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An Analysis of Whether a Single Domestic Backup Navigation System Is Needed for the Global Positioning System (GPS)

Fiscal Year 2011 Report to Congress
September 19, 2011



**Homeland
Security**

Message from the Secretary

September 13, 2011

I am pleased to submit the Department of Homeland Security's analysis of whether a single domestic backup navigation system is needed for the Global Positioning System. This report is being provided in response to the U.S. Coast Guard Authorization Act of 2010, Section 219, Supplemental Positioning System.

This report is being provided to the following Members of Congress:

The Honorable John D. Rockefeller IV
Chairman, Senate Committee on Commerce, Science, and Transportation



The Honorable John Mica
Chairman, House Committee on Transportation and Infrastructure

The Honorable Joseph I. Lieberman
Chairman, Senate Committee on Homeland Security & Governmental Affairs

The Honorable Susan M. Collins
Ranking Member, Senate Committee on Homeland Security & Governmental Affairs

The Honorable Mary Landrieu
Chairman, Senate Subcommittee on Homeland Security Committee on Appropriations

The Honorable Frank LoBiondo
Chairman, House Subcommittee on Coast Guard and Maritime Transportation

The Honorable Rick Larsen
Ranking Member, House Subcommittee on Coast Guard and Maritime Transportation

The Honorable Robert B. Aderholt
Chairman, House Subcommittee on Homeland Security Committee on Appropriations

If you have any questions, please do not hesitate to contact me at (b)(6)

Yours very truly,

A handwritten signature in black ink, which appears to read "Janet Napolitano". The signature is written in a cursive style with a horizontal line extending to the right.

Janet Napolitano

Executive Summary

The US Coast Guard Authorization Act of 2010, Section 219, Supplemental Positioning System legislatively requires that,

“Not later than 180 days after date of enactment of this Act, the Secretary of the department in which the Coast Guard is operating in consultation with the Commandant of the Coast Guard shall conclude their study of whether a single, domestic system is needed as a backup navigation system to the Global Positioning System and notify the Committee on Transportation and Infrastructure of the House of Representatives and the Committee on Commerce, Science, and Transportation of the Senate the results of such determination.”

The Global Positioning System GPS offers three services, Positioning, Navigation and Timing (PNT). To determine the need for a single, domestic system to provide a backup navigation system to GPS, the Department of Homeland Security conducted a survey of the use of GPS services by the United States Coast Guard and the Department of Transportation. Department of Defense and commercial / private sector users of GPS services were not included in this survey. The survey extended to maritime, aviation, and terrestrial navigation modes.

The survey responses show that individual applications utilized within the maritime, aviation and terrestrial modes have adequate backup to GPS for positioning and navigation uses. The survey results did not demonstrate that a single, domestic system is needed as a backup navigation system to the Global Positioning System at this time.

The survey did show that there is a potential lack of adequate backup to GPS for timing services. GPS timing services are of significant National importance for a range of commercial and government applications. Therefore, the Department of Homeland Security is conducting a further evaluation of the existing and potential backups available for timing. The Homeland Security Systems Engineering and Development Institute (SEDI™) report found that, of the 18 Critical Infrastructure Key Resource sectors, 15 sectors currently use GPS timing.¹

The systems utilizing GPS PNT services are integral to the infrastructure on which the U.S. economy and national security rely. The Departments of Defense and Transportation lead a working group that is developing a national PNT architecture and implementation plan.² The Plan promotes a Greater Common Denominator Strategy, where the core needs of many users can be efficiently met through externally-provided, commonly-available solutions, rather than by

¹ National Protection and Programs Directorate, Office of Infrastructure Protection, Infrastructure Coordination and Analysis Office, HS-SEDI™, *GPS Timing Usage Report*, July 27, 2010.

² National Positioning, Navigation, and Timing Architecture Implementation Plan, April 2010

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numerous, individually-customized systems.³ The current de facto PNT architecture consists of an ad hoc mix of externally-provided and autonomous PNT sources as well as PNT augmentations that provide PNT to a wide array of civil and military users.

