coverage without adversely impacting PNT users. When necessary on particular satellites, some or all of the NDS payloads have been turned off to decrease the satellite's power load and extend the life of the satellite's PNT mission. This capability, called power management, has partially alleviated the risk of a GPS "brownout" prior to availability of GPS III satellites.

Federal and Civil User Requirements

Federal Radionavigation Plan (FRP)

The 2005 FRP provides a consolidated statement of policy and plans for USG-provided radionavigation systems. Although GPS is the centerpiece of the U.S. planned complement of radionavigation systems for the foreseeable future and has the capacity to meet or exceed the accuracy and coverage provided by many other radionavigation systems, the FRP acknowledges that GPS is not intended to satisfy the requirements of all radionavigation system applications, particularly in the areas of availability and integrity. Consequently, the FRP describes both complementary radionavigation systems, as well as augmentations to GPS to meet the stringent needs of specific user groups. Further, while the FRP describes system capabilities, it is not considered a requirements document within the DoD requirements and acquisition processes.

Aviation Requirements

Aircraft requirements for navigation performance are dictated by: 1) an aircraft's design; 2) an aircraft's phase of flight and its relationship to terrain; 3) other aircraft that could be operating in the area; and 4) established air traffic control processes. Safety requirements for aviation navigation performance are dictated by the physical constraints imposed by the environment and the craft, as well as the need to avoid the hazards of collision, severe weather, and unnecessary grounding.

GPS SPS meets the requirements for oceanic en route navigation, as well as navigation used for more 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 more stringent 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 for those purposes.

Augmented GPS SPS can meet Federal Aviation Administration (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 FRP, for en route navigation through near-Category I precision approach.[3] The FAA commissioned WAAS for public use in July 2003 and the U.S. continues to implement ways to make it more effective. The FAA is working with industry to complete design approval of Local Area Augmentation System (LAAS) Category I precision approach capable systems for non Federal procurement by industry and/or airport authorities. Initial deployments and operational use of LAAS Category I systems are expected to start this year. Studies are currently

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

underway to determine whether LAAS meets the requirements for Category II[4] and III[5] precision approach operations. Aviation users are interested in obtaining navigation services using systems that best meet their requirements and business case needs, with stable advanced planning of any necessary transitions.

The Federal Government, in partnership with industry, is modernizing the NAS in order to meet increased future demand. The current effort is called the Next Generation Air Transportation System (NextGen) and is congressionally mandated as part of "VISION 100 – Century of Aviation Reauthorization Act" (P.L. 108-176). In this Act, Congress tasked the FAA, in conjunction with the Departments of Commerce, Defense, Homeland Security, Transportation, NASA, and the White House Office of Science and Technology Policy, to transition the existing US air transportation system into the Next Generation Air Transportation System by the year 2025. GPS and its augmentations and complements have been specifically identified as key enablers for NextGen implementation. GPS has also been highlighted as an enabling technology for capabilities leading to NextGen such as Automated Dependent Surveillance – Broadcast (ADS-B), a means of tracking dynamic aircraft movements throughout the NAS using position reports and other information from individual aircraft.

Land Requirements

Radionavigation requirements for land navigation are most easily categorized in terms of applications. Civil land navigation applications for transportation 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. Real-world GPS SPS performance (without augmentation) consistently meets 10 - 30 meter highway user accuracy requirements, but cannot provide the necessary integrity to warn users when signal integrity is in question. Augmentations are required to meet more stringent accuracy and integrity requirements.
- Rail accuracy requirements range from one meter for positive train control to 10 - 30 meters for position location. As with highway accuracy, unaugmented GPS SPS consistently meets 10 - 30 meter rail user requirements, but augmentations are required to meet more stringent (positive train and rail yard control) accuracy requirements.
- Transit accuracy requirements range up to: five meters for data collection and automated bus/train station information annunciation; 50 meters for vehicle command and control; and 100 meters for Emergency Response. Unaugmented GPS SPS can meet the requirements for Emergency Response and vehicle command and control, but is less reliable to support applications requiring five-meter accuracy.

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

[5] A set of instrument landing approach procedures that provide for approach to a height above touchdown that ranges from less than 100 feet down to zero feet.

An improved National Differential Global Positioning System (NDGPS) will meet most land and maritime PNT requirements. The NDGPS utility augments the United States' Global Positioning System (GPS) by providing increased accuracy and integrity of the GPS using land-based reference stations to transmit correction messages over radiobeacon frequencies from local beacons. The service has been implemented through agreements between multiple Federal agencies including the U.S. Coast Guard (USCG), the Department of Transportation (DOT), and the U.S. Army Corps of Engineers (USACOE).

The predictable horizontal accuracy of the NDGPS Service within all established coverage areas is specified as 10 meters or better. NDGPS accuracy at each broadcast site is carefully controlled and is consistently better than 1 meter. Achievable accuracy degrades at an approximate rate of 1 meter for each 150 km distance from the broadcast site. Typically, users report horizontal accuracies in the 1-3m range using NDGPS.

The High Accuracy NDGPS (HA-NDGPS) research program is sponsored by the FHWA to enhance the performance of NDGPS. The first HA-NDGPS station began broadcasting in a test mode in 2001 with funding from the Interagency GPS Executive Board (IGEB). The IGEB recognized the potential benefit to many Federal agencies, states, and the general public of having a nationwide high accuracy system. Two HA-NDGPS reference stations are currently operational and providing 10 to 15 cm accuracy throughout the coverage area. Further improvements to accuracy and the development of 1 to 2 second time-to-alarm integrity are anticipated.

