NDGPS Assessment Final Report

Prepared by ARINC Incorporated

for

US Department of Transportation
Federal Highway Administration

Research, Development, and Technology
Turner-Fairbank Highway Research Center
6300 Georgetown Pike
McLean, VA   22101-2296

This page intentionally left blank.

Technical Report Documentation Page

<table>
<tr><td>1. Report No.</td><td>2. Government Accession No.</td><td colspan="2">3. Recipient's Catalog No.</td></tr>
<tr><td colspan="2" rowspan="2">4. Title and Subtitle
NDGPS Assessment Report</td><td colspan="2">5. Report Date
March 2008</td></tr>
<tr><td colspan="2">6. Performing Organization Code:</td></tr>
<tr><td colspan="2">7. Author(s)
Gary Pruitt, ARINC Incorporated
Carl Eric Fly, SEAM</td><td colspan="2">8. Performing Organization Report No.</td></tr>
<tr><td colspan="2" rowspan="2">9. Performing Organization Name and Address
ARINC Incorporated
2551 Riva Road
Annapolis, MD 21401</td><td colspan="2">10. Work Unit No.</td></tr>
<tr><td colspan="2">11. Contract or Grant No.
DTFH61-04-D-00002</td></tr>
<tr><td colspan="2" rowspan="2">12. Sponsoring Agency Name and Address
Operations Research & Development
Federal Highway Administration
6300 Georgetown Pike
McLean, VA 22101-2296</td><td colspan="2">13. Type of Report and Period Covered
Final Report, March 2008</td></tr>
<tr><td colspan="2">14. Sponsoring Agency Code</td></tr>
<tr><td colspan="4">15. Supplementary Notes
FHWA Contracting Officer’s Technical Representative (COTR): James Arnold</td></tr>
<tr><td colspan="4">16. Abstract
This report presents findings an assessment of the user base and applications of the Nationwide Differential GPS (NDGPS) system.</td></tr>
<tr><td colspan="2">17. Key Words
NDGPS, GPS, GPS augmentation, GPS applications</td><td colspan="2">18. Distribution Statement
No restrictions</td></tr>
<tr><td>19. Security Classif. (of this report)
Unclassified</td><td>20. Security Classif. (of this page)
Unclassified</td><td>21. No. of Pages</td><td>22. Price</td></tr>
</table>

Form DOT F 1700.7 (8-72) **Reproduction of completed page authorized**

This page intentionally left blank.

NDGPS ASSESSMENT

EXECUTIVE SUMMARY

Overview of Effort and Methods

The specific objective of this report is to present the results of an assessment of the Nationwide Differential Global Positioning System (NDGPS) system. The goals of this assessment were to document:

- the current status of the NDGPS system;
- current and projected NDGPS user base and applications, with the primary emphasis on assessing transportation system requirements; and
- economic costs and benefits associated with continued NDGPS deployment and operations.

This assessment also addresses the potential impact of ceasing NDGPS operations on current and projected NDGPS users and applications, and the costs and benefits of ceasing operations. This assessment was performed by ARINC Incorporated, and its subcontractor SEAM, who are independent of NDGPS or other GPS service or equipment providers, and who have no business position relative to any decisions regarding NDGPS development, operation, or maintenance operation.

Data was gathered in the generation of this report by a combination of:

- contacts directly with end users;
- a survey of Federal agencies;
- evaluation of responses to the Federal Register Notice on NDGPS (RITA-2007-28836);
- evaluation of responses to a survey by the American Association of State Highway Transportation Officials (AASHTO);
- contacts at trade shows and conferences;
- information from papers and presentations; and
- information from web sites of user organizations, associations and user communities, suppliers, applications developers, Federal/state/local agencies, and others.

This report does not address details of the design or operation of NDGPS, but focuses on the user base, applications, associated economics, and the impacts of discontinuing NDGPS operation.

Overview of NDGPS

The Global Positioning System (GPS) is a space-based positioning and navigation system designed to provide worldwide, all-weather, passive, three-dimensional position, velocity, and time data to a variety of civilian and military users. GPS currently provides a Standard Positioning Service (SPS) available to civilian users. However, while GPS offers many advantages over other navigation and positioning services, many applications require the ability to warn users when the signal should not be used (integrity warnings) and greater accuracy, neither of which is currently provided by SPS. The Nationwide Differential Global Positioning System (NDGPS) provides the user with greater accuracy and other GPS information.

The Differential GPS (DGPS) technique is used to improve the accuracy of the GPS by determining the positioning error at a known location and subsequently transmitting the determined error, or corrective factors, to users of the GPS operating in the same geographical area. In general, DGPS applications can be categorized as either real time or post-processing. Real-time applications receive the broadcasted differential signal and apply the corrections at the time of data collection. The correction process normally occurs in the DGPS receiver and is automatic and transparent to the user. NDGPS provides real-time corrections as well as a source of data for post-processing.

The U.S. Coast Guard (USCG) established a Maritime DGPS Service for maritime applications. DGPS corrections are broadcast on long-established international marine radio-beacon frequencies that are given primary allocation for maritime radio-navigation. The accuracy of the Maritime DGPS (MDGPS) available to real-time users is published as 10 meters, but is observed to be as good as 1 meter under good conditions.

NDGPS is implemented with the same performance parameters as MDGPS, the primary difference being the intended areas of signal coverage. NDGPS and MDGPS accuracy at each broadcast site is carefully controlled and is typically better than 1 meter. Achievable accuracy degrades at an approximate rate of 1 meter for each 150 km distance from the broadcast site. Accuracy is further degraded by computational and other uncertainties in user equipment and the ability of user equipment to compensate for other error sources such as multi-path interference and propagation distortions. High-end user equipment may achieve accuracies better than 1 meter, throughout the coverage area, by compensating for the various degrading factors.

In Presidential Decision Directive NSTC-6, “U.S. Global Positioning System Policy”, (March 28, 1996), the President designated the USDOT as the Nation's “lead agency for all Federal civil GPS matters.” In addition, the President directed the USDOT to "develop and implement U.S. Government augmentations to the basic GPS for transportation applications." NDGPS sites are equivalent to the USCG Maritime Differential GPS sites, but located throughout the United States to provide GPS augmentation signals in areas not covered by the USCG maritime sites. A Memorandum of Agreement (included in Appendix G) was signed by the U.S. Air Force (USAF), the U.S. Army Corps of Engineers (USACE), the National Oceanic and Atmospheric Administration (NOAA), the Federal Railroad Administration (FRA), the Federal Highway Administration (FHWA), the U.S. Coast Guard (USCG), and the Office of the Secretary of Transportation (OST) to establish the NDGPS service. This Presidential Decision Directive was superseded by a new national policy on Positioning, Navigation, and Timing (PNT) on December 8, 2004. The 2004 Directive addresses the roles of various Government agencies in the development, deployment, and operation of GPS and its augmentations. USDOT has the responsibility to “develop, acquire, operate, and maintain Global Positioning System space or terrestrial augmentations for civil transportation applications”. It also says “the details of the cost sharing between; the Department of Defense and the Department of Transportation, for the Global Positioning System; and the Departments and Agencies sponsoring augmentations, and/or unique or accelerated capabilities, shall be outlined in a Five-year National Space-Based Positioning, Navigation, and Timing Plan, consistent with the guidance provided in this policy”.

USDOT formed the DGPS Policy and Implementation Team (PIT), under an Executive Steering Group, to oversee the deployment of NDGPS. The NDGPS PIT Team determined that the most viable option for NDGPS deployment for surface applications would be based on the USCG

DGPS Navigation Service Broadcast Standard. The PIT also determined that the US Air Force intended to decommission the Ground Wave Earth Network (GWEN), which had provided emergency communications at 53 sites. These sites used frequencies close to the USCG DGPS frequencies, were secured areas, and included backup power and hardened equipment shelters. On August 14, 1997, the Executive Steering Group agreed to expand the USCG DGPS network into a nationwide system, using GWEN sites where applicable. On October 27, 1997, Section 346 of Public Law 105-66 (Attachment A to Appendix G) authorized the USDOT to establish, operate, and manage the NDGPS, including taking receipt of necessary GWEN sites and equipment.

NDGPS Advancements

NDGPS is based on the USCG DGPS Navigation Service Broadcast Standard. To build on this foundation, research and development was initiated to provide higher accuracy DGPS solutions. The High Accuracy NDGPS (HA-NDGPS) program will provide the capability to broadcast GPS observables and other data to enable the user to achieve better than 10 centimeter horizontal and 20 centimeter vertical accuracy (at 95% confidence) throughout the coverage area. Additionally, with the use of multiple broadcast stations, sub-centimeter accuracies are achievable. With the timing of the broadcast synchronized to GPS, preliminary work has demonstrated an accuracy of better than 10 meters horizontal can be achieved in the event of a GPS failure. The goals of the HA-NDGPS program are to examine ways to enable 3D dynamic positioning at the centimeter level throughout the US, to co-exist with the existing infrastructure, and to be deployable with minimum deployment costs. The drivers behind the development of High Accuracy NDGPS included the need for higher positioning accuracy for future transportation applications. High Accuracy NDGPS uses the NDGPS infrastructure to transmit data used by GPS receivers to calculate this high accuracy positioning solution. HA-NDGPS modifications to an existing NDGPS site are projected to be less than $100,000, based on the current design. The solution will provide for monitoring to ensure it is providing the accuracy and integrity required for safety-of-life applications. There are currently three NDGPS sites (Hawk Run, PA; Hagerstown, MD; and Topeka, KS) that are equipped to broadcast code and carrier phase observables under test conditions. Testing is expected to continue to support ongoing system development. Further development of HA-NDGPS requirements and design features may be required to address the full integrity monitoring required for safety-of-life applications.

High Accuracy NDGPS will enable a number of future applications that require higher accuracy than now provided by existing civilian GPS augmentation systems. A number of respondents to the NDGPS Federal Register Notice, as well as some of the Federal agencies that were surveyed, supported HA-NDGPS deployment.

Primary NDGPS Applications

Sections 3 through 5, and Sections 14.1 and 14.2, of this report provide detailed lists and descriptions of the current and projected applications of NDGPS. Current users include private industry, Federal agencies, state and local government agencies, and private citizens. There are transportation applications across these user groups, as well as other applications. The applications generally fall into one of the following categories:

- Real-time tracking, navigation, and movement management of mobile assets or personnel;
- Geographic Information System (GIS) applications, which typically combine maps, asset location, and other information to provide the capability to analyze the spatial relationships between multiple layers of geo-referenced data;
- Automated machinery guidance or control;
- Command and control (both safety and non-safety applications) where accurate location of fixed or mobile assets and personnel is required;
- Construction support in terms of accurate placement or location of machines, material, and utilities, including items not visible (such as buried pipes or cabling);
- Mapping and location of cultural resources on landscapes;
- Mapping and location of natural resources on landscapes;
- Planning and applying conservation practices and programs;
- Mapping and location of assets, such as markers, signs, lights, cables, and bridges;
- Mapping and location of maintenance needs and history, such as identifying the location where a piece of fixed infrastructure requires maintenance, or being able to access maintenance history on assets which may be closely spaced;
- Measurement of work performed, where augmented GPS is used to keep track of the precise track of a piece of equipment to automatically log material removed or material placed or deposited;
- Integration of location information with condition monitoring sensors to support remote monitoring of geographically dispersed systems, or to identify the precise location of a monitored or alarmed condition (high G-force, material failures, roadway conditions, etc.);
- Use of NDGPS sites as part of the Continuously Operating Reference Station (CORS) network; and
- Use of NDGPS sites for NOAA data collection.

Transportation Applications: The primary categories of current transportation applications of NDGPS include:

- Providing a field reference for surveys of highway construction projects, or locating fixed survey monuments;
- Supporting field activities related to highway construction, such as construction staking, road centerline location, soil bore location, identifying safe digging areas, locating easement boundaries, locating buried utilities, wetlands delineation, boundary mapping, and navigating to construction sites;
- Supporting road construction planning, traffic studies, access route planning, road jurisdiction determination, and other highway or traffic planning activities;
- Transportation asset management, such as location and status of highway mile markers, signs, culverts, utilities, and other road or roadside features;
- Supporting highway management field activities such as collecting information on road surface condition and pavement ratings, snow drift limits, or other roadside attributes;
- Developing highway maps;
- Documenting traffic accidents and other incidents;
- Supporting roadside environmental applications, applications of herbicides and pesticides, reforestation and wildflower planting along highways, and National Pollutant Discharge Elimination System data collection;

- Positive Train Control;
- Railcar tracking and hazardous cargo tracking;
- Location reference for railroad event recorder logging;
- Track defect location, and other applications to identify and remedy safety issues; and
- Truck routing, terminal management, and monitoring driver Hours of Service.

NDGPS as Part of the CORS Network: The National Oceanographic and Atmospheric Administration (NOAA) coordinate two networks of Continuously Operating Reference Stations (CORS): the National CORS network and the Cooperative CORS network. Each CORS site provides Global Positioning System (GPS) carrier phase and code range measurements in support of 3-dimensional positioning activities throughout the United States and its territories. Surveyors, GIS/LIS professionals, engineers, scientists, and others can apply CORS data to position points at which GPS data have been collected. The CORS system enables positioning accuracies that approach a few centimeters relative to the National Spatial Reference System (NSRS), both horizontally and vertically. CORS data is used by a wide variety of government and commercial users for post-processing applications. NDGPS sites constitute approximately 14.5% of the current CORS sites.

NOAA Data Collection: NOAA uses NDGPS sites for collection of Integrated Precipitable Water Vapor data at NDGPS sites, which are used in severe and long-term weather models; collection of Total Electron Count data at NDGPS sites, which provide data on expected GPS performance in the area around a site; collection of weather data at sensors at NDGPS sites (GPS Surface Observing System); and collection of atmospheric moisture content data at NDGPS sites for input to a tropospheric signal delay model. NOAA also uses NDGPS signals for land surveying, GIS mapping, tracking of aircraft used in remote sensing, and construction support.

Federal Agency Applications: Users from the Department of the Interior and Department of Agriculture use NDGPS for:

- Mapping and monitoring historic and cultural sites, including Native American sites, national monuments, and other historic sites;
- Mapping and maintenance of roads and trails, land, and facilities on Federal land;
- Conducting surveys: hydrographic, sedimentation, wetlands, dam condition assessments, fire perimeters, glaciers, plate tectonic movement, and other surveys;
- Conducting natural resources inventories, including the Natural Resources Inventory (NRI); minerals; helium, oil, gas, and coal reserves; endangered species; wilderness areas; grazing areas; public recreational areas; irrigation systems; timber; fisheries; and other mandated inventories;
- Natural resources management; conservation planning and application; administration of the Farm Bill Program; and locating sensitive resources in the field;
- Law enforcement and park visitor protection and search and rescue;
- Fire management and mapping fire perimeters; and
- Navigation of aircraft to wilderness areas.

Most of these applications are in rural environments, with varying land cover and landscape conditions that are significantly more challenging than unobstructed, open-sky environments. Many of these applications are in wilderness or remote areas, often in conditions of heavy foliage cover and heavy terrain, with limited access, and often in dangerous conditions.

State and Local Agency Applications: State and local agencies identified a wide variety of applications, usually in the field and requiring real-time (vs. post-processing) data collection. The categories of applications include:

- Many of the transportation applications listed above;
- General real-time surveying;
- General navigation and mapping applications, including roads, trails, easements, sinkholes, snow plow operations, locating rural fire hydrants, E911 mapping and addressing;
- Construction support, including construction staking, utility location, line running, soil borings;
- Control adjustments on state augmentation networks;
- Asset inventory and location – signs, storm sewers, sanitary sewers, water mains, utilities, civil defense sirens, curb stops, ADA sidewalk compliance, park assets, park features, tree inventories and tree line delineation, roadside features;
- Conservation management, including location of conservation parcels, wetland delineation, forestry management, mapping archeological sites, environmental protection mapping, soil condition mapping, glacier limit mapping, mapping mining locations, herbicide and pesticide application;
- Location data collection for crime scene investigations, accident investigations, emergency response, fire management, natural resource violations; and
- Cultural resource mapping and monitoring.

Private Industry Applications: Private industry performs many of the same functions as government agencies, in support of private companies, individual private citizens, or government customers. These applications include:

- General surveying, construction staking, providing project control coordinates, and feature location for a variety of applications, including transportation projects; delineation of grading plans and survey plans; plat mapping;
- Navigating to field locations;
- Hydrographic surveys, surveys and mapping of wetlands, flood control; navigation and dredging projects;
- Precision agriculture, including land preparation, seeding, fertilizer and pesticide application, and harvesting;
- Automated agricultural and industrial machine control and machine guidance (human operated) for agricultural and construction, including road construction;
- Resource management, mapping fish barriers, natural habitat restoration;
- Conservation service; providing technical services to farmers and ranchers;
- Biological and scientific studies of wetlands, grasslands, and water purification;
- Utility mapping and asset management; and
- General GIS applications.

Private Citizen Applications: Individual private citizens use NDGPS for precision agriculture, outdoors mapping and navigation, as well as some of the applications previously identified related to travel or locating features in remote areas.

Most users have not documented specific accuracy and integrity requirements for the applications listed above in the various application categories. However, discussions with a number of the user groups indicated that they require at least 1-3 meter accuracy, and in many cases sub-meter accuracy. In responses to the AASHTO survey and the Federal Register Notice on NDGPS, a number of organizations indicated that they supported the deployment of High Accuracy NDGPS. In some cases, new Federal and state regulations, particularly related to environmental control, require a level of accuracy that NDGPS can provide, and require data collection in areas of heavy foliage cover or rugged terrain.

Alternatives to NDGPS

For real-time applications, the primary alternatives to NDGPS are the Federal Aviation Administration's Wide Area Augmentation System (WAAS) and commercial augmentation systems. In areas of clear sky coverage, these systems can provide equivalent performance to NDGPS. There are more WAAS-equipped receivers in the field than NDGPS receivers, which can primarily be attributed to the fact that WAAS is built in to many commercially-available receivers, and that users are unaware of the differences in services. WAAS is used by many recreational users for simple navigation, whereas NDGPS users typically have requirements for accurate navigation and positioning in all environments including wilderness areas, areas with topographical influences, and areas of heavy terrain or foliage which present problems for line-of-sight augmentation systems. Not all owners of WAAS-equipped receivers have activated the WAAS augmentation.