The Department of Homeland Security, in coordination with other Federal agencies, is taking the following actions to further evaluate the timing issue:

- Assess the degree to which GPS timing services are critical to operations both within and between critical infrastructure sectors;
- Establish the degree to which backup capabilities for GPS timing services are currently in place within the critical sectors;
- Assess the capabilities and robustness of both existing and potential backup capabilities for GPS timing services to support national critical infrastructure needs in case of the loss of GPS timing;
- Determine the need for a single, domestic system to serve as a backup timing service for GPS; and
- Assess the threats, vulnerabilities, likelihood, and risks to the U.S. critical infrastructure dependent on GPS.

³ The overall plan to implement the strategy is to modernize GPS; plan for divestment of projected unnecessarily redundant global navigation satellite system augmentation assets or services; and identify, establish, and monitor levels of service provided by PNT systems.

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An Analysis Of Whether A Single Domestic
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Global Positioning System (GPS)

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I. Legislative Requirement

This report is being provided in response to the Coast Guard Authorization Act of 2010 (PL 111-281; October 15, 2010), Section 219; Supplemental Positioning System (124 STAT 2918) which states:

Not later than 180 days after date of enactment of this Act, the Secretary of the Department in which the Coast Guard is operating in consultation with the Commandant of the Coast Guard shall conclude their study of whether a single, domestic system is needed as a backup navigation system to the Global Positioning System and notify the Committee on Transportation and Infrastructure of the House of Representatives and the Committee on Commerce, Science, and Transportation of the Senate the results of such determination.

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II. Background

Over the past decade, the Global Positioning System (GPS) has grown into a global utility providing multi-use services that are integral to United States national security, economic growth, transportation safety, and homeland security, and are an essential element of the worldwide economic infrastructure. In the statement by then-U.S. President Clinton regarding the United States' decision in May 2000 to stop degrading GPS accuracy, the United States recognized the increasing importance of GPS to civil and commercial users by discontinuing the deliberate degradation of accuracy for non-military signals, known as Selective Availability.

Since that time, commercial and civil applications of GPS have continued to multiply and their importance has increased significantly. Services dependent on GPS information are now an engine for economic growth, enhancing economic development and improving safety of life; and the system is a key component of multiple sectors of United States critical infrastructure. In September 2007, the United States Government (USG) announced its decision to procure the future generation of GPS satellites, known as GPS III, without the Selective Availability feature. In doing this, the USG made the May 2000 policy decision permanent and eliminated a source of uncertainty in GPS performance that had been a source of concern to civil GPS users worldwide until that time.

While the growth in civil and commercial applications continues, PNT information provided by GPS remains critical to U.S. commerce and national security. Consequently, the continuing growth of services based on the GPS presents opportunities, risks, and threats to United States homeland, and economic security. The widespread and growing dependence on GPS by military, civil, and commercial systems and key components of the infrastructure has made many of these systems inherently vulnerable to an unexpected interruption in PNT services.

III. Discussion

To fulfill this legislative requirement, the Department of Homeland Security surveyed subject matter experts at the U.S. Coast Guard and Department of Transportation (i.e., Federal Aviation Administration, Federal Highway Administration, Federal Railroad Administration and the Maritime Administration) on the agencies' use of GPS as a source of positioning, navigation or timing (PNT) services. These agencies regulate the majority of maritime, aviation and terrestrial users of GPS for navigation purposes. Due to the limited time to complete this report, the Department of Defense and commercial/private sector civil users of the Global Positioning System were not included in this survey.

The requirements of civil users of GPS PNT services are based upon operational performance characteristics necessary for transportation safety and economic efficiency. For maritime users and aviation, the requirements for navigation are defined in terms of discrete "phases of navigation." These phases are differentiated primarily by the characteristics of the navigation problem as the vehicle passes through different regions in its voyage. Phases of navigation are not as applicable to land transportation, due to the greater flexibility afforded land users to assess their position. Requirements differ depending upon user application, the type of transportation system, and the user location.

This report addresses the three aspects of GPS services.⁴ These services are:

- Positioning, the ability to accurately and precisely determine one's location and orientation two dimensionally (or three dimensionally when required) referenced to a standard geodetic system;
- Navigation, the ability to determine current and desired position (relative or absolute) and apply corrections to course, orientation, and speed to attain a desired position anywhere around the world, from sub-surface to surface and from surface to space; and
- Timing, the ability to acquire and maintain accurate and precise time from a standard, anywhere in the world and within user-defined parameters; timing also includes time transfer.