Maritime Requirements

GPS SPS can meet the navigation requirements for the open-ocean and coastal phases of navigation, but without augmentations, it does not meet the requirements for the Harbor Entrance and Approach phase. The Coast Guard operated NDGPS service 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 Hawaii and Alaska, and the majority of the Mississippi River Basin. Its predictable horizontal accuracy is less than 10 meters and signal availability is 99.7% or greater throughout the coverage area. Typically, users report horizontal accuracies in the 1-3m range using NDGPS. Furthermore, the system broadcasts integrity messages to validate the health of GPS satellites and its own differential signals.

Space Requirements

The GPS signals-in-space are key enablers for a multitude of National Security, civil, and commercial space users. NASA uses GPS signals for the full spectrum of research missions including the International Space Station, the Space Shuttle, Earth/Space Science satellites, research balloons, high-altitude Unmanned Aerial Vehicles (UAVs), and other NASA 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 higher in performance than non-GPS alternatives.

GPS Precise Positioning Service (PPS) receivers have been certified for Space Shuttle navigation. The Johnson Space Center (JSC) was involved in development efforts of GPS receivers for human spaceflight, such as the Miniaturized Airborne GPS Receiver (MAGR-S) used on the Space Shuttle and the Space Integrated GPS/INS (SIGI) receiver currently on the International Space Station (ISS). Orbiters Discovery and Atlantis have a single GPS receiver in addition to retaining their triple-redundant Tactical Air Navigation (TACAN) while orbiter Endeavour has had its TACAN removed and replaced by a triple-redundant GPS system. GPS was applied to navigation during the critical re-entry mission phase for the first time on STS-115 / OV-104 Atlantis and GPS--only navigation was used for the first time on STS-118 / OV-105 Endeavour. The SIGI receivers were tested on shuttle flights prior to deployment on ISS. The ISS has an array of 4 antennas for orbit and attitude determination.

The GPS Terrestrial Service Volume provides service to space users from the surface up to 3,000 km altitude. This includes tracking of space launches and Low Earth Orbit users such as the International Space Station operations and Earth Science missions. In addition, NASA has been engaged with the DoD to define the performance parameters to support navigation services in a Space Service Volume (SSV) designated from 3,000 km to GEO altitude at approximately 36,000 km**.** Users in the SSV include transfer stages leaving low Earth orbit and communication satellites in geosynchronous Earth orbit. NASA's Goddard Space Flight Center has developed a family of receivers which incorporate specialized software to process the side-lobes of GPS signals coming over the earth's limb as well as the increased attenuation and tracking of a very few satellites at a time. Simulations show that these receivers could allow closer spacing of satellites in geostationary orbits, providing a more dense satellite population over crucial areas of the world. They will also improve space vehicle autonomy, thereby reducing mission costs. NASA hopes that this "weak signal" research, coupled with the future advancements of GPS, will pave the way for the use of GPS and GPS-like augmentations in support of future missions to the Moon. As part of their new exploration initiative, NASA envisions that GPS technology and its augmentations go along with our future space explorers as we venture to Mars and into the far reaches of space.

NASA's Jet Propulsion Laboratory (JPL) has developed a high accuracy GPS augmentation system to support the demanding real-time positioning, timing, and orbit determination requirements for NASA science missions. The Global Differential GPS (GDGPS) system enables 10 – 20 centimeter real-time positioning accuracy for users with newer dual-frequency GPS receivers anywhere on the ground, in the air, and in space. Also, NASA is continuing its development of augmentation for the Tracking and Data Relay Satellite System (TDRSS). Named TASS, or TDRSS Augmentation Service for Satellites, it disseminates the GDGPS real-time differential correction messages to orbiting satellites, enabling precise autonomous orbit determination, science processing, and planning operations in Earth orbit. JPL is working with NASA and the Air

Force to fully utilize the unique GPS monitoring capability of the GDGPS system.

A space-based range, otherwise known as GPS Metric-Tracking (GPS-MT), will enable GPS telemetry data to be relayed via NASA's TDRSS and transmitted down to mission controllers. A Memorandum was signed in November 2006 to implement GPS-MT by January 1, 2011 for all DoD, NASA, and commercial vehicles launched at the Eastern and Western ranges.

Non-Navigation Requirements

The use of GPS for non-navigation activities is large and diverse. Some non-navigational activities include surveying, mapping, tracking, geophysical applications, meteorology, communications, power grid management, and timing. Real-time accuracy requirements range down to one centimeter or less than one nanosecond. Post-processed accuracy requirements extend to the sub-centimeter level. GPS SPS augmentations are currently used to meet many of these requirements. Unaugmented GPS SPS continues to meet non-navigation requirements in the 10 – 100 meter (30 nanosecond or higher) accuracy range.

Users who require centimeter-level positioning are able to use a nationwide network of GPS Continuously Operating Reference Stations (CORS). The National CORS network is a GPS augmentation service managed by the Department of Commerce (DOC) via the National Oceanic and Atmospheric Administration (NOAA) that supports non-navigation, post-processing applications. This network provides users with ties to the National Spatial Reference System defined by NOAA's National Geodetic Survey for accurate, three-dimensional, positioning. Typical uses of National CORS include land management, coastal monitoring, civil engineering, boundary determination, mapping, geographical information systems, geophysical/infrastructure monitoring, and future improvements to weather predicting and climate monitoring. This network contains approximately 1,300 stations and is growing at a rate of about eight 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 one site. In particular, it includes all existing NDGPS/DGPS sites and all existing FAA/WAAS ground 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 of which are 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. In this area of investigation, subtleties in the Earth's rotation and polar motion and deformation of the Earth's crust are routinely measured using GPS.