Although commercial augmentation systems are available, they require users to purchase proprietary equipment or software from the service provider, and pay annual subscriptions of up to $2500 per receiver. Advertised accuracy for these services varies from a few meters to sub-meter; some services use WAAS correction signals to achieve these higher accuracies. The precision agriculture industry represents one of the major users of these commercial services. As with WAAS, these services use geosynchronous satellites to distribute the correction data, which suffer from loss of the correction signal on the north side of tree lines or terrain, and under heavy foliage cover.

For many current NDGPS users and their applications as defined in other sections of this report, if 1-2 meter horizontal accuracy is required or if an integrity warning is required, the only viable alternative is more expensive equipment and specialized techniques such as high-accuracy survey equipment or Real-Time Kinematic (RTK) processes. Real-Time Kinematic equipment is 20-30 times more expensive than an NDGPS receiver, and requires advanced training, longer setup time and may require post-processing of position data. To achieve the highest location accuracy, the use of this type of equipment requires the user to set up their own local reference station, wait for it to achieve sufficient "lock" with the satellite constellation to achieve high accuracy (typically 20-45 minutes), and begin to use it. These systems have their own wireless link between the reference station and the user receiver, which is typically limited to line-of-sight. If the user moves out of range (radio range or line of sight) of the reference station, the reference station must be re-positioned, and the user must again wait for the reference station to achieve "lock" with the GPS satellites required for high accuracy. Farmers, surveyors, and other field users who use these types of systems have indicated that there is significant lost time during re-positioning of the reference station. This type of system is not usable for general transportation applications.

NDGPS Performance Compared to Alternatives

NDGPS has the primary attributes:

- *Real-Time Corrections*: It provides real-time differential corrections without the need to set up and move local reference stations, and without the need for a crew to man or secure a portable reference station.
- *Accuracy*: NDGPS provides 1 to 3 meter horizontal accuracy (at 95% confidence) or better, depending on distance from the NDGPS site. No post-processing is required to achieve this level of accuracy.
- *Integrity*: Integrity is the measure of trust that can be placed in the correctness of the information supplied by the navigation system. Integrity includes the ability of the system to provide timely warnings to users when the system should not be used for navigation. (definition from the Federal Radionavigation Plan). In addition to GPS signal correction factors, NDGPS sites also transmit integrity information from individual satellites, protecting against a receiver calculating a position based on bad data. The sites provide an alarm within six (6) seconds of detecting a fault with the signal from any GPS satellite. The 2004 Radionavigation Systems Task Force report indicates that the probability of broadcasting Hazardously Misleading Information (HMI) is ""Not Determined" for NDGPS, but indicates that the system provides an integrity warning within six (6) seconds with an alert limit of 10 meters.
- *Reliability*: The NDGPS network is designed to provide dual coverage (at full network build-out) for signal redundancy, and operates from ruggedized sites with backup power and reinforced towers. Sites also include redundant equipment to ensure high reliability. The sites are monitored from redundant control stations to ensure reliable operation of the NDGPS network.
- *Coverage*: The full network will provide dual coverage at ground level within the Continental United States (CONUS); NDGPS is generally unaffected by foliage, terrain, and building shadowing, unlike satellite-based augmentation systems.
- *Public Infrastructure*: NDGPS uses public infrastructure with no restrictions on choice of receivers and no user fees. Users do not have to set up their own reference stations.
- *No Cost to the User*: NDGPS service is free and available to anyone with an NDGPS beacon receiver.
- *Easy to Use:* NDGPS is simple to use and does not require any advanced training.

The primary advantage of NDGPS over WAAS and commercial satellite augmentation services is that the Medium Frequency beacon signal used to transmit the GPS correction data is able to penetrate heavy foliage and work around natural and manmade obstructions, and inside buildings (as long as a sufficient number of direct GPS signals can be received). NDGPS was designed to work at ground level. Satellite-based augmentation systems suffer from loss of the correction signal in areas on the north side of tree lines or obstructions. Many users in the most Northern states also report problems with satellite-based augmentation systems even in open areas because the augmentation satellite signal is weak in these areas. Satellite-based augmentation systems such as WAAS were not designed for ground-level applications; WAAS was developed to provide GPS augmentation at altitudes greater than 40 meters above the surface level.

NDGPS supports both real-time augmentation and data for post-processing applications. Data from CORS or other ground reference sites can be used for post-processing to provide higher accuracy, but many of the applications listed in this report either require real-time accuracy of the level that NDGPS (or other real-time alternatives) provides, or there are substantial cost savings associated with capturing the data in real time.

Market Factors

While the recent sales of NDGPS receivers have been fairly flat, there was a slight increase in sales from 2005 to 2006. GPS users are becoming more familiar with GPS performance and the ability to use NDGPS to improve performance. Completion of the NDGPS network and further education of GPS users could increase this upward trend. A potentially significant market trend has been the development of more sensitive GPS receivers, which can receive GPS signals in buildings, thereby facilitating navigation and positioning inside buildings. A major application would be homeland security and search and rescue applications, which require an augmented GPS solution, and are a natural application for NDGPS, due to the ability of the augmentation signal to penetrate buildings, terrain, and foliage. The NDGPS broadcast signal also provides the mechanism for delivery of new data streams to users

Impacts of GPS Modernization on Need for NDGPS

A GPS Modernization program is underway to replace aging GPS satellites and add new capabilities. It will include three (3) new signals intended to provide improved capabilities for civilian applications. Launch of GPS Block II satellites is underway, and design contracts for GPS Block III have been awarded. GPS III will incorporate new orbit determination capability to provide increased accuracy. It has been suggested that NDGPS may no longer be needed because GPS III will provide the accuracy needed, and have a stronger signal to provide coverage in areas that NDGPS currently serves. The combination of the new civil signals promises to provide real-time, un-augmented 1-meter accuracy. Future integrity warning networks may provide as short as 1 second notification of loss of GPS integrity. However, the time frame for a complete network of modernized GPS will be 2021+. The GPS III program is undergoing some delays, so the actual date of Full Operational Capability cannot be exactly determined.

Prior to the full deployment of GPS III, the new L2C signal will be available. This new GPS signal provides a more robust code structure to provide enhanced data recovery, will provide a more accurate correction of ionospheric errors, and better carrier tracking than the L1 civilian GPS signal. This should support development of survey grade, more accurate receivers at a lower cost. L2C will also provide an alert flag within six (6) seconds, indicating if an individual satellite signal cannot be trusted. Launches of new GPS satellites with L2C capability have begun, with full constellation capability projected to be in the 2010 - 2012+ time frame.

While at some point in the future, possibly at the point where GPS III is fully deployed, NDGPS can be transitioned out of service, there is no viable alternative to providing the level of accuracy and integrity at ground level that is available from NDGPS. However, it may be necessary to develop and publish a transition plan covering several years in order to allow NDGPS users time to purchase new equipment, develop new application software, change procedures, and train personnel to avoid significant operational and cost impacts. Even after GPS III deployment and operation, requirements for civilian real-time sub-meter accuracy may require NDGPS or other locally-derived correction information. The ability of GPS III to support ground-level, high accuracy, high integrity applications may require further analysis before NDGPS can be completely phased out of service.

NDGPS Costs

The annual costs to maintain the NDGPS network in its current level of build-out is approximately $5 million (FY08 dollars, source USCG).

The projected cost to complete deployment of the NDGPS network to 99% single coverage is approximately $6.0 million.

A projected $3.45 million is needed for recapitalization to replace outdated equipment.

The projected cost to complete deployment of the NDGPS network to Full Operational Capability is approximately $19 million. At full deployment, the estimated annual operating cost is $5.4 million (FY08 dollars, source USCG).

The projected cost to decommission the NDGPS network is $30 million.

Economic Benefits of NDGPS

Insufficient information exits to project dollar savings or benefits associated with NDGPS use for all of the applications listed, or even for selected applications across all users. An estimate was developed of the direct cost on the FHWA Operating Budget associated with NDGPS. Some state DOTs projected the cost impact on their operations of shutting down NDGPS, but no data exists to determine the full range of state and local agencies that rely on NDGPS. Some of the Federal agencies did provide estimates of the cost impact of the loss of NDGPS.

From the data that was collected, the following economic benefits of NDGPS are fairly firm:

- The direct impact on the FHWA Operating Budget if NDGPS is shut down was estimated at $18 million per year, and as high as $106 million per year. This is described in Section 9.1.
- NOAA estimates the economic value of the use of CORS data by a wide variety of users that can be attributed to NDGPS sites at $40 million per year.
- The Department of the Interior National Park Service (NPS) estimates that they would have to purchase $15-18M in new equipment (for 3000 users) to perform functions that they now perform with NDGPS, plus incur additional training, application software changes, and related personnel costs.
- The Department of Agriculture Natural Resources Conservation Service has approximately 7000 NDGPS systems in use (total across USDA). Although they did not provide a replacement cost estimate, if they pursued replacement equipment similar to NPS, this represents approximately $35-42 million.
- Reductions in the application of herbicides and pesticides of 20% or more are attributed to precision agriculture. This is the direct cost associated with the chemicals. This represents potentially billions of dollars in annual savings. However, insufficient

information is available to allocate these savings between NDGPS, WAAS, and commercial augmentation services. Significant additional savings are realized due to reduced environmental remediation resulting from chemical runoff.

- North Dakota DOT projected $335,000-395,000 per year in savings attributable to NDGPS related to highway project control, environmental and wetlands surveys, cultural resource management, and highway surveys. Of this amount, approximately $63,000-72,000 related to highway construction and management may be included in the estimate of the impact on the FHWA Operating Budget in the first bullet above.

Timing of Decision on NDGPS Continued Operation

A number of individuals and organizations surveyed or who responded to the Federal Register Notice indicated that the decision on future funding for NDGPS should be postponed for a number of years, and that at least the current level of funding should be maintained, if not increased to complete the planned Full Operational Capability. The primary reasons provided for not making any decision to shut down NDGPS at this time include:

- Many applications of NDGPS are just starting to mature and increase;
- There has not been sufficient outreach to educate potential users about NDGPS;
- Alternatives that provide equivalent capability, such as that planned in the GPS Modernization program, will not be available for many years;
- Many users have no near term alternative to NDGPS;
- Many private users cannot afford commercial, for-fee alternatives to NDGPS.

User Expectations for Continued NDGPS Operation

The Federal agencies that were surveyed indicated that they have made investments in NDGPS equipment, and have developed procedures and policies around the use of NDGPS in the belief that the full NDGPS network (CONUS dual coverage) would be constructed and maintained, and that USDOT would represent all Federal agencies on matters related to NDGPS and other GPS policy and funding. Several of the Federal agency personnel who were surveyed indicated that consideration of shutting down NDGPS represented a breach of commitment by USDOT in its role as the civilian Federal agency representative for the program. A number of respondents to the AASHTO survey (state DOTs) and to the Federal Register Notice on NDGPS also indicated that they expect NDGPS to be continued in operation, and for the full network be deployed as planned and communicated to the user community.

Opportunities for Cost Sharing

There are a number of Federal, state, and local agencies that use NDGPS. Some of the applications are transportation related, and others are more general surveying, navigation, GIS data collection, and resource and asset management applications. It may be possible to implement cost sharing among Federal agencies. A number of states have begun to implement their own GPS augmentation systems, because they require higher accuracies than available through NDGPS, because they do not have NDGPS coverage, because of the uncertainties of the future of NDGPS, or because they are unaware of NDGPS. Some of these state level augmentation systems are being implemented with partial Federal funding. A number of state and local government agencies are also major users of NDGPS. It may be possible to implement cost sharing with these state and local agencies, but this may be very difficult due to the number of parties involved. It may be more cost-effective to make these agencies more aware of NDGPS and not provide Federal funding for the individual state augmentation networks if NDGPS can satisfy their requirements.

The costs of administering a cost-sharing program should be considered in determining if and how such a program should be established.

Other Observations

Some general observations made during the conduct of this study include:

- There is a general lack of knowledge of NDGPS in the GPS user community. Many users who knew they were using Differential GPS augmentation did not know if they were receiving NDGPS or maritime DGPS signals. Others did not know what kind of system they had, only if it provided the level of accuracy that they needed, or if they had encountered any loss of accuracy during operation. A number of respondents to the Federal Register Notice on NDGPS suggested that more outreach on NDGPS is needed.
- Many states have a need for augmentation, and a number are or are planning deployment of their own augmentation networks. In some cases, they are putting in survey grade networks, and in other cases are implementing a capability that NDGPS could provide. In some cases, they are using NDGPS and complementing the coverage with their own networks. In many cases, the Federal Government is funding part of these independent augmentation networks.

Table of Contents

Page

List of Figures

List of Tables

Acronyms

AAR	Association of American Railroads
AASHTO	American Association of State Highway Transportation Officials
ADA	Americans with Disabilities Act
AFB	Air Force Base
APC	Automatic Passenger Counter
ARTBA	American Road & Transportation Builders Association
BIA	Bureau of Indian Affairs
BLM	Bureau of Land Management
BLS	Bureau of Labor Statistics
CAD/AVL	Computer Aided Dispatch/Automatic Vehicle Location
CBTC	Communications Based Train Control
CEP	Circular Error Probability
CGSIC	Civil GPS Service Interface Committee
CICAS	Cooperative Intersection Collision Avoidance System
COE	Corps of Engineers
CONUS	Continental United States
CORS	Continuously Operating Reference Station
COTS	Commercial Off-the-Shelf
CSAC	Chip Scale Atomic Clock
CSRC	California Spatial Reference Center
DGPS	Differential Global Positioning System
DNR	Department of Natural Resources
DOP	Dilution of Precision
DOT	Department of Transportation
DR	Dead Reckoning
E911	Enhanced 911
eRTK	Enhanced Real Time Kinematic
ESRL	Earth System Research Laboratory
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FOC	Full Operational Capability
FRA	Federal Railroad Administration
FRN	Federal Register Notice
FRP	Federal Radionavigation Plan
FSA	Farm Service Agency
FY	Fiscal Year
G	Measure of Force of Gravity
GASB	Government Accounting Standards Board
GBAS	Ground Based Augmentation System
GDGPS	Global Differential Global Positioning System
GDOP	Geometric Dilution of Precision
GEO	Geosynchronous (satellite)
GIS	Geographic Information Systems
GLONASS	Global Navigation Satellite System
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GSD	Global System Division

GSOS	GPS Surface Observing System
GWEN	Ground Wave Earth Network
HA	High Accuracy
HA-NDGPS	High Accuracy Nationwide Differential Global Positioning System
HDOP	Horizontal Dilution of Precision
HMI	Hazardously Misleading Information
IGS	International GNSS Service
IP	Internet Protocol
IPW	Integrated Precipitable Water
ITCS	Incremental Train Control System
ITS	Intelligent Transportation Systems
ITSA	ITS America
LAAS	Local Area Augmentation System
LIDAR	Light Detection and Ranging
LIS	Land Information System
LOS	Line of Sight
MDGPS	Maritime Differential Global Positioning System
MEMS	Micro Electro-Mechanical Systems
MF	Medium Frequency
NDGPS	Nationwide Differential Global Positioning System
MnDOT	Minnesota Department of Transportation
MOU	Memorandum of Understanding
NASDA	National Association of State Departments of Agriculture
NGS	National Geodetic Survey
NHTSA	National Highway Traffic Safety Administration
NLCS	National Landscape Conservation System
NOAA	National Oceanographic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NPS	National Park Service
NRCS	National Resources Conservation Service
NSRS	National Spatial Reference System
NWS	National Weather Service
O&M	Operation and Maintenance
OPUS	On-line Positioning User Service
OST	Office of the Secretary of Transportation
PDOP	Position Dilution of Precision
PIT	Policy and Implementation Team
PNT	Positioning, Navigation, Timing
POC	Proof of Concept
PTC	Positive Train Control
RD	Rural Development
RF	Radio Frequency
RIDE	Road Inventory Data Entry
RINEX	Receiver Independent Exchange
rms	Root Mean Square
RITA	Research & Innovative Technologies Administration
RTCM	Radio Technical Commission for Maritime
RTK	Real Time Kinematic
SBAS	Space Based Augmentation System
SBIR	Small Business Innovative Research
SEC	Space Environment Center

SHA	State Highway Administration
SOL	Safety of Life
SPS	Standard Positioning Service
TEC	Total Electron Content
UFCORS	User Friendly Continuously Operating Reference Station
USCG	United States Coast Guard
USACE	United States Army Corps of Engineers
USAF	United States Air Force
USDA	United States Department of Agriculture
USDOT	United States Department of Transportation
VII	Vehicle Infrastructure Integration
VRS	Virtual Reference Station
WAAS	Wide Area Augmentation System

This page intentionally left blank.

NDGPS Assessment
Final Report

1. Introduction and Scope of Report

This report was prepared by ARINC Incorporated, under Contract DTFH61-04-D-00002 with the US Department of Transportation, Federal Highway Administration. SEAM is providing subcontract support to ARINC for this task order.

ARINC and SEAM conducted an assessment of the current status of NDGPS and the users and applications of the NDGPS augmentation system.

There are numerous references in this report to the Federal Aviation Administration's Wide Area Augmentation System (WAAS), commercial satellite-based augmentation services, and to individually-owned and operated reference station systems. In most cases, NDGPS is compared to these other augmentation approaches in terms of coverage, performance, capabilities, and ease of use. However, this NDGPS assessment does not provide a comprehensive comparison of these alternative augmentation approaches. Comparisons of NDGPS to these other augmentation systems are based largely on feedback provided by NDGPS users and their experience in using these other augmentation systems.

1.1 NDGPS Assessment Task

1.1.1 Assessment Task Goals

ARINC Incorporated, with SEAM as a subcontractor, was tasked under contract to the Federal Highway Administration to perform an assessment of the current status of the NDGPS system, the user base for the system, and the current and planned applications. The specific objective of this task was to develop an objective assessment of:

- the current status of the NDGPS system;
- current and projected NDGPS user base and applications, with the primary emphasis on assessing transportation system requirements; and
- economic costs and benefits associated with continued NDGPS deployment and operations.