Maritime Systems Using GPS PNT Services:⁵ Many maritime systems depend, in part, on GPS for their safe, secure, and efficient operation and this dependence is continuing to increase. GPS is a critical capability that is used by the Coast Guard, other military services, ocean research vessels commercial shipping, ferries, recreational boaters, port pilots, as well as many other

⁴ National Coordination Office, <http://www.pnt.gov/> - *What is PNT?*

⁵ This is not a comprehensive list, only a sampling of maritime, aviation and terrestrial modes which are dependent on GPS PNT services.

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commercial maritime uses. It is a key component to the proper operation of most shipboard integrated navigation systems, including the Automatic Identification System (AIS). Primary uses are identified by three focus areas: safety of navigation, efficiency of the Marine Transportation System and maritime security and domain awareness.

GPS provides significant advantages over traditional means of maritime navigation in that it allows for more accurate, near real time, electronic PNT information that may readily displayed and updated. Although marine users could continue to function using traditional means of navigation and communications, loss of GPS would impact navigation safety in general and would eliminate the AIS, which is the nation's primary Maritime Domain Awareness tool for vessel tracking and security. Thus, the consequences of a total loss of GPS for any significant period of time would be a degradation of maritime safety, efficiency of transportation, and port and harbor security. The U.S. Coast Guard continues to monitor advancements in alternative PNT solutions developed by industry as an alternate system to GPS for use in the maritime environment.

Despite the inherent economic and safety advantages of using GPS as opposed to traditional means of navigation, there are sufficient means in place for mariners to fix their position, determine a safe course to steer and avoid unseen dangers in any of the three phases of navigation: ocean, coastal, and harbor/harbor approach. These additional means include radar, visual bearings, fathometer readings and celestial navigation.

Aviation Systems Using GPS PNT Services: The aviation industry uses GPS and its augmentation systems (such as Wide Area Augmentation Systems and Ground Based Augmentation Systems) for aviation users to fly direct routes, area radionavigation routes between departure and arrival airports at high altitudes, terminal routes within the local area of airports at low altitudes, and both two-dimensional and vertically guided instrument approach procedures to runways. GPS PNT services are also planned for aircraft surveillance by broadcasting the GPS-determined position to other aircraft and the Air Traffic Control system, which will use this information to provide situational displays that are used to ensure aircraft are safely separated from one another.

Terrestrial Systems Using GPS PNT Services: GPS PNT services are extremely important to transportation response, planning, information exchange and recovery of the road systems. Traffic incident management programs and resources include full function safety and service patrols that respond to incidents on the roadways and use PNT services to geo-locate accidents, which significantly reduce first responder response to an incident. These services are also integrated into traffic management systems to optimize traffic flow during an emergency to detoured traffic.

Heavily populated metropolitan areas use GPS PNT services to synchronize traffic signals for optimal traffic flow based on traffic characteristics during particular times of day. GPS is also used for highway advisory radio transmissions. Synchronization ensures transmissions do not

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interfere with one another when uniform messages are delivered to motorists such as emergency road work closures and AMBER alerts. Similarly, GPS PNT Services are used for truck size and weight enforcement. State officials are utilizing this technology to report size and weight of trucks autonomously. The key component to truck enforcement is weigh-in-motion telemetry that is highly dependent on geo-spatial information that is provided by GPS as a fundamental element of the enforcement site's identification.

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IV. Conclusions/Proposed Action

There currently is no overarching, independent backup system or systems to GPS utilized by any particular agency or group of agencies. Although there is experience with short-term, localized GPS outages, it was outside the scope of the survey to investigate specific user response in those situations.

Based on the survey responses, it appears that individual applications utilized within the maritime, aviation and terrestrial modes have adequate backup to GPS for positioning and navigation uses. The survey results did not demonstrate that a single, domestic system is needed as a backup navigation system to the Global Positioning System at this time. The navigation backups being employed at this time are independent, mission-specific or both. It is difficult to assess the implications and/or benefits of a single national navigation system able to meet all USG requirements due to the complex mission-specific systems currently being used. Absent a national backup capability, agencies have begun to investigate and deploy alternative mission-specific PNT solutions.