Distress Alerting Satellite System (DASS)
The existing Search and Rescue Satellite Aided Tracking (SARSAT) system that the United States, in addition to Canada and France, uses along with COSPAS, the Russian counterpart, have saved over 20,000 lives worldwide. The current system uses a combination of Low Earth Orbit and Geosynchronous Earth Orbit satellites. The legacy SARSAT is nearing the end of its useful lifecycle as service is expected to degrade as early as 2013. The proposed U.S. SARSAT system replacement is the DASS. A proof-of-concept demonstration for DASS was developed by NASA and includes installing 406 MHz 'bent pipe' repeaters on GPS satellites and a DASS ground station at the Goddard Space Flight Center (GSFC) in Greenbelt, Maryland. Currently the proof-of-concept DASS is included on all GPS IIR(M) and GPS IIF satellites. The operational DASS payload, which would include downlink in the Search and Rescue approved frequency band, is currently being assessed via the interagency requirements process and is a candidate as a secondary payload on GPS III.

GPS Timing and the U.S. Naval Observatory
The U.S. Naval Observatory (USNO) Master Clock is the timing standard for DoD and, as such, GPS. Coordinated Universal Time (UTC) as realized by the U.S. Naval Observatory Master Clock is known as UTC(USNO), and is the most precise time in the world. The standard international reference for timing is UTC. UTC is not a real time source, but is a "paper clock" derived once a month by combining input from approximately 50 timing centers around the world, including the USNO and the National Institute of Standards and Technology (NIST) in Boulder, Colorado. The largest single contribution to international UTC (approximately 40%) is from the atomic frequency standards (or clocks) maintained at USNO. GPS is the primary method (and the best method) to deliver UTC(USNO) to users worldwide. This precise UTC time is transmitted in the GPS signal-in-space and utilized globally for various applications (e.g., telecommunications, network synchronization, secure military communications, and the tracking of banking transactions, power grids, transportation systems) which support the national infrastructures of the U.S. and numerous other countries. Additionally, GPS utilizes atomic clocks at each dedicated Monitor Station and on-board each satellite to keep its own internal system time used for navigation purposes. Maintaining accurate atomic clocks is essential because the accuracy of GPS time relates directly to the location accuracy used for positioning and navigation. For instance, a user incurs approximately one added meter of location error for every three additional nanoseconds of timing error.

The USNO continues to improve its baseline timing capabilities and performance with new physics and software packages applied to atomic frequency standards and technologies. The addition of Rubidium Fountain clocks will aid in improving future time accuracy and general performance of GPS.

PROGRESS IN MODERNIZING GPS

The DoD is continuing a significant investment to modernize GPS and enhance its ability to meet growing military and civil PNT needs.

The objectives of the GPS Modernization effort are to improve position and timing accuracy, availability, robustness, signal monitoring capability, and to enhance the GPS (ground) control segment to increase its efficiency in continuing seamless operation of the highly dependable PNT service GPS has come to represent for all users. The process to incorporate data from NGA monitor stations into the OCS has been completed and, the combination of NGA and Air Force monitoring stations significantly improves constellation monitoring capabilities.[6] The National PNT Architecture effort has also highlighted the importance of GPS Modernization to maintaining GPS as a cornerstone of the future PNT Architecture.

The ongoing GPS Modernization Program modified a total of eight Block IIR satellites (re-designated as IIR-M) by adding the new M-code military signal at L1 and L2[7] and a second civil signal at L2 (known as L2C). Six IIR-M satellites have been launched since September 2005. Two remaining IIR-M satellites are planned to be launched during 2009. The M-code signals represent a significant performance improvement for authorized military users with keyed M-code capable user equipment. M-code provides a robust encrypted signal which is spectrally separated from the existing GPS signals to facilitate compatibility with Navwar operations and support US intent to limit Navwar impact on civil GPS applications. An advanced security architecture applied to M-code also makes it less vulnerable to deception jamming. To utilize M-code and its capabilities, the DoD has directed the GPS Wing to design, and the Services to procure, M-code capable user equipment. Existing legacy and SAASM PPS UE cannot process M-code. For civil SPS users, L2C delivers dual frequency capabilities which will correct for errors caused by the ionosphere.

An additional version of modernized GPS satellites, Block IIF, is planned for launch beginning in mid 2009. These satellites will incorporate the same signals as the Block IIR-M, as well as an additional civil signal (L5)[8] that is designed specifically for safety of life applications, in particular for aviation use. L5 will introduce triple-frequency GPS capability, enhancing the robustness of service and enabling new techniques for high accuracy positioning. Also, in response to existing and emerging threats, the IIR-M and IIF satellites include a "Flex Power" capability which will allow satellite power to be transferred between the legacy military signals and M-code to provide increased protection in an interference or jamming environment. Corresponding improvements to the GPS OCS/OCX infrastructure will also be implemented to fully support existing and future satellites.

The next stage of GPS Modernization includes the development and fielding of the next generation GPS satellite, GPS III. GPS III, when combined with OCX control segment upgrades and MGUE, will provide improved anti-jam

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[6] The standard global coordinate reference frame (World Geodetic System 1984) is defined by NGA based largely on the precise GPS-derived positions of the combined network of Air Force and NGA monitor stations.

[7] L1 is at 1575.42 MHz in the L-Band spectrum. L2 is at 1227.60 MHz.