This assessment also addressed the potential impact of ceasing NDGPS operations on current and projected NDGPS users and applications, and the costs and benefits of ceasing operations.

1.1.2 Subtasks

To meet the project goals, ARINC and SEAM performed the following tasks:

- Task 1 – Document Private Sector Users and Applications
- Task 2 – Document Government Sector Users and Applications
- Task 3 – Document Supplier Base and Other Factors Affecting Future Directions
- Task 4 – Document NDGPS Benefits
- Task 5 – Prepare Final Assessment Report

Data was gathered in the generation of this report by a combination of:

- contacts directly with end users;
- a survey of Federal agencies;
- evaluation of responses to the Federal Register Notice on NDGPS (RITA-2007-28836);
- evaluation of responses to a survey by the American Association of State Highway Transportation Officials (AASHTO);
- contacts at trade shows and conferences;
- information from papers and presentations;
- and information from web sites of user organizations, associations and user communities, suppliers, applications developers, Federal/state/local agencies, and others.

The full Statement of Work for the study is included in Appendix G. This assessment was performed by ARINC Incorporated, and its subcontractor SEAM, who are independent of NDGPS or other GPS service or equipment providers, and who have no business position relative to any decisions regarding NDGPS development, operation, or maintenance.

2. Overview of NDGPS

2.1 NDGPS Capabilities

The Global Positioning System (GPS) is a space-based positioning and navigation system designed to provide worldwide, all-weather, passive, three-dimensional position, velocity, and time data to a variety of civilian and military users. GPS currently provides a Standard Positioning Service (SPS) available to civilian users. However, while GPS offers many advantages over other navigation and positioning services, many applications require the ability to warn users when the signal should not be used (integrity warnings) and greater accuracy, neither of which is currently provided by SPS. Therefore, the Nationwide Differential Global Positioning System (NDGPS) provides the user with greater accuracy and other GPS information.

The DGPS technique is used to improve the accuracy of the GPS by determining the positioning error at a known location and subsequently transmitting the determined error, or corrective factors, to users of the GPS operating in the same geographical area. In general, DGPS applications can be categorized as either real time or post-processing. Real-time applications receive the broadcasted differential signal and apply the corrections at the time of data collection. The correction process normally occurs in the DGPS receiver and is automatic and transparent to the user. NDGPS sites also provide a source of data for post-processing, as part of the National CORS network.

Post-processing applications use a multi-step process. First, GPS data is collected at the measurement site and saved in electronic format. Next, the user returns to an office or facility equipped with software applications and access to the Continuously Operating Reference Stations (CORS) archived GPS data files. Finally, the user commences computer calculations to correct the site GPS data using the CORS data.

The U.S. Coast Guard (USCG) established a Maritime DGPS Service for maritime applications. DGPS corrections are broadcast on long-established international marine radio-beacon frequencies (285 to 325 kHz) that are given primary allocation for maritime radio-navigation. The accuracy of the Maritime DGPS (MDGPS) available to real-time users is published as 10 meters (reference: USCG DGPS Navigation Service, COMDTINST M16577.1, April 1993), but is observed to be better than 1 meter under good conditions. USCG has a minimum performance criteria of 8-20 meters for the Harbor Entrance and Approach phase of maritime navigation (reference: page 2-18 of the 2001 Federal Radionavigation Systems document, DOT-VNTSC-RSPA-01-3.1/DOD-4650.5).

The U.S. Department of Transportation (DOT) decided to expand the Maritime DGPS Service for land applications and initiated the Nationwide Differential Global Positioning System (NDGPS). NDGPS is implemented with the same performance parameters as MDGPS, the primary difference being the intended areas of signal coverage. NDGPS and MDGPS accuracy at each broadcast site is carefully controlled and is typically better than 1 meter. Achievable accuracy degrades at an approximate rate of 1 meter for each 150 km distance from the broadcast site. Accuracy is further degraded by computational and other uncertainties in user equipment and the ability of user equipment to compensate for other error sources such as multi-path interference and propagation distortions. High-end user equipment may achieve accuracies better than 1 meter, throughout the coverage area, by compensating for the various degrading factors. CORS offers post-processing users two levels of accuracy: (1) one centimeter using the carrier phase and (2) one meter using the code range.

[Applicable references in Appendix A: 3, 4, 6, 7, 8, 11, 12, 27, 61.]

2.2 Development of NDGPS

In Presidential Decision Directive NSTC-6, "U.S. Global Positioning System Policy", (March 28, 1996), the President designated the USDOT as the Nation's, "lead agency for all Federal civil GPS matters." In addition, the President directed the USDOT to "develop and implement U.S. Government augmentations to the basic GPS for transportation applications." Differential GPS (DGPS) corrections are broadcast on long-established international marine radiobeacon frequencies (285-325 kHz). NDGPS sites are equivalent to the USCG Maritime Differential GPS sites, but located throughout the United States to provide GPS augmentation signals in areas not covered by the USCG maritime sites. A Memorandum of Agreement (included in Appendix G) was signed by the U.S. Air Force (USAF), the U.S. Army Corps of Engineers (USACE), the National Oceanic and Atmospheric Administration (NOAA), the Federal Railroad Administration (FRA), the Federal Highway Administration (FHWA), the U.S. Coast Guard (USCG), and the Office of the Secretary of Transportation (OST) to establish the NDGPS service. USDOT formed the DGPS Policy and Implementation Team (PIT), under an Executive Steering Group, to oversee the deployment of NDGPS. The NDGPS PIT determined that the most viable option for NDGPS deployment for surface applications would be based on the USCG DGPS Navigation Service Broadcast Standard. The PIT also determined that the US Air Force intended to decommission the Ground Wave Earth Network (GWEN), which had provided emergency communications at 53 sites. These sites used frequencies close to the USCG DGPS frequencies, were secured areas, and included backup power and hardened equipment shelters. On August 14, 1997, the Executive Steering Group agreed to expand the USCG DGPS network into a nationwide system, using GWEN sites where applicable. On October 27, 1997, Section 346 of Public Law 105-66 (Attachment A to Appendix F) authorized the USDOT to establish, operate, and manage the NDGPS, including taking receipt of necessary GWEN sites and equipment. One of the primary applications of NDGPS was envisioned to be Positive Train Control.

This Presidential Decision Directive was superseded by a new national policy on Positioning, Navigation, and Timing (PNT) on December 8, 2004. The 2004 Directive addresses the roles of various Government agencies in the development, deployment, and operation of GPS and its augmentations. A new management structure was created to ensure a high level of performance and visibility to the GPS program and its augmentations. The Secretary of Transportation retains lead responsibility for the development of requirements for civil applications for all Federal Government civil Departments and Agencies. USDOT has the responsibility to "develop, acquire, operate, and maintain Global Positioning System space or terrestrial augmentations for civil transportation applications", and to ensure the earliest operational availability for modernized civil signals and services for GPS and its augmentations, in coordination with the Secretary of Defense. It also says "the details of the cost sharing between; the Department of Defense and the Department of Transportation, for the Global

Positioning System; and the Departments and Agencies sponsoring augmentations, and/or unique or accelerated capabilities, shall be outlined in a Five-year National Space-Based Positioning, Navigation, and Timing Plan, consistent with the guidance provided in this policy".

[Applicable references in Appendix A: 1, 2, 3, 5, 57, 61. MOU included in Appendix F. 2004 PNT policy fact sheet included in Appendix H.]

2.3 Augmentation Requirements Considered

There are a number of methods of augmenting GPS location information. Some of these methods provide real-time corrections to data received by a GPS receiver, and others use post-processing to provide corrections after the location data is collected in the field and brought back to an office for augmentation. To address the types of applications for which NDGPS is intended, this effort focused on the use of commercial receivers and applications which have the following characteristics:

- Applications which require real-time corrections and use of the location data, rather than the use of post-processing (this was not intended to limit the use of NDGPS for post-processing applications, but the identification of applications focused on those that would take advantage of real-time correction information) ;
- Applications which require better than the standard 10m accuracy achieved with a typical commercial (non-military signal) GPS receiver;
- Requirements for known confidence and integrity of the location solution being provided by the combination of the GPS receiver and the augmentation source;
- Applications requiring high reliability of the source of augmentation (correction) information;
- Nationwide geographic coverage, typically at ground level for surface transportation and other surface applications;
- Support to operations under tree or other canopy, in areas of shadowing by terrain and buildings, and under conditions of signal multi-path (signal reflections caused by buildings, terrain, or other man-made or natural structures).

2.4 NDGPS Features and Attributes

NDGPS has the following features and attributes relative to these augmentation requirements:

- NDGPS provides real-time differential corrections.
- Accuracy: NDGPS typically provides 1 to 2 meter measured horizontal accuracy (at 95% confidence), depending on distance from the NDGPS site.
- Integrity: Integrity is the measure of trust that can be placed in the correctness of the information supplied by the navigation system. Integrity includes the ability of the system to provide timely warnings to users when the system should not be used for navigation. (Definition from the Federal Radionavigation Plan). In addition to GPS signal correction factors, NDGPS sites also transmit integrity information from individual satellites, protecting against a receiver calculating a position based on bad data. The sites provide

an alarm within 6 seconds of detecting a fault with the signal from any GPS satellite. The 2004 Radionavigation Systems Task Force report indicates that the probability of broadcasting Hazardously Misleading Information (HMI) is “”Not Determined” for NDGPS, but indicates that the system provides an integrity warning within 6 seconds, with an alert limit of 10 meters.

- Reliability: The NDGPS network is designed to provide dual coverage (at full network build-out) for signal redundancy, and operates from ruggedized sites with backup power and reinforced towers. Sites also include redundant equipment to ensure high reliability. The sites are monitored from redundant control stations to ensure reliable operation of the NDGPS network.
- Coverage: The full network will provide dual coverage at ground level within the Continental United States (CONUS); NDGPS is generally unaffected by foliage, terrain, and building shadowing, unlike satellite-based augmentation systems
- Commercial receivers are available from multiple manufacturers.
- Public Infrastructure: NDGPS uses public infrastructure with no restrictions on choice of receivers and no user fees.
- *No Cost to the User*: NDGPS service is free and available to anyone with an NDGPS beacon receiver.
- *Easy to Use:* NDGPS is simple to use and does not require any advanced training.

A Small Business Innovative Research (SBIR) project is underway to explore the capability for an NDGPS receiver to provide a positioning solution even when the user GPS receiver is not receiving GPS satellite signals. The research will determine if the signal from the NDGPS reference station can be used as a ranging signal, and maintain a sub 10-meter location solution as long as the timing can be maintained.

[Applicable references in Appendix A: 6, 8, 12, 18, 20, 24, 27, 39, 40, 41, 45, 61, 70, 80, 110, 116.]

2.5 High Accuracy NDGPS

NDGPS is based on the USCG DGPS Navigation Service Broadcast Standard. To build on this foundation, research and development was initiated to provide higher accuracy DGPS solutions. The High Accuracy NDGPS (HA-NDGPS) program will provide the capability to broadcast GPS observables and other data to enable the user to achieve better than 10 centimeter horizontal and 20 centimeter vertical accuracy (at 95% confidence) throughout the coverage area. Additionally, with the use of multiple broadcast stations, sub-centimeter accuracies are achievable. With the timing of the broadcast synchronized to GPS, preliminary work has demonstrated an accuracy of better than 10 meters horizontal can be achieved in the event of a GPS failure. The goals of the HA-NDGPS program are to examine ways to enable 3D dynamic positioning at the centimeter level throughout the US, to co-exist with the existing infrastructure, and to be deployable with minimum deployment costs. The drivers behind the development of High Accuracy NDGPS included the need for higher positioning accuracy for future transportation applications.

HA-NDGPS provides the user with raw data (GPS observables, tropospheric and ionospheric models, accurate ephemeris data, and accurate clock data). The GPS receiver also looks at data from different reference stations. This new approach enables the user to use data that best fits their application. HA-NDGPS units have quad-frequency receivers, which enable interpolation of position between broadcast sites, and will allow faster code and carrier resolution, enabling dynamic navigation solutions in seconds rather than minutes. HA-NDGPS will have the capability to broadcast GPS observables from current and planned civilian GPS signals (L1, L2C, L5, and others). It will use an advanced broadcast link, with data transmission synchronized to GPS time; the carrier signal calibrated with GPS to sub-Hertz levels; spectrally efficient modulation; and GPS "one second data" in compact mode. HA-NDGPS receivers will use the broadcast code and carrier phase data to generate the high accuracy positioning solution. The potential also exists to use the HA-NDGPS signal as a means of ranging, providing a further means of location augmentation.

High Accuracy NDGPS uses the NDGPS infrastructure to transmit data used by GPS receivers to calculate this high accuracy positioning solution. An additional diplexer and transmitter are added to existing NDGPS (and MDGPS) sites to broadcast an additional GPS correction signal. Deployment costs are kept low by building around the existing NDGPS facilities. The cost of the HA-NDGPS modification to an existing NDGPS site is projected to be less than $100,000, based on the current design. The solution will provide for monitoring to ensure it is providing the accuracy and integrity required for safety-of-life applications. High Accuracy NDGPS has been installed at three (3) sites. Installations are planned for an additional four (4) sites. Further development of HA-NDGPS requirements and design features may be required to address the full integrity monitoring required for safety-of-life applications. There are currently three NDGPS sites (Hawk Run, PA; Hagerstown, MD; and Topeka, KS) that are equipped to broadcast code and carrier phase observables under test conditions. Testing is expected to continue to support ongoing system development, and additional HA-NDGPS sites are expected to be authorized.

High Accuracy NDGPS will enable a number of future applications that require higher accuracy than now provided by existing civilian GPS augmentation systems. A number of respondents to the NDGPS Federal Register Notice, as well as some of the Federal agencies that were surveyed, supported HA-NDGPS deployment.

[Applicable references in Appendix A: 8, 17, 20, 58, 59, 88, 133.]

2.6 Categories of NDGPS Applications

In subsequent sections of this report, a number of private and public sector applications of NDGPS have been identified to date. However, most of these applications fall into one of the following categories:

- Real-time tracking, navigation, and movement management of mobile assets or personnel;
- Geographic Information System (GIS) applications, which typically combine maps, asset location, and other information to provide the capability to analyze the spatial relationships between multiple layers of geo-referenced data;
- Automated machinery guidance or control;
- Command and control (both safety and non-safety applications) where accurate location of fixed or mobile assets and personnel is required;

- Construction support in terms of accurate placement or location of machines, material, and utilities, including items not visible (such as buried pipes or cabling);
- Mapping and location of assets, such as markers, signs, lights, cables, and bridges;
- Mapping and location of maintenance needs and history, such as identifying the location where a piece of fixed infrastructure requires maintenance, or being able to access maintenance history on assets which may be closely spaced;
- Measurement of work performed, where augmented GPS is used to keep track of the precise track of a piece of equipment to automatically log material removed or material placed or deposited;
- Integration of location information with condition monitoring sensors to support remote monitoring of geographically dispersed systems, or to identify the precise location of a monitored or alarmed condition (high G-force, material failures, roadway conditions, etc.);
- Use of NDGPS sites as part of the CORS network;
- Use of NDGPS sites for Total Electron Content and Precipitable Water Vapor data collection.

3. Private Sector Applications

This section presents current and potential future applications of NDGPS that are purely private in nature, and those that will require joint private and public sector deployment and operation. The sections on Federal Applications and State and Local Applications focus on potential NDGPS applications involving only government assets.

3.1 Vehicle Infrastructure Integration (VII)

The VII program is a cooperative effort between the U. S. Department of Transportation (USDOT), State departments of transportation, and the automobile industry, to develop and test an information infrastructure that uses advanced communications technologies to exchange real-time information between the roadside and vehicles to improve safety and mobility. There are three general categories of VII applications:

- Safety;
- Mobility; and
- Private.

The specific list of potential applications continues to evolve, and specific location performance requirements are still being defined. The most recent information can be found at the following web sites:

- The Research and Innovative Technology Administration (RITA) website: www.its.dot.gov/vii;
- The ITS America website: www.itsa.org, search word "VII".

Additional information on VII is included in Appendix I.

3.2 Cooperative Intersection Collision Avoidance System (CICAS)

Another program related to VII is the Cooperative Intersection Collision Avoidance System, or CICAS. Like VII, this program is currently in the Research and Development phase, lead by the US Department of Transportation, in partnership with state agencies and private industry.

CICAS consists of:

- Vehicle-based technologies and systems—sensors, processors, and driver interfaces within each vehicle;
- Infrastructure-based technologies and systems—roadside sensors and processors to detect vehicles and identify hazards and signal systems, messaging signs, and/or other interfaces to communicate various warnings to drivers; and
- Communications systems—dedicated short-range communications (DSRC) to communicate warnings and data between the infrastructure and equipped vehicles.

CICAS will require precise knowledge of the relative locations and speeds of vehicles in relation to each other, to the infrastructure, and within the perspective of the phase of the signal for vehicles as they approach the intersection. Due to the early stage of development of this system, it cannot be determined what combinations of technologies will be required. Detailed accuracy and integrity requirements for CICAS have not been documented as of the time of writing of this report.

Additional information on CICAS is included in Appendix I.

3.3 Transit Applications

The transit industry consists of operations of buses, light rail, subways, and commuter rail systems. All of these modes of transportation use location tracking systems as part of their command and control structure. Bus operators, which constitute the largest mode in terms of both vehicles and passengers carried, continue to equip bus fleets with Computer Aided Dispatch/Automatic Vehicle Location (CAD/AVL) systems. Most of these systems use unaided GPS, which can provide the location accuracy necessary for fleet management and schedule adherence tracking. However, new trends in integrating CAD/AVL systems with Automatic Passenger Counter (APC) and Fare Collection systems will require higher accuracy to ensure that passenger counts and fares are attributed to the appropriate bus stop, which are in close proximity in some areas.