The impact of loss or disruption of GPS varies based on a number of factors. These variables include the specific function or application being supported by GPS, the duration of the loss/disruption, the geographic size of the affected region, and the availability and implementation of effective backup capabilities and contingency plans. Due to significant interdependencies and the possibility of enterprise-wide cascading affects, the USCG and DoT agencies have taken some measures to ensure continuity of operations in the event GPS PNT services are not available⁶.

Many commercial maritime operators currently use GPS as a primary input to AIS and electronic charting systems for situational awareness, track keeping and navigation. The integration of these onboard electronic systems allows the navigator to readily monitor other vessels in the area for collision avoidance. The Nationwide Automatic Identification System is a key contributor to the Maritime Safety and Security Information System which allows for data sharing of vessel information worldwide. Should GPS as a fundamental requirement of AIS become unavailable in the maritime environment, alternative means for safe navigation and Maritime Domain Awareness that were used prior to the introduction of AIS are still available; however, the safety and efficiency gains for vessel movement provided by AIS could be lost until GPS is restored. Additionally, tests conducted by the General Lighthouse Authorities of the United Kingdom, Ireland and Scotland have indicated degraded performance in a GPS denied environment,

⁶ Agencies surveyed have taken some measures to safeguard against disruptions to the GPS signal that are likely to be encountered; however, to date, no industry or Government exercise has sought to replicate the impact of a long-term or permanent GPS outage simultaneously on all industries. The likelihood of such an outage is also undetermined. NSTAC Report to the President on the Commercial Communications Reliance on the GPS, February 28, 2008.

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including incorrect speed indications, display of hazardously misleading information and incorrect navigation and maneuvering information.

The Federal Aviation Administration retains ground-based radionavigation systems to sustain flight operations in the event of the loss of GPS navigation and positioning services; consequently, GPS PNT services are not essential to maintaining the National Airspace System. However, air traffic control systems dependent on terrestrial communication services may be impacted by the loss of GPS-based timing services. Further, as the National Airspace System evolves to the Next Generation Air Transportation System, greater reliance will be placed on the Performance-Based Navigation operations enabled by GPS, such as various Trajectory-Based Operations. Performance-Based Navigation operations help increase the capacity of the National Airspace System to deal with the anticipated increased demand for aviation services. These efficiency benefits would not be supported by the retained ground-based radionavigation systems and would be lost throughout the duration of a GPS outage, resulting in disruption and delays.

The terrestrial navigation mode of GPS PNT services has proliferated over the last decade. The level of impact resulting from a loss of PNT services will depend significantly on the transportation mode and the extent to which GPS PNT services have been integrated into modal operations. Backup capabilities for rail, pipeline, and highway operations vary greatly between modes.

For rail, the extent of the transition from the use of a physical wayside signal and track circuit-based position determination approach to virtual signaling systems and GPS-based position determination will establish the need for GPS PNT backups. In the near term, while physical wayside signals and track circuit-based position determination continue to be operated in parallel with virtual signals and GPS-based positioning, railroads may fall back to operations based solely on the former. The loss of efficiency, and the level of safety resulting from loss of GPS PNT services, will depend upon the extent to which non-GPS PNT-based operations have continued to be exercised by individual railroads. Railroads that have maintained their physical wayside signals and track-based position determination systems in a good state of repair, and have regularly exercised operations utilizing these systems, will have significantly more efficient and safe operations than those railroads that have not.

In the long term, railroad operations will transition from a combination of physical wayside signal and track circuit augmented with GPS PNT virtual signal and location determination-based systems entirely to GPS PNT-based system. Physical wayside signals and track circuits will almost certainly be eliminated due to the extremely high cost of their maintenance compared to GPS-based systems. When this transition to GPS PNT-based services has been completed, loss of GPS PNT services will have a significant, if not potentially catastrophic, adverse impact on railroad efficiency and safety. Fall back methods of rail operations in this situation will, by necessity, be based entirely on manual train control systems first introduced in the 1880's. Even

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if well exercised, throughput will be decreased and the level of safety risk resulting from manual operations increased

Of the three GPS-provided PNT services, timing is the most critical component; loss of timing services is considered more significant than loss of positioning and navigation. The survey revealed that there is a potential lack of adequate backups to GPS for timing applications. GPS timing services are of significant National importance for both commercial and government applications. This is indicated by the President's National Security Telecommunications Advisory Committee report which stated that commercial communications networks are significantly reliant on GPS for network timing⁷. The Homeland Security System Engineering Development Institute (SEDITM) report also found that, of the 18 Critical Infrastructure Key Resource sectors, 15 sectors use GPS timing⁸.