[8] L5 will be at 1176.45 MHz in the L-Band spectrum.

capability, accuracy, availability, integrity; and is intended to satisfy military and civil requirements through and beyond 2020. An Acquisition Decision Memorandum was signed on 8 May 2008, authorizing the Air Force to proceed with procurement of the first four GPS III (Block A) satellites. Subsequent acquisition decisions regarding additional Block A satellites, and future GPS III blocks, will follow directed technology assessments and DoD requirements process actions. The target date for launch of the first GPS III satellite is 2014.

A critical element of the GPS III acquisition strategy, required by the NSPD, is that civil agencies fund civil-unique requirements. Per the 2004 NSPD, the DOT is committed to providing resources for new civil unique capabilities in GPS III to include the new civil signal, L1C, and for civil signal performance monitoring. The DOT provided $7.2 million in FY 2008 to support civil-unique GPS modernization requirements and concluded a Memorandum of Agreement with DoD to transfer the funds to the GPS Wing. Stability of both civil and military funding will be essential if the GPS III procurement is to proceed successfully. This will represent an additional challenge for the Departments and for the congressional committees overseeing the different budget requests to maintain that stability.

Another of the challenges facing the DoD throughout the GPS modernization process involves requests from military and civil users to modify existing payloads or add payloads which increase the size, weight, and power requirements for future GPS satellites. All such requests must be validated through the rigorous DoD or interagency requirements process, as appropriate, as they present significant financial and schedule consequences for the DoD. Interagency (military and civil) requests that are currently being considered include addition of the DASS and laser reflectors to future GPS III blocks.

CONGRESSIONAL QUESTIONS REGARDING GPS III AND RELATED ACTIVITIES

In the Conference Report accompanying the FY 2008 National Defense Authorization Act (H.R. 1585), dated December 6, 2007, the conferees requested that the Department address specific issues with respect to GPS III and related activities. They noted that the block approach adopted for GPS III is a good step toward reducing technical risks and ensuring that the program stays on budget and schedule. However, they were concerned that capabilities like spot-beams and cross-links may not be properly phased to support the warfighter requirements or may no longer be required. They therefore requested that the DoD and the Secretary of the Air Force examine the GPS acquisition strategy and warfighter requirements to determine the appropriate next generation capabilities to include in each subsequent block to meet user needs, while maintaining schedule, cost, and appropriate level of technical risk. This request is consistent with the direction contained in the May 8 Acquisition Decision Memorandum for GPS III (Block A). A study of content and strategy for future GPS III blocks is being planned by the DoD, to be conducted between October 2009 and March 2011, in preparation for the next GPS III milestone decision.

The conferees also noted that the DoD budget request included funds for other PNT capabilities and augmentations such as the initiative, known as iGPS, that proposes combining GPS signals with signals transmitted through the Iridium communications system. They expressed concern that such investment decisions are being made without an integrated PNT architecture and directed the DoD, as one of the co-chairs of the EXCOM, to report to the congressional defense committees on future PNT-related investments for the next 5 years and an integrated PNT architecture plan. As noted previously, the DoD and DOT have jointly sponsored a National Positioning, Navigation, and Timing (PNT) Architecture Study. The study has been under way since early 2006 and is intended to provide a framework for developing future PNT capabilities and supporting infrastructure and to inform investment decisions accordingly. Its purpose is to provide more effective and efficient PNT capabilities focused on the 2025 timeframe and an evolutionary path for government-provided systems and services. Initial Architecture development was completed in late 2007 with an enterprise-level version, including vectors and recommendations for assessment of future alternatives. With final approval of the way ahead by the co-sponsors in 2008, transition planning activities are now underway with nearly 30 military and civil departments and agencies participating. An essential element of transition planning will be assessments of alternatives specifically addressing proposals such as iGPS and others that involve different combinations of capabilities from communications, digital networks, and diverse other technologies. These alternative assessment activities will begin in 2009 and continue over the next several years as the Architecture is further evolved. An initial report of the Architecture development activity and recommendations for further actions was released by the DoD/DOT team in September 2008. With regard to the request for future PNT-related investment plans, the NCO, on behalf of the EXCOM, is currently preparing an annual update to the National Space Based PNT Five Year Plan, which is planned to be available by December 2008.

INTERNATIONAL COOPERATION AND CHALLENGES

Civil, Commercial, and Scientific Activities

In late 2006, a multi-lateral International Committee on GNSS (ICG) was established under the auspices of the United Nations Office of Outer Space Affairs to stimulate support and awareness of international GNSS cooperative activities. The ICG provides an international forum for disseminating information regarding GNSS status and capabilities. An important objective of the ICG is to reach out to developing countries to promote the use of civil space-based positioning, navigation and timing applications and address related technical issues. Among the activities to be taken up by the ICG are: supporting the establishment of standard reference frames and GNSS performance monitoring; increasing awareness of protecting GNSS spectrum from interference and providing assistance to developing countries in identifying and eliminating sources of electromagnetic interference; and increasing educational opportunities related to GNSS application and use. Further, in order to enable focused discussions on compatibility and interoperability among current and future global and regional space-based systems, a Providers' Forum affiliated with the ICG was also recently established. The Providers' Forum includes representatives from the U.S., the European Union, Russia, Japan, China, and India, comprising all current and prospective providers of GNSS services.

The first meeting of the ICG was held in Vienna, Austria in November 2006. The second meeting, which included the inaugural meeting of the Providers' Forum, was held in Bangalore, India, in September 2007. The next meeting of the ICG and Providers' Forum is being hosted by the United States and will be held in Pasadena, CA, in December 2008. Russia plans to host the following meeting in 2009.