Communications Based Train Control (CBTC), referred to as Positive Train Control by the FRA, is growing in deployment in all rail modes. CBTC is becoming more widely deployed because it provides operational and capacity benefits over traditional track-circuit based train location and control systems. In subway systems, which operate largely underground by definition, the most common method of train location in CBTC systems is using trackbed-mounted transponders, which are read by interrogators located under the train. Between transponders, the location is interpolated based on wheel rotations. While transponder technology is proven in train control applications, commuter railroads as well as freight and inter-city passenger railroads have concerns about the reliability of these devices due to track and ballast maintenance practices, and the costs of installing and maintaining transponders installed over a large geographic area. For these reasons, there continues to be an interest among commuter rail operators in using GPS for train control, and general train management functions on top of traditional train control technology. Unaided GPS cannot distinguish between tracks, which are typically 13 feet between track centerlines, and does not provide sufficient accuracy for determining if a train is past a “fouling point”, which is the location beyond which a train could be in conflict with another train on the same or an adjacent track, or sitting on a switch, preventing its movement. NDGPS or an equivalent or more accurate GPS system would enable the deployment of CBTC systems for transit and mainline railroad applications.

Transit operators must perform many of the same mapping, construction, and maintenance activities which will be described in other sections of this report. Many of these applications require identifying the location of a fixed or mobile asset with accuracy better than what can be achieved with unaided GPS. Some operators currently use NDGPS, and others temporarily deploy expensive Real Time Kinematic (RTK) or survey grade systems.

[Applicable references in Appendix A: 67.]

3.4 Railroad Applications

One of the critical mainline railroad applications of NDGPS is Positive Train Control (PTC), the specific name given to communications-based train control (CBTC) systems by the mainline railroad industry and the FRA. CBTC systems are being developed and deployed to enforce limits of authority (prevent train collisions) and to enforce speed restrictions to reduce derailments. CBTC systems also provide protection of track workers by establishing limits of authority at track work limits and enforcing either a stop or a restricted speed. All of the Class I railroads are developing and/or have pilot programs for CBTC systems. Individual suppliers have product names which are often used within the freight rail industry to refer to their individual CBTC projects. Accurate train location is a fundamental technology to enable CBTC deployment. Train location must be known with accuracy better than provided by unaided GPS, with a high confidence level, high integrity, and high reliability for safety-critical train control applications. However, even NDGPS with its current level of accuracy has not proven adequate for safety-level track separation information. Highly accurate GPS-based surveys are needed to provide the locations of railroad infrastructure (curves, interlockings, speed zones, etc.) that will be used in CBTC or train management systems. In its response to the Federal Register Notice on NDGPS (RITA-2007-28836), the Association of American Railroads (AAR) recommended that the NDGPS network be completed to Full Operational Capability, and upgraded to High Accuracy NDGPS.

Figure 3.4-1. The Railroad Industry Continues to Explore a Variety of Applications for NDGPS, As Represented by this Picture of a Train Enroute

There has been an initial deployment of a CBTC system using NDGPS, but this project is being transitioned to a test bed for further evaluation. Other CBTC projects are using unaided GPS for train management (non-safety) applications. The railroads have tested transponder-based location systems in the past, which may provide suitable location accuracy and integrity, but the railroads would prefer not to deploy transponders because: (a) they are expensive to program, install, and maintain (because of damage by track maintenance machinery); (b) large numbers of transponders are required to cover the geographic expanses; and (c) the interrogators are difficult to mount under a locomotive and subject to damage from debris (ballast, ice, tree limbs, man-made objects) on the tracks. Deployment of transponders has been limited to systems on the Northeast Corridor and in Michigan, and in these cases transponders are used to provide static or dynamic signal or civil speed information as well as location data. No applications of general coverage augmentation systems have been identified as of the date of this report; however, the Michigan Incremental Train Control System (ITCS) program has set up its own differential network.

By knowing train location, the system can also provide automatic warnings to track workers that a train is approaching. Rail/highway grade crossing systems on freight tracks are also generally limited to providing the standard grade crossing activation at a maximum speed of 79 miles per hour without expensive modifications to track circuits which trigger the grade crossing activation. However, as more freight tracks are being upgraded to support higher speed passenger operations, the grade crossing device must be activated sooner. CBTC systems can provide the accurate train location information to activate the grade crossing sooner to support higher speed operations at lower cost than extending the track circuits.

In addition to protection of track workers through CBTC systems, railroads are also using GPS systems to track the location of track maintenance personnel and equipment to provide protection through existing train control systems. However, effective use of GPS in this mode requires sufficient accuracy to know whether or not the personnel and equipment are outside the clearance envelope of the train or clear of the fouling point of a switch. Unaided GPS cannot provide sufficient confidence of this accuracy of location and NDGPS will require higher accuracy enhancements (HA-NDGPS) to provide the performance needed for safety applications.

Railroads use combinations of automated and manual inspection of track and other infrastructure. GPS is often currently used to provide the location of identified defects or maintenance requirements. Unaided GPS cannot always provide sufficient accuracy to re-locate the defect when maintenance personnel are sent to the documented location, particularly for identification of defects which are not visible, such as internal rail defects. Railroads also use helicopter survey systems which use differential GPS and LIDAR systems to provide detailed cross-section maps of the rail bed for maintenance planning. This type of survey is performed on the Northeast Corridor every year. GPS is also used to generally provide coordinates for field work performed, such as replacement of ties and rail. Higher accuracy or augmented GPS systems make this documentation much more effective since the precise location can be re-located quickly.

As railroads continue to deploy CBTC and similar GPS-based train management and asset management systems, they must survey the railroad in GPS coordinates. Railroads cover too much territory to practically employ mobile survey-grade reference stations for these surveys, so a mobile system is required to perform the mapping. NDGPS can provide the mobility and sufficient accuracy for railroad network and asset mapping.

[Applicable references in Appendix A: 12, 112, 138, 139. Applicable references from responses to the Federal Register Notice, Table E-1, entries 0006, 0007, 0045, 0048, 0066, 0101.]

3.5 Agriculture Applications

Today modern agriculture is producing more food and fiber, and providing more environmental protection than ever before. Much of these accomplishments have been the result of the Precision Agriculture industry, a multi-million dollar industry dedicated to increasing crop yields, decreasing production costs, and providing greater protection of our natural resources. Over the past ten years, the precision agriculture industry has moved from an obscure group of small equipment and research companies to main stream agriculture, being incorporated into every major agricultural company in the United States. Over these ten years, the precision agriculture industry has developed equipment and techniques which include steering assist on tractors, yield monitors for combines, and variable-rate applicators which have helped to reduce fuel consumption, reduce operator fatigue, increase crop yields, and minimize application of fertilizers and pesticides. Variable rate technology has increased the accuracy and efficiency of the application of fertilizer and chemicals which have helped to reduce production costs and reduce nutrient runoff. Field data collectors using GPS, moving maps, and Geographic Information Systems (GIS) are enabling agronomists and farm professionals to accurately map farms and ranches, pinpoint problem areas, prescribe treatments, and analyze results of complex cropping systems.

Figure 3.5-1. As Represented by This Picture of a Harvesting Machine, the Precision Agriculture Industry is a Major User of NDGPS and Other Forms of GPS Augmentation

Advances in modern agriculture are a direct result of an increased use of GPS and GPS augmentations. In the beginning, the ability to simply collect GPS positions while harvesting provided the Agricultural producers the ability to see the yield variation in the field. Development of precision farming continued with field mapping. Agricultural producers with GPS and augmentations could now accurately map farm and field boundaries, farm assets, conservation practices, irrigation patterns, pest populations, erodible soils, wet areas, and many other cultural and natural features on their farms and ranches. These maps could be turned into geographic information that enabled farmers and ranchers to start farming by the meter rather than farming by the field. As the agricultural industry integrated augmented GPS navigation into farm and ranch machinery, tractors, combines, trucks, and other vehicles and machinery, the opportunity to apply lessons learned from mapping was apparent. Today, agricultural producers can use GPS and GPS augmentations to accurately map their fields and range, develop a prescription for application of fertilizers, herbicides, and pesticides, and accurately apply them where needed. They can monitor crops during the growing season and accurately record yields at harvest. They can manage and track their farm assets better, direct operations more effectively, and reduce many of the inherent risks related to agricultural production. Precision agriculture is the most significant advancement in modern day Agriculture.

Development of commercial space-based augmentation was the next step in the use of augmented GPS for the agriculture industry. Companies such as Navcom, Omnistar, Racal, and Satloc developed space-based, for-fee systems that for the first time advertised nationwide GPS augmentation to the agriculture community. These nationwide systems helped move the precision agriculture industry and its many benefits forward, and their nationwide capabilities provided the basis for precision agriculture companies to become profitable by expanding their market areas. The deployment of the DOT/FAA Wide Area Augmentation System (WAAS) provided a low-cost alternative to commercial augmentations, although less accurate than some of the subscription services provided by industry. At the same time, NDGPS was moving forward and building inland augmentation sites across the country. Like WAAS, NDGPS is a free service and provides capabilities that are incorporated into precision agriculture. Current NDGPS augmentation does not provide the sub-meter accuracy needed to accurately navigate farm machinery on very precise courses across fields. Although WAAS and other space-based augmentation systems currently have greater acceptance in the agriculture industry because of the relatively low cost for the receiver, these satellite-based systems have limitations, primarily due to the fact that the satellites are somewhat low on the southern horizon, resulting in limited reception on the northern side of tree lines and terrain and in much of the land in northern states, and also that these signals do not penetrate foliage and terrain as well as the NDGPS medium frequency beacon transmissions. Refer to Section 10 of this report that addresses the performance of different GPS augmentation approaches.

Precision agriculture is increasing significantly and will soon dominate the process by which food and fiber are produced in America and around the world. Along with conservation, Precision Agriculture is the most responsible way to sustain our natural resources and protect our food supply, while reducing production risks and providing farmers and ranchers the ability to farm by the square foot rather than field by field. GPS and GPS augmentations are the drivers for precision agriculture, agricultural industry, and agricultural producers.

Through the reduction in production cost, the increase in crop yields, and greater environmental protections through more precise and controlled application of fertilizers and pesticides, the precision agriculture industry is generating hundreds of millions of dollars for the U.S. economy, with reduced chemical runoff. Rapid adoption of precision agriculture depends on GPS augmentations. It is estimated that over 20% of agricultural lands in the United States cannot use space-based augmentation due to tree canopies and land formations that block the sky, or northern areas of fields adjacent to tree lines or terrain. There is a need for greater accuracy and availability from GPS and GPS augmentation in order to increase the efficiencies of current precision agriculture practices and allow the development of new precision agriculture equipment and techniques. It is estimated that over 100,000 acres are currently farmed using centimeter-level augmentation in the performance of high accuracy precision agriculture. These centimeter GPS augmentation signals are being provided by RTK base stations and RTK space- based systems. These systems are expensive and require periodic re-location of ground level base stations.

There is insufficient information to show the actual number of NDGPS users in the agriculture industry; however, it is clear that the sale of NDGPS-capable receivers into the agriculture market increased in the United States in 2006. Survey information indicates that this growth is being driven by the need for additional ground-based, non-line of sight augmentation systems.

With completion of NDGPS, it could become the GPS augmentation of choice for the majority of small family farms and limited resources agricultural producers because of the relative low cost for equipment, the free service, the improved accuracy and integrity monitoring, and the ease of use. NDGPS offers a low end entry level into precision agriculture. NDGPS also offers increased efficiencies to high end (subscription, dual frequency) users who need only 1-3 meter horizontal accuracy for field mapping and asset management. This equates to reducing overhead cost and achieving the same results. Where appropriate, alternate wireless technologies can be used to distribute the augmentation data to agricultural machinery that originates from NDGPS sites.

[Applicable references in Appendix A: 64, 65, 66, 68, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 89, 90, 91, 92, 93, 94, 95, 96, 97 98. Applicable references from responses to the Federal Register Notice, Table E-1, entries 0023, 0029, 0032, 0034, 0036, 0046, 0050, 0056, 0066, 0069, 0071, 0077, 0078, 0079, 0080, 0086.]

3.6 Industrial Applications

Commercial industry uses GPS with various forms of augmentation during mapping, construction, and maintenance phases of projects. Augmented GPS is often used in conjunction with other technologies, such as LIDAR, to provide ground contour information before, during, and after site preparation or construction. Differential GPS receivers are placed at the ends of long booms that contain LIDAR sensors, and carried over a site by a helicopter or fixed wing aircraft. The differential GPS provides accurate ground track information, and the LIDAR provides detailed readings of the ground contours, including excavations. Similar systems are used in perimeter security systems to detect intrusion into an area.

Augmented GPS is used to precisely locate construction equipment and materials during construction, mining, and maintenance activities. The use of accurate GPS systems saves significant time over the use of conventional survey methods. Survey grade receivers may be used for locating the detailed construction footprint, but NDGPS may be used for applications requiring 1-3 m accuracy without the need to set up local reference stations.

Similar to agricultural applications, systems using NDGPS or other forms of augmentation are used for guidance or automated control of construction vehicles. This automated guidance (typically with a light bar or similar navigation display) or totally automated control is used for applications such as precision grading and dredging, guiding dump trucks to specific unloading positions, or applications of chemicals. These applications provide significant productivity and economic benefits by ensuring that the work performed is what is being paid for, and is in accordance with work permits and environmental regulations. These systems also provide automated records of work performed, material removed or placed/deposited, or chemicals applied.

Industrial applications of augmented GPS also include locating utilities (including buried cables, pipes, conduit, fiber, etc.) and location of previous construction. Accurate location of utilities or other hidden construction helps protect against damage during construction or to minimize the amount of modifications to structures, roadbeds, or other existing infrastructure to work around it or make connections (such a connecting to existing pipes).

Ground-based augmentation is required to meet the requirements of these industrial, as well as many other, GPS applications. As the national PNT infrastructure evolves, it may be possible to achieve the necessary accuracy for many applications with less infrastructure. These requirements are being considered as part of the evolved PNT reference network for the 2025 PNT architecture.

[Applicable references in Appendix A: 21, 73, 76, 89, 92, 93, 94, 95, 96, 97, 98, 99, 100, 101, 102,103, 104, 124. Applicable references from responses to the Federal Register Notice, Table E-1, entries 0005, 0022, 0045.]

3.7 GIS Applications

A Geographic Information System (GIS) is a system for capturing, storing, manipulating, analyzing and managing data and other attributes which are referenced to locations on the earth. GIS systems perform integration, storage, editing, analysis, sharing, and display of geographically-referenced information. GIS systems allow users to create interactive queries of spatially-referenced data, analyze the spatial information, edit data, create maps, and generate custom reports that relate items of interest to their location. GIS systems are used in a wide variety of industries and applications. There are a number of commercial suppliers of GIS software products and tools. GPS is a major tool for GIS data collection. Since the information contained in a GIS database may change fairly quickly (even in real time, such as tracking vehicles), GPS provides a valuable tool for cost-effective and timely update and validation of GIS data. GPS is used to create, validate, and update location information in a GIS database.

There are GIS products that directly incorporate GPS, so that data about objects of interest are input as the location reference data is collected in the field. Other GIS products are based on maps into which the location of an object of interest is entered, along with the attributes of the item. Data from the integrated GIS/GPS device may be entered into an office system when a worker returns from the field. Some devices also support downloading GIS data from the office system into the field device, to support returning to the field to validate and update the GIS data for an object or feature.

Information collected about an object or feature that is related to its position include descriptive data, status, condition, or variable data (traffic level, rainfall, soil moisture content, type of crop, etc.). In some cases, the location of the edge of a feature may be the variable being measured, such as delineation of a wetlands, water level in reservoirs, tree lines, glacier limits, tectonic plate boundaries, snow drifts, flood limits, fire perimeters, sedimentation, where chemicals were applied, etc. In some cases, the location information may be continuously variable, such as tracking a vehicle or hazardous cargo movement.

In many cases, raw civilian GPS accuracy is not sufficient for GIS applications. NDGPS, WAAS, RTK, or survey-grade augmentation systems may be used to provide the required level of location accuracy. For some applications, post-processing using CORS or other sources of correction data may be used, if the application is not time critical or the user does not have an augmented GPS field data collection capability. In most cases, users indicated that the ability to collect accurate location references in real time resulted in significant manpower and other cost savings. The location data may require higher positional accuracy because it is necessary to distinguish the object of interest, to support relocating a small object, because the positional data is used to measure distances for an application requiring better than raw GPS accuracy, to enable relocation of an item in the field, or to meet specific application requirements.

NDGPS is one of the primary means of achieving higher accuracy in locating objects and features that are included in GIS databases. Most GIS applications are related to features on the ground, so the ability to provide accurate location data collection in real time at ground level is critical to the GIS application. Some of the GIS applications used in conjunction with NDGPS that were identified by users during this assessment include:

- Road construction and other construction planning, monitoring, and management;
- Transportation planning, including traffic studies;
- Developing highway, road, and trail maps;
- Asset management, such as signs, street lights, markers, utilities, easements, road condition, park assets;
- Emergency response planning, execution, and monitoring;
- Law enforcement, accident investigation, search and rescue, monitoring environmental compliance;
- Maintenance management and condition monitoring;
- Historical and cultural resource mapping and monitoring;
- Vehicle and cargo tracking;
- Monitoring natural resources;
- Mapping topographic, hydrographic, and other natural features.

In many GIS applications, it is critical to be able to efficiently relocate an object or feature, to ensure that the GIS data is still accurate, to update the GIS database, to support maintenance and repairs, and to support field operations and construction.

There is a community of private consultants, surveyors, contractors, and other private groups who use augmented GPS and GIS systems to support natural resource management, wildfire protection, and conservation efforts. These groups perform many of the same functions listed above and in Sections 4.2, 4.4, 5.1, 5.2, and 5.3.

[Applicable references in Appendix A: 13, 16, 25, 26, 30, 31, 32, 37, 38, 71, 115, Applicable references from responses to the Federal Register Notice, Table E-1, entries 0006, 0007, 0008, 0009, 0012, 0014, 0015, 0016, 0017, 0019, 0020, 0021, 0024, 0025, 0026, 0027, 0029, 0030, 0031, 0032, 0033, 0035, 0037, 0038, 0039, 0042, 0043, 0048, 0049, 0050, 0052, 0053, 0055, 0056, 0060, 0062, 0064, 0066, 0069,0071, 0076, 0081, 0082, 0083, 0084, 0085, 0086, 0088, 0088, 0089, 0091, 0093, 0095, 0097, 0100, 0103, 0104, 0106, 0107, 0108, 0109, 0110, 0112, 0113.]