The systems described are integral to the infrastructure on which the U.S. economy and national security rely. The Departments of Defense and Transportation lead a working group that is developing a national PNT architecture and implementation plan⁹. The Plan promotes a Greater Common Denominator Strategy, where the core needs of many users can be efficiently met through externally-provided, commonly-available solutions, rather than by numerous, individually-customized systems¹⁰. The current de facto PNT architecture consists of an ad hoc mix of externally-provided and autonomous PNT sources as well as PNT augmentations that provide PNT to a wide array of civil and military users.

The Department of Homeland Security, in collaboration with other USG Agencies, will conduct further evaluation of the existing and potential backups to GPS following the guidelines in the National PNT Architecture Implementation Plan. Areas for consideration will be:

- Assess the degree to which GPS timing services are critical to operations both within and between critical infrastructure sectors;
- Establish the degree to which backup capabilities for GPS timing services are currently in place within the critical sectors;
- Assess the capabilities and robustness of both existing and potential backup capabilities for GPS timing services to support national critical infrastructure needs in case of the loss of GPS timing;

⁷ The National Security Telecommunication's Advisory Committee report to the President on *Commercial Communications Reliance on the Global Positioning System (GPS)*, February 28, 2008.

⁸ National Protection and Programs Directorate, Office of Infrastructure Protection, Infrastructure Coordination and Analysis Office, HS-SEDITM *GPS Timing Usage Report*, July 27, 2010.

⁹ National Positioning, Navigation, and Timing Architecture Implementation Plan, April 2010

¹⁰ The overall plan to implement the strategy is to modernize GPS; plan for divestment of projected unnecessarily redundant global navigation satellite system augmentation assets or services; and identify, establish, and monitor levels of service provided by PNT systems.

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- Determine the need for a single, domestic system to serve as a backup timing service for GPS; and
- Assess the threats, vulnerabilities, likelihood, and risks to the U.S. critical infrastructure dependent on GPS.

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V. Survey Questionnaire

1. Please describe your agency's or department's main uses of the positioning, navigation and timing (PNT) services provided by GPS, both for internal purposes and for those purposes which impact your external sector stakeholders (e.g. vehicle navigation systems, handheld PDA electronic maps, emergency vehicle tracking & dispatch, first responder geo-location & routing, air/land/sea navigation, time synchronization, synchronization of remote sensors, automated air/maritime surveillance systems (AIS, ADSB), Incident mapping, personnel locator beacons, location-based services, etc.).
2. Of the PNT services you listed in Question #1, which, if any, are essential to maintain the Nation's critical infrastructure as defined In the US Patriot Act (Section 1016(e): "critical infrastructure" means systems and assets, whether physical or virtual, so vital to the United States that the incapacity or destruction of such systems and assets would have a debilitating impact on security, national economic security, national public health or safety, or any combination of those matters. For each essential use, please indicate which of GPS' capabilities (Positioning, Navigation, or Timing) are required?
3. Per the essential PNT services listed In Question #2, please list the adverse affects of a disruption of GPS PNT services for less than one day, one day, one week, one month and one year If possible, please assign an approximate safety, security, and efficiency dollar value to these hypothetical GPS disruptions.
4. Does your agency or sector have GPS backup capabilities or contingency plans in place so that those critical functions relying on GPS could continue without unacceptable degradation to safety, security, and efficiency of those functions? If so, what are those backup/contingency plans? If not, what are the main reasons that a backup or contingency plan has not been implemented?
5. If a national PNT backup system were to be adopted, that could be incorporated into user equipment as an integrated package, available at a nominal cost, with "fail-safe" GPS capability immune to GPS jamming and interference, would your agency or department be willing to procure the hardware to use it and eliminate any existing redundant systems listed in Question #4? Would you advocate for its use by your external stakeholders? If so, would your interest stem from a safety, security, or efficiency concern?

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