The U.S. and Japan continue to enjoy an excellent working relationship with respect to GPS cooperation. U.S. and Japanese experts have engaged in technical discussions since 1998 to ensure that GPS and the proposed Japanese space-based GPS augmentation known as the Quasi-Zenith Satellite System (QZSS) complement each other and increase utility for civil PNT users in the Pacific Rim. During 2008, NASA, NOAA, and the State Department conducted discussions with Japan to locate QZSS monitor stations at U.S. facilities in the Pacific region. The monitor stations will serve the same purposes for QZSS (monitoring signal quality and integrity) that USAF and NGA monitor stations serve for GPS.

The U.S. has continued meeting with Russian PNT experts to discuss areas of mutual interest regarding space-based PNT. These ongoing consultations, regarding potential cooperation in future civil signal structure design, are focused on resolving compatibility and interoperability issues between GPS and GLONASS. In April 2008, the Russians announced a major modification to the GLONASS signal structure that will involve broadcast of GPS-like signals in addition to the legacy GLONASS signals. Discussions are under way with Russia to ensure those new signals are compatible with current and planned GPS signals. Discussions are also ongoing to establish interoperability between the search and rescue payloads that will be featured on future GLONASS satellites and potentially on GPS III.

India has recently joined the countries aspiring to national satellite-based PNT services. The U.S. and India have been engaged in policy and technical discussions since 2005 and in September 2007 issued a Joint Statement on GNSS cooperation. The Statement focused on GPS-based augmentation services planned by India through operation of the GPS Aided GEO Augmented Navigation (GAGAN) system. Further, India also plans an independent regional satellite navigation system called the Indian Regional Navigation Satellite System (IRNSS). Continued U.S./India discussions are planned to ensure cooperation and compatibility with GPS and any future Indian space-based PNT system.

The Chinese have recently announced their intention of implementing a Chinese GNSS, called the Compass or Beidou II system. This initiative represents an extension and evolution of an earlier Chinese space-based PNT program known as Beidou. The U.S. has conducted limited technical discussions with China regarding compatibility with GPS signals under the auspices of the International Telecommunication Union, and information is exchanged regarding Compass and compatibility and interoperability with other space-based PNT systems through the previously mentioned ICG Providers' Forum.

NASA continues to participate in international cooperative programs to apply GPS-based Earth observation techniques. Most notable among these are the GPS remote sensing platforms such as the COSMIC, GRACE, SAC-C, and CHAMP satellites that utilize advanced techniques to measure atmospheric and ionospheric weather and climate variability. The GPS-based GRACE (a NASA/German Aerospace Center collaboration) mission is demonstrating a new revolutionary capability to measure the transport of mass within the Earth system. Germany, Argentina, and Taiwan are cooperating in these missions. NASA also provides considerable support to the International GNSS Service for cooperative international research and products such as precise GPS orbits and the promotion of new GPS-related activities such as the African Geodetic Reference Network project.

GPS and Galileo

The U.S., the EU, and its member states are continuing cooperative discussion under the GPS-Galileo agreement signed in June 2004. The agreement lays the foundation for a common civil signal to be broadcast by both Galileo and the GPS III constellation. Agreement was reached between the U.S. and EU in July 2007 regarding technical details and designs of the new GPS L1C civil signal and the Galileo equivalent, known as the L1 Open Service signal. Also in 2007, the U.S. and European Community issued a joint fact sheet highlighting the mutual benefits of GPS-Galileo cooperation.

Defense Activities

The DoD continues to support agreements with more than forty allied and friendly nations to enable their access to GPS PPS as a primary source of military PNT information. Such agreements significantly contribute to improved interoperability and situational awareness when those nations join with U.S. forces in allied and coalition operations.

There is concern that adversaries and allies could use emerging satellite navigation systems for future military operations once those systems are fully operational. From an allied standpoint, this could be an impediment to the increased interoperability already achieved through the integration of GPS PPS in numerous U.S. and allied systems and platforms. From an adversarial standpoint, these emerging satellite systems could provide hostile nations increased force enhancement value and allow them precise positioning, navigation and timing similar to that enjoyed by the U.S. today. The DoD is continuing to implement the "International Cooperation Guidance for GPS and Navwar" document released by DoD in Apr 2005, through which various agencies of the USG work in joint and international forums to track these issues and mitigate any operational or political impacts they might cause.

International Standards
Radionavigation services and systems address 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 and recommended practices for international use of radionavigation systems. The International Maritime Organization (IMO) plays a similar role for the international maritime community. Consistent with the goal of advocating the acceptance of GPS and USG augmentations as standards for international use, the FAA and U.S. Coast Guard (USCG) have offered the GPS SPS to ICAO and IMO, respectively, as a cornerstone of future GNSS services envisioned to create a seamless PNT capability for all civil users around the world. Those offers were renewed in September 2007 (ICAO) and July 2008 (IMO). ICAO accepted the renewed offer in December 2007 and a response from IMO is pending (IMO had formally accepted a previous offer).

In 2007, the FAA completed the integration of additional reference stations in Mexico and Canada into the WAAS ground network, thereby expanding the coverage of WAAS to include nearly the entire North American airspace.

The FAA took a leadership role in organizing the original ICAO GNSS Panel in 1993 (which is now known as the Navigation Systems Panel – NSP). As a result, GPS and its augmentations were adopted by ICAO as the international GNSS standard. At present, foreign Space-Based and Ground-Based Augmentation Systems (SBAS and GBAS) conform to ICAO standards. Additionally, the USG continues cooperative activities with Japan, Brazil, Canada, China, India, Mexico, and Russia to promote and assist in the implementation of GPS and its augmentations, and supports regional PNT initiatives and working groups in North America, South America, Europe, and Southeast Asia.