3.8 Maritime and Intermodal Applications

It is outside the scope of this report to address the differential GPS applications supported by the Coast Guard DGPS sites.

However, there are many similar applications that are on waterways beyond the range of the USCG DGPS sites. For example, inland ports are being constructed farther up major rivers. There are also inland cargo handling, storage, and inspection facilities in operation and under construction that operate like a port, but containers and other cargo are being transported by rail or truck to these inland facilities which act as customs/security inspection stations, international trade zones, bonded warehouses, and distribution centers. An example of a major new facility currently being developed is the conversion of the former Kelly Air Force Base in San Antonio, Texas, to the Port of San Antonio, which will provide customs and security inspection of cargo coming into ports along the Gulf of Mexico.

NDGPS is used for vessel navigation in inland waterways and lakes similar to its applications in coastal areas served by USCG sites. NDGPS is also in precision ship and handling and docking systems, where the precise location and rate of movement provide information to a captain or pilot to safely maneuver the ship during docking or in placing the ship for unloading or connection to pipelines or other unloading or discharge systems. NDGPS is also used for tracking the handling of containers and other cargo. For example, there are systems to track forklifts, top picks, and other container handling equipment in a terminal or yard to automatically register where a container was placed in the stacks of containers, or where it was retrieved. These systems are an integral part of the overall container terminal management system, including the data systems used by customs inspectors who must efficiently locate containers or other cargo for inspection.

NDGPS is also used during dredging operations to monitor the limits of the planned material removal. It is economically important to the dredging contractor to only remove the material they are being paid to remove, and it is important to the site owner to ensure that waterside or underwater structures are not damaged or undermined, which could lead to collapse.

[Applicable references in Appendix A: 16, 61. Applicable references from responses to the Federal Register Notice, Table E-1, entries 0014, 0018, 0024, 0069.]

3.9 General Transportation Application Requirements

The January 2004 report of the Radionavigation Systems Task Force to the Secretary of Transportation, entitled “Radionavigation Systems: A Capabilities Investment Strategy” examined a number of issues related to Radionavigation system requirements for the different transportation modes, GPS augmentation methods and their applications, other navigation aids, and costs and investment needs for these systems. Section 3.2 of that report addresses “Agency Requirements” and defines terms used in the specification of those requirements. Of particular note is the definition of integrity, which is defined as “Integrity is the ability of a system to provide timely warnings to users when the system should not be used for navigation. Integrity has three components: probability of broadcasting Hazardously Misleading Information (HMI), alert limit, and time to alarm.

Appendix J contains tables from Appendix D of the report, relating to:

- Land Requirements (Highway); and
- Land Requirements (Railroad and Transit).

This page intentionally left blank.

4. Federal Applications

There are a number of current, planned, or potential NDGPS applications that overlap Federal Government, state and local government, and commercial operations. This section focuses on the applications of NDGPS directly by Federal agencies in the execution of their operations.

4.1 Continuously Operating Reference Station (CORS) Network

The National Geodetic Survey (NGS), an office of NOAA's National Ocean Service, coordinates two networks of Continuously Operating Reference Stations (CORS): the National CORS network and the Cooperative CORS network. Each CORS site provides Global Positioning System (GPS) carrier phase and code range measurements in support of 3-dimensional positioning activities throughout the United States and its territories. Surveyors, GIS/LIS professionals, engineers, scientists, and others can apply CORS data to position points at which GPS data have been collected. The CORS system enables positioning accuracies that approach a few centimeters relative to the National Spatial Reference System (NSRS), both horizontally and vertically. CORS data are used by a wide variety of government and commercial users for post-processing applications.

The CORS system benefits from a multi-purpose cooperative endeavor involving about 200 government, academic, commercial and private organizations. New sites are evaluated for inclusion according to established criteria. All national CORS data are available from NGS at their original sampling rate for 30 days. After that time, the data are decimated to a 30 second sampling rate. Cooperative CORS data are available from the participating organization that operates the respective site. Figure 4.1-1 shows the current map of CORS sites.

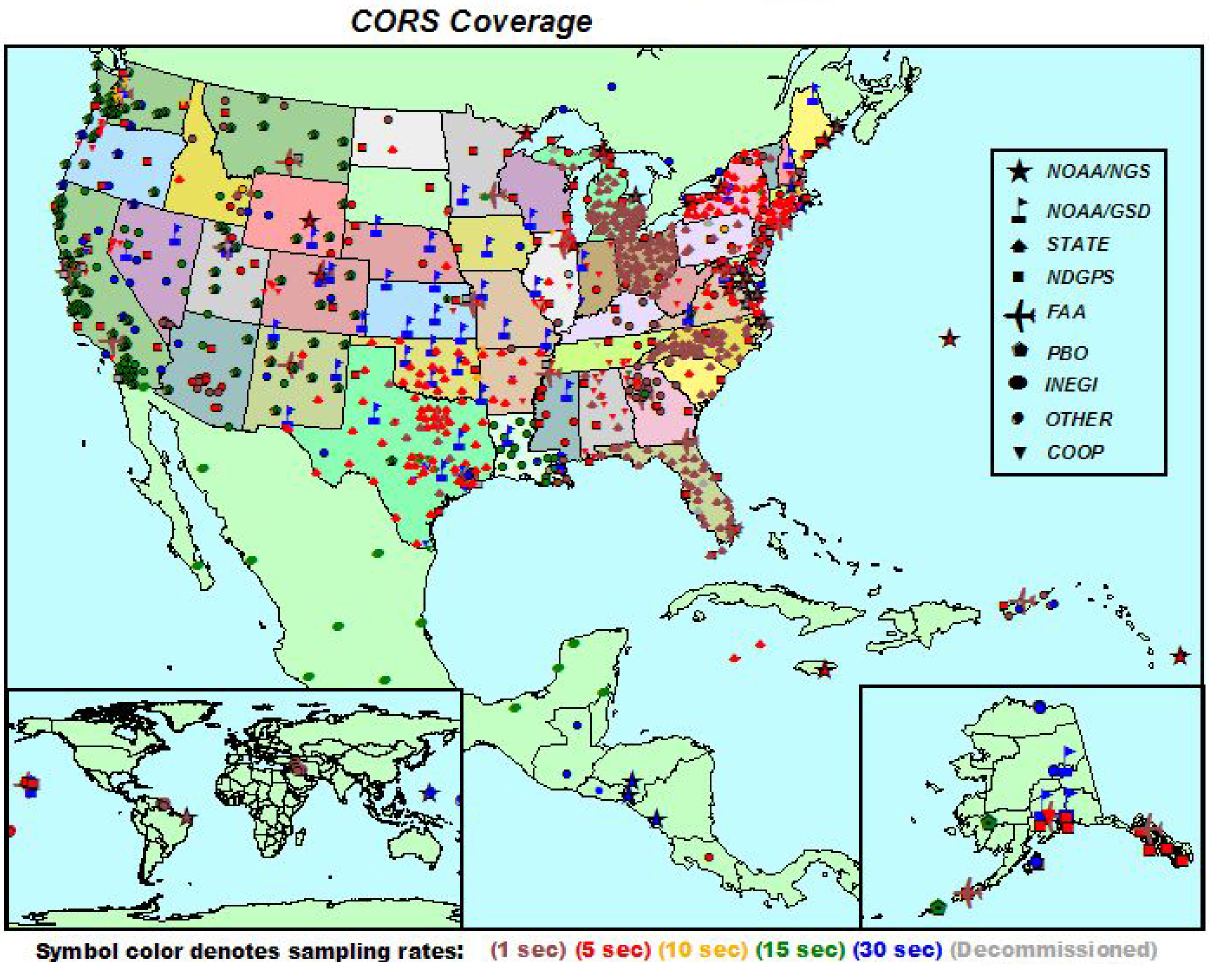

Figure 4.1-1. Current CORS Sites (from NGS web page, as of August 2007)

The CORS network includes reference stations built by about 200 different organizations. The NDGPS, MDGPS, and WAAS reference stations form the backbone of the network. A list of CORS contributors can be found at http://www.ngs.noaa.gov/CORS/Organizations/Organizations.html. There are two categories of CORS partners: National CORS and Cooperative CORS. NGS archives and disseminates data from the National CORS sites in the standard Receiver Independent Exchange (RINEX) format. RINEX files contain dual-frequency carrier phase and pseudorange measurements. Data from CORS sites are used for differential positioning applications. Users download the GPS data from CORS sites and use it for post-processing of field collected location data to obtain more accurate location readings. There are approximately 50,000 to 100,000 individual users of CORS data.

The National Geodetic Survey also operates the On-line Positioning User Service (OPUS) as a means to provide GPS users with easier access to the National Spatial Reference System (NSRS).

OPUS allows users to submit their GPS data files to NGS via the Web, whereupon the data will be processed to determine a position using NGS computers and software. Each data file that is submitted is processed with respect to three (3) CORS sites. The positional coordinates corresponding to the user's data are then emailed back to the user within minutes.

As of this writing, 170 of the 1175 CORS sites are NDGPS sites, or 14.5%; the number of CORS sites continues to increase at a rate of approximately 200 sites per year. The NDGPS sites are considered to be among the most reliable sites in the CORS network, and among the most popular. A recent study by NOAA identified the top 20 sites in the CORS network in terms of CORS data sets that were downloaded via the User Friendly CORS (UFCORS) Web utility. Of these 20 sites, 8 are NDGPS sites. In a number of cases, particularly in the Western states, the NDGPS sites are the only CORS sites within a usable range to provide sufficiently accurate reference points.

The NOAA CORS web site can be found at http://www.ngs.noaa.gov/CORS. Information on OPUS can be found at http://www.ngs.noaa.gov/OPUS.

[Applicable references in Appendix A: 3, 4. 6, 7, 8, 13, 14, 20, 28, 29, 30, 33, 37, 42, 55, 62. Applicable references from responses to the Federal Register Notice, Table E-1, entries 0006, 0012, 0015, 0017, 0019, 0042, 0055, 0056, 0060, 0076, 0082, 0085, 0086, 0089, 0090, 0091, 0093, 0096, 0100, 0104, 0106.]

4.2 Department of Interior NDGPS Applications

4.2.1 Bureau of Land Management

The US Department of Interior Bureau of Land Management (BLM) uses GPS and augmented GPS to support a number of field mapping and survey tasks. BLM manages the National Landscape Conservation System (NLCS) for conservation purposes under its multiple-use mandate. These wild and often remote places provide opportunities for scientific research, recreation, and a wide range of other uses. The NLCS, created in 2000, is comprised of more than 800 units totaling more than 25 million acres.

These areas consist of the BLM's National Conservation Areas, National Monuments, Wild and Scenic Rivers, Wilderness Areas, Wilderness Study Areas, and National Scenic and Historic Trails. BLM undertakes a broad range of activities to safely protect the public, the natural landscape, wildlife habitat, and recreational areas through its wildland fire operations program.

BLM manages more Federal land than any other agency – 261 million surface acres and 700 million sub-surface acres of mineral estate – and plays a key role in ensuring our country's needs are met by managing both Federal renewable and non-renewable sources of energy in an environmentally sound way. BLM also manages oil and gas, helium, coal, and increasingly, renewable sources of energy such as geothermal, wind, and biomass on Federal property. Because of this, the BLM's role in implementing the Energy Policy Act of 2005 is critical.

Due to the nature of the land managed by BLM, many of these applications include data collection under foliage canopy, which limits the utility of satellite-based augmentation systems. The types of applications by BLM include:

- Locating sensitive resources in the field;
- Mapping sites of interest in detail;
- Mapping roads and trails across Federal land;
- Mapping historic or cultural sites, such as native American sites, national monuments, or other historic sites on Federal property;
- Surveys of changes in sedimentation;
- Hydrographic surveys;
- National resource management, including minerals, helium, and oil, gas and coal reserves, as well as vast areas of wilderness areas, grazing areas, and public recreational areas.

GPS is the predominant data collection tool in the field. BLM uses a combination of NDGPS and WAAS receivers in the field for the applications listed above. They also use some RTK equipment. They do not use commercial augmentation services. BLM estimates that it has approximately 200 NDGPS receivers in regular use. The BLM policy is to use the most accurate available GPS signal, as documented in the *Standards and Guidelines for Cadastral Surveys Using Global Positioning System Methods*. BLM uses a combination of real-time field location and navigation and post-processing methods (to increase accuracy and to validate data consistency). For most of the BLM applications, it is necessary to be able to re-locate a specific spot in the field, following the initial mapping of the area or item of interest. While WAAS is used in many instances because it is built-in to many commercial GPS receivers, BLM noted that the WAAS augmentation signal is unavailable in many field locations, and that it takes 5-10 minutes to re-acquire the augmentation signal; the NDGPS signal is almost always available and more reliable in areas that have coverage by the current NDGPS network, and provides a location solution as long as the basic GPS signals are available.

BLM personnel indicated that the NDGPS sites should continue to be operated, and that there should be dual coverage of NDGPS signals across CONUS. It is particularly important that dual coverage be completed, and that more CORS sites are added, across the Western US. BLM feels that NDGPS represents a low cost for the benefits achieved and applications supported. They also feel that a higher accuracy ground-level augmentation system is warranted.

If the network of NDGPS sites were shut down, the most critical impact to BLM would be loss of CORS sites, particularly in the Western part of the country.

More information about BLM and its GPS applications can be found at http://www.blm.gov (search word = *dgps*).

[Applicable references in Appendix A: 25, 26, 32, 51. Applicable references from responses to the Federal Register Notice, Table E-1, entries 0019, 0091, 0098.]

4.2.2 National Park Service

The US Department of the Interior National Park Service (NPS) has many of the same applications as BLM, with the same environment of often having to operate under foliage canopy. Some specific NPS applications of NDGPS include:

- Mapping cultural and historic resources;
- Mapping and managing natural resources, including endangered species;
- Hydrology surveys;
- Mapping roads and trails;
- Mapping land and facilities;
- Law enforcement;
- Visitor protection and search and rescue;
- Personnel management;
- Fire management and mapping of fire perimeters;
- Measuring glacier movement; and
- Facility management.

Some applications are considered safety-of-life, such as park police law enforcement activities, visitor search and rescue, and fire management, including helicopter navigation in fire areas.

NPS estimates that it has 3000 NDGPS users. They use some WAAS receivers, but do not consider the ground-level coverage reliable for most of their applications. They do some post-processing, but try to avoid it because of an estimated two to four times increase in costs. In general, NPS does not consider other GPS augmentation methods cost-effective or practical for their applications. The benefits of NDGPS to NPS are the level of location accuracy; the ability to work in areas of foliage and heavy terrain; the ground-hugging nature of the NDGPS signal; the fact that NDGPS provides real-time GPS augmentation; good repeatability; notification of loss of integrity; and that NDGPS automatically puts data on the NAD-83 data set as required for Federal Government applications. Many of the applications of NDGPS include direct automatic location data entry into GIS applications. For many of its applications, NPS needs to be able to quickly get back to a specific field site.

Most of the current NPS applications of NDGPS are based on the need for accurate, real-time location data for navigation and mapping applications. Their applications require a stable augmentation source that can penetrate rough terrain and heavy vegetation. New laws require increasing levels of location accuracy in managing wilderness areas. They need 1-2 meter accuracy, but operate with 5-10 meter accuracy when necessary. They indicated a need for improved NDGPS signal coverage, and deployment of a higher accuracy augmentation system in the future. Currently, approximately 42% of the area of the National Park system is covered only by existing NDGPS reference stations (as part of the national CORS network), according to responses received from the Federal Register Notice on NDGPS. They recommend that sending additional data sets over the NDGPS signal should be evaluated.

NPS feels that there was a Federal Government commitment to provide complete CONUS, dual-coverage of NDGPS signals (single coverage in Alaska), operated with no user charges, and that USDOT committed to represent all civilian Federal agencies. They indicated that NDGPS should be viewed as a national infrastructure investment, and that funding should be evaluated on the basis of the complete user base.

If NDGPS were shut down, NPS would have to set up its own augmentation system, otherwise it would lose the ability to collect higher resolution data sets in areas of rough terrain where WAAS does not work. The estimate direct cost impact would be to have to replace existing receivers that cost $1500-$1700 with units that cost $5000-6000 each. Not counting the sunk cost of existing NDGPS receivers, this translates into $15-18M of new investment for replacement equipment. They would also incur costs related to training, application software, and personnel costs. NPS feels that there was a commitment to complete the planned NDGPS network, and to continue operation, and have purchased equipment based on that understanding.

Information in this section is based on discussions with NPS personnel, NPS responses to the NDGPS Federal Register Notice, articles presented by NPS personnel, and information on the NPS website.

More information on NPS applications of GPS and NDGPS can be found at www.nps.gov/gis/gps.

[Applicable references in Appendix A: 31, 60. Applicable references from responses to the Federal Register Notice, Table E-1, entries 0055, 0074, 0081, 0082, 0083, 0084, 0085, 0087, 0088, 0089, 0090, 0096, 0100, 0106, 0107, 0108, 0109, 0110, 0112, 0113.]

4.2.3 Bureau of Indian Affairs

The US Department of Interior Bureau of Indian Affairs (BIA) has responsibility for the administration and management of 55.7 million acres of land held in trust by the United States for American Indians, Indian tribes, and Alaska Natives. There are 561 federal recognized tribal governments in the United States. Developing forestlands, leasing assets on these lands, directing agricultural programs, protecting water and land rights, developing and maintaining infrastructure and economic development are all part of the agency's responsibility.

BIA applications of NDGPS include:

- documentation of dam condition assessments;
- inventory and assessment of irrigation facilities;
- natural resource inventories;
- fire-fighting support and remediation;
- timber management;
- fisheries management;
- range management; and
- inventory and maintenance of roads.

These applications require a 1-2 meter level of accuracy. To achieve this accuracy, GPS augmentation is required. These applications often require operation in areas of tree canopy and rugged terrain. Most of the applications require input of location data into GIS systems. The NDGPS applications related to fire fighting and emergency preparedness are considered safety-of-life applications.