The USCG continues to be an active participant in the International Association of (Marine Aids to Navigation) and Lighthouse Authorities (IALA) in addition to the IMO. The USCG-operated national DGPS system has been adopted by more than 50 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.

An agreement with the Canadian Coast Guard to establish a “seamless DGPS service” between our common borders remains in effect. This service combines the two national 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 those operated by one nation.

Economic Competitiveness of U.S. Industry
The GPS industry continues to experience the same healthy growth it has experienced in years past. GPS has become a household name among the general population, as evidenced by the proliferation of television and print

advertisements touting it as a prominent feature and selling point in new cars and cellular phones, and for tracking children and pets, among myriad other applications. U.S. GPS companies attribute their success to the continuing stability and predictability of the GPS program, performance, and policies, which have allowed them to innovate and compete freely in the international marketplace.

U.S. companies excel at integrating GPS receivers into innovative form factors, with embedded GPS applications appearing in an ever-increasing range of devices. Growing sales, particularly in consumer application products such as car navigation, cellular telephones, and recreational equipment, 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.

User equipment sales represent only a portion of the economic growth potential from GPS applications. As with personal computers, the true value of GPS is not in the cost of the equipment, but in the productivity and growth it enables. U.S. industry has created new services and enhanced existing products by accessing GPS capabilities. One particular area of growth most recently has been in Location-Based Services enabled by the addition of GPS to cell phones and the multiple applications beyond simple navigation the cellular providers can then offer their customers.

In 2006, the Department of Commerce released the results of an economic study on the benefits of GPS modernization, especially the new L2C signal, in terms of productivity gains. Under the most likely scenario, the study forecast $5.8 billion in net productivity benefits from L2C through the year 2030, above and beyond the baseline benefits of the non-modernized GPS. In addition, on the receiver sales side, U.S. companies are already reaping significant economic benefits from the GPS modernization program, having already sold thousands of units of L2C-capable equipment before the signal is fully operational.

The Commerce Department works closely with the U.S. GPS industry to ensure that the international market for space-based PNT goods and services remains open and fair as foreign GNSS capabilities emerge with the potential to disrupt markets through discriminatory behaviors. In particular, DOC co-chairs a working group with the European Commission to ensure a level playing field for competition in the GNSS market as Galileo arrives. The working group met twice during 2007-2008 and maintains open channels for communication on issues such as equal access to intellectual property rights for the commercial development of Galileo receivers.

PROGRESS IN PROTECTING GPS FROM INTERFERENCE

Unintentional and Intentional Interference

The potential harmful effects of interference on GPS services continue to justify attention from the DoD and civil agencies. Whether aiding air traffic control, navigating harbors and restricted waterways, maintaining timing and frequency for critical communications or the electrical power infrastructure, or supporting emergency responders, availability of GPS signals, and backups where necessary, have received careful attention. The DHS in August 2007 completed an Interference Detection and Mitigation Plan which was approved by the President. The DHS and the FAA, through the Volpe Transportation Center, are completing an update to the 2006 GPS Timing Criticality Follow-On Study originally conducted by the Homeland Security Institute in 2005. Additionally, the President's National Security Telecommunications Advisory Committee completed a report to the President in February 2008 regarding commercial communications reliance on GPS. In general, the reports confirmed the susceptibility of GPS to interference. Within the telecommunications infrastructure, backups are in place to mitigate intermittent disruptions to GPS service; however, as the infrastructure becomes increasingly reliant on GPS time and frequency, providers of all affected infrastructure services must also anticipate operations during longer-term GPS disruptions. The reports recommend regular actions to exercise GPS backups under simulated emergency situations.

Infrastructure protection is an ongoing concern in the US. The DHS and the DOT continually assess the adequacy of backup systems for vital transportation functions that rely on GPS. As a result of recent analyses and subsequent discussions, the DHS decision to designate the enhanced Loran (eLoran) system as a national backup to GPS for two dimensional position determination and timing was endorsed by the EXCOM in March 2008.

The FAA continues to operate national air and ground assets that detect and isolate GPS interference sources. DHS (USCG), DOT (FAA), and DoD (STRATCOM) also maintain 24-hour operations centers to receive interference reports, as well as any other important GPS-related information that could impact users around the globe. These centers have established strong working relationships and are developing a Memorandum of Agreement (MOA) to ensure all pertinent GPS constellation health and performance information is shared in real or near-real time.

In October 2007, NGA brought into operation the GPS Jammer Location (JLOC) Master Station. The JLOC system is designed to monitor for GPS interference threats and provide alerts to military users in the field when a threat is detected. The web-based system allows military users to subscribe to automated alerts in their area of interest. Authorized users can download client software to run in mission planning systems. This allows them to view the affected area of degradation based on known GPS threats. By providing the warfighter situational awareness on GPS threats and their predicted effects on military operations, users are able to plan their missions accordingly and also develop tactics to counter the threats where appropriate.

Spectrum Management

Potential interference to GPS signals at L1, L2, and L5 (and subsequent service disruptions) must continue to be addressed through the appropriate regulation of the radio frequency (RF) spectrum used by GPS. The GPS community carefully monitors recommendations regarding emissions limits intended to protect GPS users from potentially harmful interference from Ultra-Wide Band (UWB) and other RF transmission systems. Under rules approved by the Federal Communications Commission (FCC) in consultation with the National Telecommunications and Information Administration (NTIA), certain unlicensed UWB devices (e.g., ground penetrating radars) are allowed to intentionally emit (for specific limited purposes) in the Radio-Navigation Satellite Service (RNSS) bands used by GPS. The emissions of these devices are limited to levels that provide adequate protection to GPS users. However, if those limits are relaxed, or not enforced, they will hamper the ability to protect GPS from interference despite the modernization efforts of the DoD and the interference mitigation efforts of the DHS and DOT mentioned earlier.