BIA prefers NDGPS to other forms of augmentation because the augmentation signal is more reliable in varied terrain and wooded areas. They use WAAS in some areas where the signal is available. BIA had used commercial GPS augmentation services in the late 1990's, but dropped these services when the NDGPS network began to be built out. They use NDGPS to support real-time augmentation, and would have to revert to post-processing if real-time augmentation data is not available, decreasing personnel efficiency.

BIA personnel indicated that NDGPS should continue to be operated to provide a valuable GPS augmentation service to GPS users. The decision to invest in NDGPS field units was based on the increased efficiency and productivity. They feel the original commitment to build NDGPS implied a continuing service to support user benefits. The NDGPS network should be completed to support operations such as fire support and natural resource field work in areas where NDGPS coverage was planned, but is not yet operational. The fact that the coverage is not universal requires BIA to have different user equipment and procedures in areas without NDGPS coverage. NDGPS single coverage should be completed (including Alaska), and dual coverage is also needed to ensure the availability of augmentation data when a site is out of operation.

If the network of NDGPS sites were shut down, BIA would have reduced flexibility in their GPS data collection efforts and would experience difficulty in collecting data to the required level of accuracy. New equipment would have to be purchased to provide augmentation, before the planned economic life of the NDGPS equipment, and likely with reduced capability for remote field data collection.

4.3 National Oceanographic and Atmospheric Administration (NOAA)

NOAA, the National Oceanic and Atmospheric Administration within the U.S. Department of Commerce, is the federal agency responsible for atmospheric monitoring and prediction on time scales ranging from minutes and hours, to decades and longer in the case of climate.
Another part of NOAA's mission is to promote commerce and safe transportation. It shares this mission with other federal agencies including the U.S. Departments of Transportation, Defense, and Homeland Security. Common among all these activities is the use of GPS for a growing number of conventional and non-conventional applications related to NOAA's mission.
NOAA is a partner in the deployment of NDGPS. NOAA collects weather data at NDGPS sites, which is used in real-time weather forecasting models. NOAA also operates specialized severe weather tracking vehicles which require accurate tracking.

Organizations within NOAA that use NDGPS include: National Geodetic Survey (NGS), National Weather Service (NWS), NOAA Satellite and Information Service, and NOAA Research.

NOAA applications of NDGPS or NDGPS sites include:

- Collection of weather data from sensors at NDGPS sites;
- Generation of atmospheric water vapor data from analysis of the GPS signals at NDGPS sites;
- NDGPS sites are part of the infrastructure for providing data for the NOAATrop troposphere signal delay model;

- NDGPS sites constitute approximately 10% of the CORS sites;
- Generation of Total Electron Count data from analysis of GPS signals at NDGPS sites;
- Land surveying;
- GIS mapping;
- Determining the travel path of aircraft used in remote sensing;
- Construction support; and
- Monitoring crustal motion.

A potentially new application of NDGPS data by the National Geodetic Survey is distribution of NDGPS data over the internet in real-time to support high-precision, real-time positioning.

NDGPS is very important to NOAA, particularly its use of the NDGPS sites for weather-related data collection. They consider the NDGPS sites as part of their backbone of data collection sites for weather forecasting and climate modeling. They use the carrier phase measurements from the sites for applications described below. These data are provided as input to weather models, and are also sent to all National Weather Service (NWS) sites, all state DOTs, researchers and others.

Figure 4.3-1. As Represented by this Photo from Space of a Hurricane, NOAA Uses Data from NDGPS Sites as Part of the National Weather Data Collection Network

Surface Meteorological Sensors

The Forecasting Systems Laboratory has meteorological instruments at NDGPS and other GPS sites. These sensors are part of the GPS Surface Observing System (GSOS), which is a real-time meteorological observing network which records air temperature, relative humidity, station pressure, and surface pressure at many GPS-IPW stations. Data from these sensors is combined with data from the Integrated Precipitable Water Vapor system, described below, to provide real-time data in the National Weather Forecasting System Model.

Integrated Precipitable Water Vapor Measurement

NOAA's Earth System Research Laboratory (ESRL) in Boulder, Colorado, uses data from NDGPS receivers (and other CORS sites) to measure satellite propagation delay, which is correlated with precipitable water vapor present in the atmosphere and data taken from other equipment installed at each NDGPS broadcast site (and other CORS sites) to measure temperature, barometric pressure, and humidity. These observations of water vapor and other measurements in the lower atmosphere improve short-term (0-6 hour) moisture and precipitation forecast accuracy. This knowledge is critical for forecasting severe weather events such as tornados, hurricanes, thunderstorms, and snow storms. Continuous monitoring of water vapor will also improve the understanding and predictability of the Earth's climate because of the relationship to the El Niño-Southern Oscillation and cloud formation. This data is fed into the National Weather Service's forecast models, providing improved short-term weather forecasts for all users, which include transportation departments.

Tropospheric Signal Delay Model

Techniques have been developed to treat the atmosphere as a source of noise or measurement error and remove it to improve their GPS positioning accuracy. Atmospheric scientists at the Global System Division (GSD) of NOAA's Earth System Research Laboratory (ESRL) realized that these error estimates told us something very important about the atmosphere and they developed ways to use this noise to continuously measure the amount of moisture in the atmosphere. The operational use of this information by NOAA's National Centers for Environmental Prediction has resulted in substantial improvements in U.S. weather forecast accuracy in recent years. GSD is using GPS data to improve weather forecast accuracy, then an improved weather model could be used in turn to estimate and correct for the atmospheric signal delays that are a major source of GPS PNT error.

GSD has developed a new model, NOAATrop, to improve GPS positioning, navigation, and timing (PNT) accuracy using real-time weather data. NOAATrop uses the ESRL Rapid Update Cycle (RUC) weather prediction model to calculate real-time atmospheric correctors for high-accuracy GPS positioning applications. Several years of independent testing and evaluation around the U.S. by three universities have proven NOAATrop's value in high-accuracy GPS surveying. The initial tests in California using NOAATrop as part of a California Spatial Reference Center (CSRC) Height Modernization project, funded by NOAA's National Geodetic Survey (NGS), indicated 15-25% improvements in accuracy, with the greatest improvements shown in height measurements made during rapidly changing weather conditions. From CSRC's perspective, using NOAATrop increases the accuracy and productivity of field surveys for its user community. Based on CSRC's experience, the NOAATrop model is currently being used in the Central Valley as a way to increase accuracy and productivity of their road and infrastructure surveys.

NDGPS sites are part of the infrastructure for collection of the data that feed the NOAATrop model.

National Spatial Reference System

NOAA's National Geodetic Survey defines and manages the National Spatial Reference System (NSRS). NSRS is a consistent coordinate system that defines latitude, longitude, height, scale, gravity, and orientation throughout the United States. NSRS comprises a consistent, accurate, and up-to-date national shoreline; a network of Continuously Operating Reference Stations (CORS, see Section 4.1) which supports 3-dimensional positioning activities; a network of permanently marked points; and a set of accurate models describing dynamic geophysical processes that affect spatial measurements. NDGPS sites, as part of the CORS network, make up part of the NSRS.

Total Electron Content

NOAA produces a data product called "US Total Electron Content (US-TEC)" which is designed to specify Vertical and Slant TEC over the Continental US (CONUS) in near real-time. This technique is driven by data from ground-based Global Positioning System (GPS) dual frequency receivers, including NDGPS sites. The primary data stream comes from the Maritime and Nationwide Differential GPS (M/NDGPS) real time network of stations, and is provided to the Space Environment Center (SEC) by the National Geodetic Survey (NGS) Continuously Operating Reference Station (CORS) network. Secondary data streams are provided by the GPS/Met network (meteorological application of GPS data) and the Real Time IGS (International GNSS Service) network. The real-time US-TEC Product is provided by SEC as part of its mandate to provide real-time monitoring and forecasting of solar and geophysical events. New maps are produced approximately every 15 minutes.

The TEC and slant path maps are used to estimate GPS signal delay due to the ionospheric electron content between a receiver and a GPS satellite, which can be used to determine expected GPS reliability and performance at a specific location. GPS users in the surveying, commercial and general aviation, shipping, emergency management, and other communities have an interest in knowing if their GPS use may be degraded by a disturbed atmosphere, such as a major storm. Rapid changes in the ionosphere, which can be determined by measuring the spatial-temporal distribution of free electrons in the upper atmosphere, affects satellites, aircraft, some radio communications, and power distribution grids.

Importance of NDGPS Sites

If NDGPS were shut down, NOAA would lose all data from these sites. The NDGPS sites are considered to be critical locations that would otherwise be under-observed. NOAA would have to develop its own network of sites to collect data for the applications described above. These sites could be less robust than the NDGPS sites, since the NDGPS sites are built around ruggedized facilities originally built for nuclear war survivability. The use of Medium Frequency beacon transmission by NDGPS provides more reliable reception in the field than other transmission means, such as satellite-based augmentation systems.

As a partner in the development of NDGPS, NOAA considers the future of these sites critical to future operations. The NOAATrop and US-TEC models also provide a form of correction data that can be used in GPS location systems; they indicated that loss of data from NDGPS sites would have a major impact on the GPS-Met and US-TEC projects. NOAA leverages the existing NDGPS infrastructure as part of their overall network of data collection sites. Many of the applications described above have been in development over the last several years, and their development was cited as part of the rationale for building the NDGPS network. As part of the overall network of data collection sites, the NDGPS sites are a part of the critical infrastructure of NOAA's mission. These new systems are scheduled to become operational in 2010. Weather forecasts are important to transportation operations, as well as other civilian and military applications, with safety of life implications.

NGS has estimated that the financial benefits of the CORS program to the CORS user community exceed $400M per year. Based on 10% (actually currently 14.5%) of the CORS sites being NDGPS sites, they project the financial benefits attributable to NDGPS sites to be approximately $40M per year.

NOAA indicated that enhancing NDGPS sites to provide higher accuracy would provide significant benefits to the real-time positioning community, including surveying and mapping applications.

[Applicable references in Appendix A: 13, 20, 28, 33, 35, 37, 42, 43, 44, 47, 48, 49, 50, 51, 52, 53, 54, 56, 111. Applicable references from responses to the Federal Register Notice, Table E-1, entries 0045, 0066, 0069, 0093, 0103, 0111.]

4.4 Department of Agriculture NDGPS Applications

4.4.1 Natural Resources Conservation Service

The United States Department of Agriculture (USDA) Service Center Agencies, Natural Resources Conservation Service (NRCS), Farm Service Agency (FSA) and Rural Development (RD), all use NDGPS in varying degrees. In executing their mission of “Helping People Help the Land”, NRCS provides technical assistance and service to landowners and cooperators daily. Often the assistance NRCS provides includes field personnel using NDGPS to locate or position point, line, and area data. They use NDGPS as a geo-tool to augment these data and recordings that require 1-2 meter horizontal positioning in real time. NDGPS is often used for conservation planning; application of some conservation practices; conducting inventories of natural resources, soil, and other landscape mapping; and any other application that may need 1-2 meter horizontal positioning. NDGPS is not used for any activity that requires vertical accuracy. NRCS does not have any safety of life applications.

Figure 4.4.1-1. As Represented by this Figure of Natural Scenery, A Number of Federal Agencies Responsible for Monitoring and Managing Natural Resources Use NDGPS for Field Surveys, Navigation, and Other Applications

USDA awarded a contract for two USDA GPS Configurations, one of which was a GPS/NDGPS system. During the contract period, approximately 7,000 GPS/NDGPS systems were purchased and distributed to the three Service Center Agencies. NRCS has personnel in approximately 2500 Service Center locations in the U.S. The Service Center offices where NDGPS is available have the USDA GPS Configuration 1 GPS/NDGPS. NRCS has approximately 4,000 USDA GPS Configuration 1, GPS/NDGPS systems. The other 3000 NDGPS units are distributed among other USDA agencies. Based on the number of USDA GPS Configuration Systems that NRCS has, there could be as many as 4000 potential users daily.

NRCS sees the primary benefit of NDGPS as improved accuracy, since the real time corrections broadcast to the user generally provide 1-2 meter horizontal positioning. This improved accuracy, over autonomous GPS, meets the horizontal positioning requirements of many field applications. The precision associated with NDGPS is another benefit. The performance repeatability and ability to return to a specific field location at any time are very important. The ground based signal is unaffected by terrain, which is a real advantage for natural resource applications. NRCS personnel do use WAAS augmentation signals where they are available, and use some RTK equipment. NRCS does not have or operate any fixed reference stations. NRCS does use RTK equipment and OPUS for adjusting positions and is looking at eRTK capability. Some new geospatial applications will require dual frequency, multi-constellation, Real Time Kinematic (RTK) capability. For natural resource applications, NRCS prefers real-time solutions to avoid extra processing steps for Field Office personnel. Real time corrections alleviate dependency on post-processed solutions. Landscape Characterizations and Engineering practices have used post-processed solutions via software or OPUS. In the near future, NRCS will be evaluating eRTK capability for real time, high accuracy positioning.

If the NDGPS signals were no longer available, then NRCS may incur additional expense for purchasing new GNSS equipment that meets NRCS requirements. However, the USDA GPS configurations are past design life and consideration is being given as to the next generation of GNSS equipment for NRCS. Loss of NDGPS would accelerate the decision-making process to consider the next generation GNSS equipment for NRCS. Lack of NDGPS would decrease Agency efficiency in completing and reviewing conservation practices and conducting natural resource inventories. If NRCS moves forward with the development of the next generation GNSS equipment, the Agency would need to invest in new equipment for testing, develop requirements for a potential acquisition, and ultimately go through an acquisition process for awarding a new contract. Along with new equipment, there would be training and implementation issues.

NRCS indicated that the Department of Transportation (DOT) was designated to represent Federal Civilian Agencies in the development and use of GPS and augmentations, including NDGPS. At this time, they feel that DOT has not demonstrated a commitment to completing the planned network of NDGPS sites or the continued operation of NDGPS. They indicated that a significant increase in fiscal funding for the next four years is required for completion of the NDGPS network as designed and promised by DOT. They indicated the following priorities:

- complete single coverage, especially in Idaho and Texas;
- complete Alaska and then finish dual site coverage;
- in addition to broadcasting corrections, evaluate value-added services for first responders and other unique user groups.

NRCS has location requirements that include:

- 1-2 meter horizontal accuracy at 98% confidence;
- 2-10 centimeter horizontal and vertical accuracy at 98% confidence;
- 1-2 centimeter horizontal and vertical accuracy at 98% confidence.

Some of these last two requirements could be satisfied with a high-accuracy augmentation to NDGPS.

4.4.2 Forest Service

The US Department of Agriculture Forest Service has similar applications of augmented GPS to BLM and NPS. They are responsible for fire and incident management in the lands and properties under their jurisdiction. They conduct detailed land surveys and map the location of critical resources and changes such as spread of invasive species and diseases, and other threats to forests and wilderness areas. They are responsible for management of the Federal National Forests, including managing development and utilization of mineral and other resources, including bio-energy and renewable energy. The Forest Service uses NDGPS to find boundary corners where existing markers have often disappeared, to navigate to plot centers of areas of previous inventory and analysis work, to determine boundaries of sensitive streams, establish fire lines, define silviculture prescription boundaries, and support carbon deposit measurements. Other applications include mapping fire perimeters, research work, forest inventories, mapping of recreation trails and off-road vehicle trails, and mapping of noxious weeds. Many of these applications require levels of accuracy achievable with NDGPS (1-3 meters) and are in areas where WAAS or other satellite-based augmentation will not work. NDGPS is used to provide repeatability of navigating back to specific areas of interest, and to capture field data without post-processing, saving significant time.

Newer applications include ground mapping of noxious weed areas for aerial application of herbicides, mapping wildlife road crossings, and accurate inventories of forest resources at approximately one-third the cost of using survey instruments. NDGPS has improved field productivity of personnel because post-processing is not required. Forest Service personnel indicated that loss of NDGPS would require them to purchase more expensive equipment, and that costs to collect and enter data into their database would increase by 10-20%. Loss of CORS sites that are also NDGPS sites would also impact the ability to do post-processing.

Forest Service personnel indicated that NDGPS single coverage should be completed across CONUS and Alaska, and that states in the West under forest canopies, where only NDGPS has been shown to be effective, have been neglected, increasing costs of field data collection, and in some cases making this field data collection cost prohibitive. Higher accuracy would also benefit many applications.

The Forest Service has over 600 GPS users, approximately 120 of which rely on NDGPS.

[Applicable references for Section 4.4 in Appendix A:20, 2, 34, 36, 38, 39, 63, 64, 65, 71. Applicable references from responses to the Federal Register Notice, Table E-1, entries 0050, 0086, 0093, 0103, 0104.]

This page intentionally left blank.

5. State and Local Applications

5.1 Overview of State and Local Applications

Information collected demonstrates an increasing usage of NDGPS among both state and local governments. Both State and Local governments are using NDGPS to better manage their assets, helping to reduce the cost of government to their citizens. However, it should be noted that information on the usage and the number of NDGPS users in each state is very difficult to obtain, as all states studied had very little knowledge of the NDGPS program and its capabilities. In some cases, in order to obtain whether a certain state agency is using NDGPS, the assessment team had to physically inspect the GPS receiver being used to determine the source of augmentation being used. The only exception to this finding was the State Highway Departments that outfit their equipment with NDGPS due to the lack of coverage supplied by other forms of augmentation. In most states, the usage of NDGPS and GPS augmentation are the same. One of the primary applications of NDGPS at the state and local level is in the area of land management and maintenance of state-owned streets and roads. Other uses for NDGPS include asset tracking, maintenance location, and tracking of utilities, environmental monitoring, and the development of GIS information.

Figure 5.1-1. As Represented by this Snow Plow in Operation, State and Local Government Agencies Are Finding Increasing Applications of NDGPS

One area that the states express a concern with is in the area of survey and road construction. In these applications, NDGPS along with WAAS and other forms of GPS augmentation are not accurate enough for these industries. The ability of the NDGPS to provide a usable augmentation signal in areas where satellite-based augmentation systems do not work (such as urban canyons, in areas of dense foliage, or on the north side of tree lines or terrain) is very desirable; however, the system is not accurate enough for all road construction and surveying applications being performed in each state. To help overcome this situation, many of the states studied are developing and in some cases, deploying RTK networks to supply a highly accurate signal. These RTK networks are state owned and supported. In the case of California, the state plans to spend over 10 million dollars deploying 250 ground sites in an effort to cover the state with centimeter level GPS augmentation. The discovery that states such as Florida and

Tennessee have already begun the deployment of state sponsored RTK networks shows a growing need for highly accurate GPS augmentation. However, this discovery also raised the question of why states would spend millions of state funds to build these systems when the Federal Government is also developing high accuracy GPS augmentation.

The thirteen states studied (California, Tennessee, Kentucky, New York, Massachusetts, Washington, Oregon, Florida, Minnesota, Texas, Utah, Indiana, Illinois) were revisited and asked that very question. It was determined that these states had very little knowledge of the Federal Government's work on High Accuracy NDGPS, and that the states that were aware of high accuracy augmentation work by the Federal Government informed us that NDGPS was for railroad use only. Clearly, improved communications between state and Federal agencies is needed.

This communication situation could have grave consequences if not corrected. Once again, California helps illustrate this growing situation. California is prepared to deploy 250 reference stations statewide to perform various survey, ITS, and land management functions. However, California also states that their state supported RTK network can be used for a variety of situations including harbor navigation and aircraft take off and landings. The positive and negative impacts of possibly having 50 separate augmentation systems in the United States should be evaluated.

Information collected also shows that each state studied thus far is facing major congestion problems along their state and federal highways. Many of these states identify traffic congestion as one of the major problems facing their state. Many east coast states, along with California, see traffic congestion as a growing deterrent to economic growth and are looking to the development of Intelligent Transportation Systems (ITS) to help ease this situation.

The fact that many states are implementing their own augmentation networks is indicative of the need for an augmentation system that operates reliably at ground level. It may be possible to establish standards for these independent augmentation networks in order to integrate them into a nationwide, shared system that functions as a national GPS augmentation utility. This opens the opportunity for exploring options for cost-sharing or at least rationalization of the funding of what are otherwise fragmented, independent augmentation systems. This is explored further in Section 7.

State and local agencies identified a wide variety of applications, usually in the field and requiring real-time (vs. post-processing) data collection. The categories of applications include:

- Many of the transportation applications listed above;
- General real-time surveying;
- General navigation and mapping applications, including roads, trails, easements, sinkholes, snow plow operations, locating rural fire hydrants, E911 mapping and addressing;
- Construction support, including construction staking, utility location, line running, soil borings;
- Control adjustments on state augmentation networks;
- Asset inventory and location – signs, storm sewers, sanitary sewers, water mains, utilities, civil defense sirens, curb stops, ADA sidewalk compliance, park assets, park features, tree inventories and tree line delineation, roadside features;
- Conservation management, including location of conservation parcels, wetland delineation, forestry management, mapping archeological sites, environmental protection

mapping, soil condition mapping, glacier limit mapping, mapping mining locations, herbicide and pesticide application;
- Location data collection for crime scene investigations, accident investigations, emergency response, fire management, natural resource violations; and
- Cultural resource mapping and monitoring.

[Applicable references in Appendix A: 16, 21, 58, 59, 70, 87, 118, 123, 134, 142. Applicable references from responses to the Federal Register Notice, Table E-1, entries 0006, 0008, 0009, 0015, 0018, 0020, 0021, 0022, 0024, 0025, 0027, 0029, 0030, 0031, 0033, 0037, 0042, 0049, 0056, 0060, 0064, 0065, 0069, 0076, 0092, 0095, 0099.]

5.2 Use of NDGPS to Satisfy Regulatory Reporting Requirements

Some state-level agencies contacted during this study indicated that they used NDGPS to document boundaries required for regulatory reporting requirements, such as wetland mapping, flood plain mapping, endangered species and wildlife reporting, protected areas mapping, and GASB 34 (Government Accounting Status Board 34) capital asset reporting. GASB 34 requires reporting on the installation, location, and condition of long-lived capital assets, including transportation assets such as roads, bridges, and other transportation infrastructure assets.

5.3 AASHTO Survey

The American Association of State Highway Transportation Officials (AASHTO) surveyed their membership (state DOTs) regarding their applications of NDGPS. Table 5.3-1 summarizes the responses to this survey.

Table 5.3-1. Results of AASHTO Survey of NDGPS Applications			
State	**Point of Contact**	**Primary Applications**	**Other Points**
North Carolina	Charles Brown State Location & Surveys Engineer North Carolina DOT	• Searching for property corners • Staking out roadway centerlines • Estimating roadway construction costs	• Current NDGPS applications reduced staff time for walking property lines, using survey crews, locating geotechnical reference points, and developing construction cost estimates. • Planning to use NDGPS for wetlands mapping, pavement mapping and analysis, maintenance support, and vehicle tracking. • Want to minimize use of post-processing. • Experience shows NDGPS more accurate than WAAS • People more aware of WAAS, trying to increase awareness of NDGPS • NDGPS provides best performance until GPS modernization (which has been delayed) is complete. • Could operate with WAAS, but with reduced performance. • Support development of High Accuracy NDGPS.
Vermont	James McCarthy, PE Engineering Services Vermont Agency of Transportation	• Map locations of roads • Used in conjunction with video vans and grade data to map and measure roadside features • Map storm-water features • Map wetlands	• No other system can provide NDGPS levels of accuracy and coverage • Experienced significant dead zones when tried to use geostationary satellite augmentation systems
Maryland	Joseph White Maryland State Highway Administration	State Highway Administration • Developing highway maps • Road Feature Inventory • Asset Management • Reforestation and Wildflower Planting • National Pollutant Discharge Elimination System	

Table 5.3-1. Results of AASHTO Survey of NDGPS Applications			
State	**Point of Contact**	**Primary Applications**	**Other Points**
		Natural Resources Police • Mapping violations to be used for court evidence • Positioning aids to navigation and regulatory signs Department of Natural Resources • Monitor Forest Inventory plots • Wildfire burn area mapping and reporting • Fire Team action during fire fighting and rescue functions • Rural Fire Hydrant locating for fighting forest fires in remote areas • Herbicide and pesticide application	
New Hampshire	Charles P. O'Leary, Jr. Commissioner New Hampshire DOT	• Lay out soil borings • Position wetland flags • Support asset management program • Support National Pollution Discharge Elimination System data collection • Support Statewide Mile Marker Safety Program	• Only approximately one-half of NH covered by MDGPS sites • WAAS not adequate due to spotty coverage in non-aviation applications and incompatible mapping datum, which cause a 2-meter error in the data • Having to switch to a commercial augmentation service would cost approximately $150,000 for new receivers plus approximately $24,000 per year for subscriptions. • NDGPS provides required accuracy and real-time capabilities
Washington	John Conrad Washington State DOT	• Video logging for transportation data • Roadside Feature Inventory Program • Wetlands and other environmental feature data collection • Mapping traffic-related features • Ferry System navigation • Navigation of Geographic Services aircraft for geodetic surveys for highway construction • Use data from NDGPS and other	• Support continued operation of no-fee service

Table 5.3-1. Results of AASHTO Survey of NDGPS Applications

State	Point of Contact	Primary Applications	Other Points
		CORS sites in Washington State Reference Network	
Minnesota	Rich Arnebeck Director, Engineering Services Division Minnesota DOT	• Locating and inventorying culverts; data entered into GIS system to determine maintenance and improvement priorities • Locate and map environmental features such as historic sites and wetlands for project planning and alternatives analyses • Locate and inventory highway signs; data entered into GIS system for developing work management and business plans • Position auger trucks and locate test holes for soil borings • Locate and map snow drift areas and snow storage areas • Locate survey control points	• If NDGPS no longer available, state users would have to purchase significantly more expensive equipment to support applications shown.
North Dakota		• Roadway centerline planning • Cultural resource mapping • Environmental mapping • Highway-related surveys • Wetland and tree line delineations	• Response listed numerous users from state and local government, Federal government, land surveyors and engineers, and other organizations • Identified future applications for High Accuracy NDGPS • RTK is expensive to buy, and the base station has to be guarded, increasing costs of field data collection • Estimate 81% savings of time and cost for highway project control using NDGPS, representing $60-80,000 per year • Identified the following savings related to use of NDGPS: o Reduction of staff hours o Reduction of GPS receivers required o Reduction of vehicles to do the work o Reduction in cost to do the work

Table 5.3-1. Results of AASHTO Survey of NDGPS Applications			
State	**Point of Contact**	**Primary Applications**	**Other Points**
			• Estimate increase in Environmental Section costs of $75,000 per year for wetland tree field delineations if NDGPS is lost. • Estimate additional costs of $100,000 per year for wetlands mitigation due to errors in wetlands delineations if NDGPS is lost. • Estimate additional costs of $20-60,000 per year in Cultural Resources Section if NDGPS is lost due to additional manpower required to do field work and data processing. • ND invested $300,000 in NDGPS site Medora. • Estimate up to $80,000 per year to complete highway surveys if NDGPS is lost, due to requirement to go back to concrete monuments. • Without NDGPS sites, ND would only have data from two CORS sites, which is insufficient to accurately determine coordinates and elevation of survey points.
Montana		• CORS data from NDGPS sites • Survey project control • Mapping wildlife perimeters • Mapping wildlife kill along highways • Real-time map updates • Precise navigation	• Received input from US Forest Service units • No alternatives to NDGPS CORS sites in some locations • Alternative to CORS sites in other cases is use of distant reference stations, which affect accuracy, or pay subscription fee to private company

This page intentionally left blank.

6. GPS Market Trends

6.1 The Study of GPS Marketing Trends

As a guide to understanding substantial NDGPS uses, a study of market trends in the GPS industry was conducted to see if any marketing patterns could be established. If any market patterns were found, these patterns would then be analyzed to provide guidance and direction in the search for present and future uses of the NDGPS program within the United States. The study was conducted using historical information provided by SEAM, new market information provided by top executives of major GPS manufacturers, and information provided by major GPS retailers based in the United States and Europe.

6.2 Findings

Preliminary information from the study showed that clear market development patterns do exist in the GPS industry. One of these market patterns was discovered in a market segment entitled “Low Strength Receiver”. It is defined as the development, production and sale of a GPS receiver that can operate at full capacity in an environment less than -150dBm signal strength and was discovered to have a potential impact on the need for NDGPS and the NDGPS program. This pattern labeled NDGPS-P1 was explored to determine the impact this market development would have on the NDGPS program over the next three years.

6.3 NDGPS Market Patterns

The market pattern identified as NDGPS-P1 shows ten clear market steps that could become reality based on information collected. The NDGPS-P1 is built on the long accepted principle that the GPS industry will continue to search, learn, and harness the power of current GPS and GPS augmentation systems and then look for ways to capture more performance out of these same systems. The NDGPS-P1 also follows other long established GPS marketing patterns, helping to add to the confidence level and the predictability of the NDGPS-P1 and its “Low Strength Receiver” market segment. Below are the ten marketing phases that have been identified and validated in the creation of the NDGPS-P1:

1. Positioning Environment;
2. GPS Only;
3. GPS + Dead Reckoning (DR);
4. GPS + GLONASS;
5. GPS + Differential;
6. Low Strength GPS Environments;
7. Low Strength GPS Only;
8. Low Strength GPS + GLONASS;
9. Low Strength GPS + DR; and
10. Low Strength GPS + Augmentation.

The realization of the NDGPS-P1 is well underway as steps 1 thru 9 have already taken place. This is evident by Trimble's release of their new Lassen® Dead Reckoning + GPS receiver, a Low Strength GPS + Dead Reckoning receiver. As stated before, the NDGPS-P1 follows the same market patterns that were followed in the beginning of the GPS industry. It can be expected that the market will begin to move to Phase Ten within the thirty six months. The question left unanswered is what current augmentation system will meet the demands of the NDGPS-P1.

6.4 NDGPS-P1 Augmentation

With the development of NDGPS-P1 Phase Ten, a preliminary examination of all current augmentation systems, Private L-Band subscription fees, RTK Base Stations, WAAS, and NDGPS was conducted to see which augmentation system would best meet the demands of the NDGPS-P1, and the "low Strength Receiver" market. Information was gathered from the manufacturers of the new Low Strength GPS receiver to establish both the environments in which these new generation receivers would be operating and the percent of full operational capability needed to satisfy the target market. The information collected showed the target markets to be the Automotive, Survey, Fire and Rescue, and the Personal Location markets. Users in these target markets often operate in areas of heavy tree canopy coverage, rugged terrain, and other natural and man-made sources of signal blockage. The information further showed that a system had to provide a minimum of 85% areas coverage to satisfy the needs of the target markets. Based on historical and field data collected, the only augmentation that would currently meet the 85% coverage at ground level requirement for the NDGPS-P1 is the NDGPS program.

6.5 Conclusion on Marketing Trends

The NDGPS-P1 shows a clear upward trend in the use of "Low Strength GPS Receivers" operating in very poor GPS environments. The NDGPS-P1 also shows a clear need for the current NDGPS program in order to allow this market segment to grow. However, even though the assessment team believes that the information gathered suggests that the NDGPS-P1 will be a substantial market trend in the future growth of the GPS industry, especially in the automotive industry, it is not possible to tell from this preliminary information just how big the economic impact of the NDGPS-P1 will be on the US economy. However, it is clear that over the next thirty six months this market segment cannot be explored and developed without NDGPS. An area where improvements could be made to NDGPS receivers is the size and weight of the units, as compared to GPS receivers with built-in satellite receivers. Satellite-based augmentation receivers tend to be smaller and lighter. In applications where the differential correction information is distributed to the user over a radio frequency data link other than the MF beacon frequency, it should be possible to make NDGPS units that are smaller and lighter. This is already true of NDGPS receivers that do not include the MF beacon receiver.

7. Augmentation Fragmentation in the United States

7.1 Observations on Augmentation Fragmentation

As part of this NDGPS assessment, information was gathered from a number of states on their current and future use of NDGPS and other forms of augmentation. This data collection identified a trend towards the deployment of independent augmentation systems. A total of 28 states that were contacted are both developing and have deployed, or are developing or have plans to develop and deploy, state-sponsored High Accuracy Augmentation. Most of these systems were initially developed to assist the survey markets in each state. However, each state involved is rapidly coming to an understanding that these augmentation systems cannot be justified from a cost stand point based on just one industry. This has led these states to begin to develop state-sponsored augmentation to serve the general public. This is clearly seen in the California case study. California is promoting the deployment of 250 High Accuracy Reference sites to meet the needs for all industries including the navigation of marine shipping in harbors and rivers, aircraft landing control, and Intelligent Transportation Systems. Other states that are developing state sponsored augmentation include: Tennessee, Kentucky, New York, Massachusetts, Washington, Oregon, Florida, Minnesota, Texas, Utah, Indiana, Illinois, and others. At first glance, this information may lead some to begin to believe that the Federal Government should remove itself from the development of augmentation and allow the states to continue their development. However, a careful analysis of uncoordinated state sponsored augmentation shows the dangers that exist if the Federal government allows the situation to continue. Below are a few of the potential dangers of uncoordinated development of augmentation systems:

- *Fragmented Augmentation across the United States*: The very reason the Federal Government funded and developed augmentation was to develop a seamless navigation system worldwide. The current trend would see the United States as the only country with GPS capabilities with an uncoordinated augmentation system.
- *Multiple Augmentation System Effect on Receiver Development*: Multiple systems will cause the cost of receivers to increase significantly due to the low volumes of production runs.
- *Duplication of Efforts*: Without a rapid coordinating effort by the Federal Government, State and Federal projects will overlap, creating unwise use of tax dollars.
- *Impact on Navigational Safety for Transportation*: The current trend could adversely impact the safety of transportation as each state develops its own standards.
- *National Security*: To date, all GPS and National augmentation systems are under control of the Federal Government. The current trend will create 30 to 40 separate augmentation systems that would have to be dealt with independently during a time of National crisis.
- *Competing Systems will Slow the Adoption of New Technology*: In its early development, GPS differential competing systems caused confusion in the market place and slowed the adoption of GPS technology into the private sector. The current trend of state sponsored augmentation will have the same slow down effect.
- *Increase in Federal Government Cost:* State-sponsored augmentation systems that would be developed for safety of life applications would require oversight by the Federal

Government, requiring new government programs and inter-agency coordination and management.

There are many potential pitfalls that currently exist in the development of individual state-sponsored augmentation. However, there are also some very positive aspects to be gained from this same information. First, the information clearly shows the interest that many States have in developing augmentation systems. Secondly, discussions with individual States shows that the states prefer Ground-Based Augmentation Systems over Satellite-Based Augmentation Systems. This preference is based on the better performance of Ground-Based Augmentation Systems in conditions where the user is behind a tree line, in heavy foliage, or in rolling terrain where it is difficult to receive the signal from the geosynchronous satellites used in Space-Based Augmentation Systems. States that are implementing their own augmentation systems are installing an independent network of ground reference stations. Thirdly, each state interviewed expressed the need for high accuracy augmentation.

As the current generation of GPS augmentation systems evolved, the system was typically a concurrent selection of the augmentation technology, selection of deployment sites for installation of the reference stations, and a method of distribution of the correction information from the reference station to the end user. NDGPS and MDGPS use Medium Frequency beacons to transmit the data to end users; WAAS and some commercial subscription augmentation services use geosynchronous satellites for data distribution; and commercial survey-grade systems typically use a proprietary short-range communications radio between the moveable reference station and the user receiver. In collecting and evaluating information on the pros and cons of these different GPS augmentation systems, it is difficult to separate user opinions based on the characteristics of the augmentation method itself, and the type of communications path used to transmit the augmentation data to the end user equipment. Therefore, users may prefer one augmentation system over another based on either the augmentation performance (accuracy) or the communications performance (e.g., ability to receive the augmentation signal in their application environment).