The portion of the radio frequency spectrum useful for communications is a finite and heavily burdened resource. Approximately 93 percent of all spectrum use takes place in less than one percent of the total available spectrum (below 3 GHz). That narrow region of the spectrum is popular in part because of favorable technical characteristics and its related suitability for various kinds of services. As a result, the protection of the portion of spectrum used by GPS is of critical importance to both existing GPS, as well as the planned GPS modernization.

MILITARY SYSTEM EFFECTIVENESS

National Security Operations

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 of GPS through a combination of increased power from space, investment in MGUE, and selectively upgraded high-priority surface, air, and space platforms with additional anti-jam features. Other Navwar goals include preventing adversary exploitation of GPS and not unduly disrupting peaceful use of GPS outside an area of military operations and finding/neutralizing hostile GPS jamming sources. As discussed in many forums, the DoD's program to modernize GPS is already underway with: 1) the addition of flex-powered military signals; 2) PPS UE with advanced antenna electronics and enhanced anti-jam designs; and 3) M-code that is spectrally separated from civil signals.

GPS continues to be a major force enhancement tool in the modernization and upgrade of military weapon systems and combat support platforms, not only in this country, but throughout the world. At the same time, the scientific, economic, and industrial infrastructure of the U.S. and friendly nations are continuing to expand the uses and applications of GPS. Transportation, telecommunications, banking, agriculture, mining, forestry, emergency response services, and search and rescue, are just a few of the industries that rely on GPS positioning and timing accuracy. As a result, the protection, sustainment, and modernization of GPS must remain critical national security objectives. In addition, the continued exploitation of GPS by potential adversaries necessitates the development and employment of capabilities to counter this threat. The DoD continues to address this need through its Navwar development activities.

Impact to Military Operations

Use of commercial SPS receivers continues to be an issue in the Afghanistan and Iraq theaters. In a study conducted in 2006, AFSPC determined that many GPS-impacting interference events were unintentional and self-inflicted, and had a significant impact on commercial (SPS) GPS receivers in theater. Keyed military PPS receivers were not observed to be impacted by this unintentional interference. To mitigate this problem, AFSPC recommended that field commanders enforce the use of keyed military PPS devices for combat and combat support operations. It also advised that USCENTCOM update any EMI-related CONOPs and expand the duties of their centralized spectrum management office to better track and troubleshoot negative impacts to GPS in the region's increasingly crowded electro-magnetic spectrum. To address these and other EMI issues, USCENTCOM established and continues to operate the Combined Theater Electronic Warfare Coordination Cell.

These real-world experiences highlight the importance of: 1) keyed PPS user equipment for military operations (versus using SPS receivers or unkeyed PPS receivers); 2) the continued development of Navwar Electronic Protection (EP) hardware, software, CONOPs and TTPs; and 3) timely delivery of M-code, MGUE, and GPS III (with supporting OCX) capabilities.

The DoD also took an important step on 1 October 2007 to align the Joint Navigation Warfare Center (JNWC) with USSTRATCOM. The JNWC had been formally established on 1 October 2004 under sponsorship of the Office of the Secretary of Defense. It is located at Kirtland AFB, New Mexico. The JNWC is specifically intended to look across the range of PNT sources and capabilities, assess evolving threats to U.S. military PNT applications, and develop and demonstrate response techniques and technologies. Its original focus was to achieve synergies among test and evaluation organizations that had been conducting GPS interference tests since the late-90s. In the future, in addition to its test and evaluation responsibilities, the JNWC will also collect and analyze intelligence and threat data, spearhead advanced Navwar development efforts, participate in Navwar-related Crisis Action Planning, and inform/educate the Services, Combatant Commands, and U.S. allies to: 1) minimize reliance on commercial GPS receivers, 2) highlight the importance of protecting our use of PPS, 3) prevent hostile use of space-based PNT when necessary, and 4) not unduly disrupt peaceful PNT use outside an area of operations. As owner of the overall Navwar mission, USSTRATCOM will also ensure the JNWC remains linked to appropriate intelligence sources that aid in the detection and location of hostile GPS jamming sources. As soon as more Navwar capabilities are implemented, U.S. national and regional security objectives supported by GPS will be better maintained. Until then, such GPS-related interests and capabilities remain vulnerable to disruption.

GPS continues to enhance military operations globally and GPS applications are pervasive in all areas of operation. GPS contributions to UAV operations and to precision weapons delivery have been well documented. In future conflicts, DoD will expect to continue expanding the use of GPS enabled systems and applications.

New and improved jammers and jamming employment concepts are expected to emerge as potential adversaries come to recognize and appreciate the asymmetric advantage U.S. and coalition forces now enjoy through the use of GPS. Several countries have openly concluded that GPS jamming is an effective means of disrupting U.S./allied operations. Some manufacturers are even marketing GPS jammers on the internet and in trade magazines. This is another reason why continued Navwar development and implementation are so important.

In the near-term, the most effective protection against jamming and interference during military operations is afforded by keyed PPS user equipment in hostile areas and stressed environments. SAASM equipment, which provides dual frequency/24-channel capability, is the necessary bridge from yesterday's legacy GPS capability to tomorrow's M-code, MGUE, and GPS III capabilities.

SUMMARY

Since the last report to the Congress in 2006, GPS has continued to expand its applications in: 1) the national security and economic infrastructures; 2) the future U.S. and allied military operations; and 3) increasing scientific and commercial industries and venues. Both traditional and nontraditional applications of GPS continue to materialize unabated. The DoD's bottomline goal is to keep overall program risk to a minimum, while delivering modernized space-based PNT capabilities to millions of users worldwide.

The Departments of Transportation, Homeland Security, State, and Commerce, and NASA, continue to work closely with the Department of Defense in establishing GPS as an integral component of the 21st century global marketplace and maintaining U.S. preeminence in space-based PNT technologies and services. Through modernization of GPS and implementation of a National PNT Architecture with GPS as its foundation, the U.S. will ensure GPS remains the world's "gold standard" for space-based PNT.

The continued acceptance and widespread application of GPS will present new challenges to our ability to maintain a decisive competitive edge in the battlespace of the future. To meet these challenges, DoD Navwar activities have included demonstrations of existing and emerging capabilities, and provided new tactics, techniques and procedures for the warfighter. Plans to expand the use of GPS anti-jam technologies and develop methods to access alternative sources of PNT information continue to be paramount to DoD mission success. To be fully effective, the procurement and fielding of advanced Navwar and PNT capabilities requires the necessary resources and continued senior leadership support in both the executive and legislative branches of the USG.

GPS currently enjoys unprecedented acceptance throughout the world as the global standard for space-based PNT systems. Progress continues in bilateral and multilateral discussions with foreign satellite navigation service providers to ensure compatibility and interoperability with GPS. At the same time, new threats to GPS service and usage continue to emerge. To remain the preeminent space-based PNT system, it is imperative that modernization of the GPS spacecraft and ground control system continues on schedule. The DoD is well on the way to an incremental/systematic upgrade of a number of space, control, and user features through the GPS Modernization Program. Maintaining synchronization of these elements to keep GPS at the forefront of the world's space-based positioning, navigation, and timing technology can only be achieved through a continued national commitment to GPS and Navwar accompanied by adequate and stable funding throughout their lifecycles.

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OCT 3 1 2008

IETWORKS AND INFORMATION
INTEGRATION

The Honorable Daniel K. Inouye
Chairman, Subcommittee on Defense
Committee on Appropriations
United States Senate
Washington, DC 20510-6028

Dear Mr. Chairman:

The enclosed contains the biennial report, *Global Positioning System (GPS) 2008, A Report to Congress* as required by Section 2281 of Title 10 of the United States Code. This report provides the current status of GPS and the direction that the United States Government is pursuing to ensure that it remains an international standard for positioning, navigation, and timing services. The report also addresses questions raised in the Conference Report accompanying the FY 2008 National Defense Authorization Act (H.R. 1585). Similar letters have been sent to the House and Senate Armed Services Committees and to the House Appropriations Committee, Subcommittee on Defense.

Sincerely,

John G. Grimes

Enclosure:
As stated

cc:
The Honorable Ted Stevens
Ranking Member

ASSISTANT SECRETARY OF DEFENSE
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WASHINGTON, DC 20301-6000

OCT 3 1 2008

IETWORKS AND INFORMATION
INTEGRATION

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

Dear Mr. Chairman:

The enclosed contains the biennial report, *Global Positioning System (GPS) 2008, A Report to Congress* as required by Section 2281 of Title 10 of the United States Code. This report provides the current status of GPS and the direction the United States Government is pursuing to ensure it remains an international standard for positioning, navigation, and timing services. The report also addresses questions raised in the Conference Report accompanying the FY 2008 National Defense Authorization Act (H.R. 1585). Similar letters have been sent to the House Armed Services Committee and to the House and Senate Appropriations Committees, Subcommittees on Defense.

Sincerely,

John G. Grimes

Enclosure:
As stated

cc:
The Honorable John McCain
Ranking Member

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WASHINGTON, DC 20301-6000

OCT 3 1 2008

IETWORKS AND INFORMATION
INTEGRATION

The Honorable Ike Skelton
Chairman, Committee on Armed Services
United States House of Representatives
Washington, DC 20515-6035

Dear Mr. Chairman:

The enclosed contains the biennial report, *Global Positioning System (GPS) 2008, A Report to Congress* as required by Section 2281 of Title 10 of the United States Code. This report provides the current status of GPS and the direction that the United States Government is pursuing to ensure that it remains an international standard for positioning, navigation, and timing services. The report also addresses questions raised in the Conference Report accompanying the FY 2008 National Defense Authorization Act (H.R. 1585). Similar letters have been sent to the Senate Armed Services Committee and to the House and Senate Appropriations Committees, Subcommittees on Defense.

Sincerely,

John G. Grimes

Enclosure:
As stated

cc:
The Honorable Duncan L. Hunter
Ranking Member

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OCT 3 1 2008

NETWORKS AND INFORMATION
INTEGRATION

The Honorable John P. Murtha
Chairman, Subcommittee on Defense
Committee on Appropriations
United States House of Representatives
Washington, DC 20515-6018

Dear Mr. Chairman:

The enclosed contains the biennial report, *Global Positioning System (GPS) 2008, A Report to Congress* as required by Section 2281 of Title 10 of the United States Code. This report provides the current status of GPS and the direction the United States Government is pursuing to ensure it remains an international standard for positioning, navigation, and timing services. The report also addresses questions raised in the Conference Report accompanying the FY 2008 National Defense Authorization Act (H.R. 1585). Similar letters have been sent to the House Armed Services Committee and the House and Senate Appropriations Committees, Subcommittees on Defense.

Sincerely,

John G. Grimes

Enclosure:
As stated

cc:
The Honorable C.W. Bill Young
Ranking Member