7.2 Recommendations on Augmentation Rationalization

Looking ahead, it would seem prudent to establish a program to consolidate these fragmented augmentation systems, based on a standard that covers performance, integrity, and interfaces. The standard should separate the derivation of the corrections and the means of distribution of the augmentation data to the end user. This would support combining different augmentation systems into a consolidated network, or at least sharing the resources of the different augmentation networks. Needed receiver characteristics, RTCM and other data formats, impacts of delays in delivery through different communications paths, and other system characteristics would need to be evaluated to support development of a standard for civilian GPS augmentation.

If there was a standard interface for delivery of correction information that met common performance standards, different user communities could use different communications paths to deliver the data. For example, many users may use the MF beacon, vehicles could use DSRC, railroads could use their own data link, state and local agencies may have their own data links, commercial services such as cellular systems could be used, and aviation could use satellite services. There would also be network (internet or other) delivery of the correction information from the augmentation reference station to the communications delivery system or service.

If there was one common correction standard, it is likely that all future industrial receivers would have augmentation built in. There could be an internal GPS augmentation receiver, and a data port(s) for receiving augmentation information from the communications receiver. Since it may not be cost effective for a manufacturer to produce different boards or different chip sets with and without augmentation, the marginal cost for augmentation could be nominal.

At some point in the future, deployment of a single, robust new augmentation network, funded by or through one agency, may be justified to support multiple application environments. This could be done in concert with the GPS modernization program. However, the current projected timeline for the full-scale GPS modernization program is beyond 2025, whereas it should be possible to rationalize the current fragmented set of augmentation systems in a few years, providing the benefits earlier. This option needs to be evaluated relative to plans for GPS modernization, to determine how this rationalized augmentation network fits into technical parameters for a future PNT system, and how other programmatic, technical, and schedule parameters line up. It may turn out that it would not make economic sense to spend money to consolidate current augmentation systems until GPS modernization, and that maintaining current augmentation systems is justified until there is a viable alternative.

Combining different Federal Government augmentation systems, as well some state or private networks, would provide better coverage and augmentation signal availability. If there are standard performance characteristics and communications interfaces, users would benefit and the combined system would support a variety of wireless communications paths to users. This would enhance user acceptance, provide the basis for supplier product development planning, and be consistent with cost-sharing.

In order to evaluate the effectiveness of such a rationalized augmentation network for different GPS applications, it may be necessary to build a mathematical model to evaluate the effect of end-end latency (and other factors) on the achievable accuracy for different applications. This would allow evaluation of the impact of latency at different steps in the process, from the derivation of the correction data through the various communications paths to the handling of the positioning data within the user equipment. For example, for a mobile application like VII, latency relates to loss of accuracy at the application level, since the vehicle has moved before the final position is used by the application. The latency through the delivery path for the correction data may not be much of a factor, but a complete end-end model would allow sensitivity analysis of all factors to provide credibility for evaluating higher accuracy, real-time applications, and the model could be evaluated against field tests with a ground truth.

The other area that should be addressed through both standards and modeling is dead reckoning. National level forums on future PNT needs have identified the need for enhanced dead-reckoning sensors such as Micro Electro-Mechanical System (MEMS) motion sensors and Chip Scale Atomic Clocks (CSACs) for future applications. Currently, most MEMS-based motion sensors are inexpensive but have high drift rates. There needs to be a standard for dead reckoning (in general, operating through GPS signal blockage or poor GDOP). There also needs to be a standard for calculating the actual current accuracy level, confidence interval, and integrity of the end user device solution, considering all inputs into the solution.

In summary, the following future GPS augmentation activities should be considered:

1. Evaluation of the requirements and approaches for developing a consolidated augmentation network. This would include development of draft standards for performance, interfaces, and integrity. This would require discussions with receiver and chip suppliers, as well as suppliers of reference stations. The impact of consolidation of GPS augmentation techniques on receiver cost should be explored. Further discussions should be conducted with states that are establishing their own augmentation networks to determine if the reference stations they are deploying could be nodes in a consolidated network, and under what programmatic approaches the states would consider such an arrangement. There may be opportunities for partnerships for deployment and operation of a rationalized GPS augmentation network that involves various Federal agencies, state agencies, and commercial entities.

2. Development of standard requirements for dead reckoning inputs to GPS receivers, and possibly standard requirements for data fusion of raw GPS, correction data, and dead reckoning or other inputs.

3. Evaluation of how this approach fits into GPS modernization plans.

4. Development of a model(s) to evaluate the impact of correction equipment performance, data link latency, dead reckoning inputs, end user processing steps, user speed of movement, and other factors that impact the accuracy as seen by the user or user application.

5. If the concepts look feasible, development of nationwide augmentation standards.

6. Explore means of improving the performance of MEMS or other technology dead reckoning devices in more detail, to determine the cost/performance trends, standardization of performance or requirements for processing the sensor outputs and providing a dead reckoning input, Kalman filter characteristics, and other design parameters. Given that dead reckoning seems to be a requirement for most vehicle applications, this seems like a fruitful area for research and standardization.

These activities would affect all civilian users, so there may be various means of funding and managing these activities. The future requirements for GPS augmentation also need to consider the planned upgrades to the GPS constellation and GPS signal suite, as described in summary form in Section 10.2.

8. Federal Register Notice

On August 1, 2007, a Federal Register Notice was released providing background on the current status of the assessment of NDGPS, and requesting comments. The Notice can be found in Appendix F of this report, and on pages 42219-42220 of the Federal Register. The reference is RITA docket number RITA-2007-28836.

The table in Appendix E presents a summary of the comments received, as extracted from the Regulations.gov web site. At the time of writing of this report, the actual responses can be viewed on the web site http://www.regulations.gov/search/index.jsp, entering “28836” into the *Search* dialogue box, and selecting the entry for “RITA-2007-28836”.

There were a total of 128 responses to the Federal Register Notice, including six (6) duplicate responses and three (3) blank entries, as of the date of this report. Of the responses received as of the date of this report, there was one negative response (from a commercial DGPS service provider), and one neutral response; the other 117 responses were in favor of continuing NDGPS. Several responders recommended building out the network to the planned Full Operational Capability, and some recommended adding High Accuracy NDGPS capability to the sites.

This page intentionally left blank.

9. NDGPS Costs and Benefits

9.1 NDGPS Costs

The annual costs to maintain the NDGPS network in its current level of build-out is approximately $5 million (FY08 dollars, source USCG).

The projected cost to complete deployment of the NDGPS network to 99% single coverage is approximately $6.0 million.

A projected $3.45 million is needed for recapitalization to replace outdated equipment.

The projected cost to complete deployment of the NDGPS network to Full Operational Capability is approximately $ 19 million. At full deployment, the estimated annual operating cost is $5.4 million (FY08 dollars, source USCG).

The projected cost to decommission the NDGPS network is $30 million.

9.2 Overview of NDGPS Benefits

This section describes various categories of benefits. Sufficient data did not exist to quantify all of these benefits. The basis for providing the benefits to be discussed includes:

- NDGPS provides the accuracy required for many future transportation applications;
- NDGPS does not suffer from the line-of-sight restrictions of geosynchronous satellite augmentation systems, and provides superior operation under dense foliage canopy and around terrain and man-made obstructions;
- Users don't have to set up and move their own reference stations;
- NDGPS provides sufficient accuracy for guidance or automated control of machinery, and measurement of work performed, in a number of industries; and
- NDGPS can contribute to improved environmental conditions and adherence to environmental regulations by enabling reduced applications of chemicals of various types, and to target the applications to only those areas requiring them.

While other methods of GPS augmentation can be, and in some cases, are being used to achieve some of these benefits, the primary distinguishing factors are that NDGPS works under certain field conditions where satellite-based augmentation fails.

The following subsections will qualitatively describe the types of benefits that will be examined further as candidates for quantification in the final report. The categories of benefits being considered for quantification include:

- Direct Impact on FHWA Operating Budget;
- Transportation Economics;
- Value of CORS data;

- Cost Savings;
- Life Savings;
- Efficiency Increases; and
- Environmental Impact.

These will be described in the subsections that follow.

9.3 Direct Impact on FHWA Operating Budget

9.3.1 Introduction

An evaluation was conducted to determine the direct impact, if any, the loss of NDGPS would have on the Federal Highway Administration's Operating Budget. To accomplish this task, a very strict set of guidelines were developed that only allowed the gathering and consideration of information that would produce a direct increase or decrease in the Federal Highway Administration's Operating Budget. In doing this, many applications and economic benefits that could be contributed to the NDGPS were ignored. This report also does not address any cost savings that could be obtained by the Federal Highway Administration (FHWA) itself due to improvement in the NDGPS.

To narrow the focus of this report even more, the evaluation focused only on the construction and maintenance costs of highway projects that make use of Federal Highway Administration dollars. This report also uses information from the American Road & Transportation Builders Association (ARTBA) that only considers highway projects whose benefits out weighed cost. In using this information from the ARTBA, many highway construction projects that will be performed over the next five years were removed from the final dollars to be invested by the Federal Highway Administration. This report does not attempt to calculate the economic or social effects that delays, advances, or cancellations of highway construction projects would create on the State, Federal and Local levels of government.

9.3.2 Projected Highway Construction Needs over the Next Five Years

In their report entitled *The Nations Highway and Transit Needs Through 2015*, the ARTBA estimates over $131 billion dollars will be needed each year until 2015 to maintain the current surface transportation system as it relates to highways and bridges. These estimates include all government costs including State, Local and Federal monies that will be needed for road and bridge maintenance and improvements.

9.3.3 Projected Actual Highway Construction Funding Over the Next Five Years

Using information from four different sources, including the 2006 DOT *Report on Conditions and Performance of the Nations Highways, Bridges and Mass Transit Systems* and *The Nations*

Highway and Transit Needs Through 2015 report from the ARTBA, along with other State and Local data, suggests that a minimum of $78.8 billion dollars will be invested in road construction and maintenance each year for the next 10 years. Additional information obtained during this evaluation suggests that Congress could, over the next five years, increase this amount with additional highway budget increases. However, for this study on the effects that NDGPS will have on the Federal Highway Operating Budget, only the minimum annual amount of $78.8 Billion dollars per year that has been budgeted is considered over a time frame of five years. It should be noted that the $78.8 billion dollar amount is the total estimated investment by State, Local and Federal governments (in 2004 dollars) and is restricted to highway and bridge construction and maintenance only. Using these estimates, over $394 billion dollars will be invested in highway construction and maintenance over the next five years.

9.3.4 Projected Actual FHWA Costs Over the Next Five Years

The ARTBA estimates that, over the past twenty years, FHWA has provided 45% of all highway construction and maintenance funding, leaving the remainder to be funded on the state and local levels. Using this data, the estimated Federal Highway investment or operating budget over the next five years, as it relates to road construction and maintenance, would be $177 billion dollars. (Note: This figure is based on 2004 dollars with no correction for inflation.) With the amount that FHWA is estimated to spend over the next five years calculated, our study turned to the question of the impact that the loss of NDGPS would have on this base amount of $177 billion dollars.

9.3.5 Projected Increases or Decreases in the FHWA Budget Due to NDGPS

Two questions were addressed in evaluating the impact of NDGPS on the FHWA Operating Budget: First, would the loss of NDGPS decrease the Federal Highway Operating Budget; and second, would the loss of NDGPS increase the Federal Highway Operating Budget. It should be noted that the conclusions reached are based on information provided by construction companies and state departments of transportation, and are not based on any field work or comparison of different GPS equipment. Only professionals with a deep understanding of road construction and the use of GPS and GPS augmentation were used. Therefore, it is assumed that the information provided by each group is accurate.

Question One: Would the loss of NDGPS decrease the five year, $177 billion dollar operating budget of the Federal Highway as it relates to construction and maintenance cost? As the NDGPS program is not funded by FHWA at this time, there is no evidence that would support a decrease in the FHWA's operating budget due to the loss of NDGPS as it relates to construction and maintenance project.

Question Two: Would the loss of NDGPS increase the five year, $177 billion dollar operating budget of FHWA as it relates to construction and maintenance cost? To determine the answer to this question, two areas of road construction and maintenance were evaluated. The first issue was whether NDGPS is currently used in automated equipment controls in road construction and maintenance. The second issue was the operating costs of Planning, GIS, Environmental

Evaluation, and Surveying needed to carry out the construction and maintenance of highway projects.

Automated Equipment Control: A review and survey of major road construction companies across the United States showed that one of the most advanced technologies being used today is found in the automation of road construction equipment. These new technologies are greatly decreasing the amount of time it takes to construct a modern highway. The developers and users of automated construction equipment have known for some years that the ability of NDGPS to provide an augmented GPS signal in very tough terrain is highly desirable and useful in the road construction industry. However, these types of applications now require greater accuracy levels than can be obtained by the current NDGPS. Therefore, there is no impact on this segment of road construction that would be effected, at this time, if NDGPS were to be lost. However, it was interesting to note that two of the construction companies surveyed stated that WAAS had some value to their road construction projects. This statement stands out due to the ability of the WAAS to operate under poor conditions of heavy foliage and terrain (or other causes of loss of signal) is much less than the ability of NDGPS to operate in the same environment. Once again, there seems to be a lack of industry knowledge and information as it relates to the applications of NDGPS. It should also be noted that the addition of High Accuracy NDGPS could create large benefits in this area of operation and provide the Federal Highway with increased cost savings.

Planning, GIS , Environmental Evaluations, and Surveys: The second segment of the road construction industry that was identified as potentially being effected by the lack of NDGPS were the areas of Planning, GIS Work, Environmental Evaluations, and Surveys. To gain an understanding of how the lack of a NDGPS signal would affect these construction segments, ten State Departments of Transportation (Virginia, North Carolina, South Carolina, Florida, California, New York, Minnesota, Massachusetts, Vermont, and Maryland) were surveyed and asked to place a value on the loss of the NDGPS as it relates to highway construction and maintenance. These States were asked to limit their data to only information that would affect projects that would receive FHWA dollars and to projects that depend mainly on NDGPS as the augmented GPS source. This segment of the study was very difficult to evaluate as no existing data base can supply this information. Therefore each State involved was asked to express, as a percentage, the increase in total road construction and maintenance costs, if any, which would be generated if the NDGPS was no longer available. Based on this survey, and averaging the data from the ten states, it was established that there would be a 0.3% increase in road construction and maintenance costs if NDGPS was not available.

9.3.6 Conclusion

Using the established five-year base value of operating cost for FHWA of $177 billion dollars, as it relates to construction and maintenance, and applying the 0.3% increase in construction and maintenance estimated by the states, the FHWA Operating Budget could increase as much as $106,200,000 dollars per year. However, refining the report even more, we assumed that the entire amount of $106,200,000 dollars per year could not be a completely attributed to NDGPS, as some of this Planning, GIS, Environmental Evaluations, and Surveys could be accomplished with WAAS or private augmentation services. To conservatively evaluate the impact that the loss the NDGPS would bring to the operating cost of FHWA, only the percentage of the nation-wide coverage of GPS augmentation that can *only* be serviced by NDGPS due to signal strength and ground-level coverage issues would be counted. To determine the true impact the lack of NDGPS would have on the operating budget of FHWA, data was used from a study conducted by SEAM in 2000 (*Evaluation of the Availability of GPS Augmentation Throughout the United States*) that evaluated, as a percentage, the amount of land in the United States that could only be served by NDGPS; i.e., areas where satellite-based augmentation services would not work or were not suitable. This study took into consideration that some portion of the land that can only be served by the NDGPS is not eligible for development or construction. Therefore, only the areas in the U.S that would or could be considered for development and construction were included. The study also based its information on the fact that a loss of signal of over 15 % of the total time in usage was not acceptable for a commercial application and therefore could not be used on projects that had either schedule or profit margin constraints. The SEAM study concluded that 17% of the United States can only be serviced by NDGPS due to lack of availability of augmentation signals from satellite-based augmentation services in those areas, or loss of signal from the satellite-based services more than 15% of the time.

Using this 17% national coverage factor, and relating it back to the $106,200,000 dollars estimated annual increase in the FHWA Operating Budget due to the loss of NDGPS, it is estimated that the total annual impact on the FHWA Operating Budget due to the loss of NDGPS would exceed $18 million dollars. This is considered to be a conservative estimate since no value is attributed to the areas where satellite-based augmentation services are viable, even though some users may use NDGPS in those areas, which represent 83% of the nation. Further, some data sets which include state and private company information indicated that the 0.3% increase factor could be as high as 0.6%, bringing the total increase of the FHWA's operating budget to over $36 million dollars per year.

[Applicable references for Section 9.3 in Appendix A: 123, 124, 125, 126,127.]

9.4 Transportation Economics

Several of the categories of economic impacts already described relate to the economics of transportation operations. One purpose of this assessment was to determine the transportation applications of NDGPS. The information gathered in conducting this assessment point to potentially increasing transportation applications, and the potential to achieve a number of areas of benefit. These include:

- Reduced accidents, resulting in lives saved, reduced accident costs, and potentially reduced insurance rates for those drivers or operations taking advantage of advanced telematics and command and control applications;
- Improved traffic flow management and Congestion Mitigation, resulting in reduced fuel costs, reduced emissions, and reduced travel delays (with associated labor cost savings and improvements in national productivity);
- Reduced maintenance costs from better targeting of maintenance activities, better records of previous maintenance actions, and automation or guidance of maintenance machinery; and
- Enhanced command and control of emergency response vehicles and operations by having more accurate location of incidents, utilities, and vehicles and personnel, resulting in quicker response with fewer errors, lives saved, and more efficient use of emergency response equipment.

9.5 Value of CORS Data

As described in Section 4.1, GPS users throughout the Nation use data from the Continuously Operating Reference Stations (CORS) sites, through a service by the National Geodetic Survey, to post-process GPS location data collected in the field in order to improve the accuracy of their data. NGS estimates the economic benefits of using CORS data at $400M per year.

NDGPS sites constitute approximately 10% (currently 14.5%) of the CORS sites; therefore, the value that can be associated to the NDGPS sites for these post-processing applications is approximately $40M per year.

[Applicable references in Appendix A: 29.]

9.6 Cost Savings

GPS is used to support a number of tracking, monitoring, mapping, and field work guidance and automation applications that can produce cost savings to commercial and Government operations. Many of these require real-time augmented GPS to provide the enhancements to operations and safety necessary to realize the potential benefits. The categories of cost savings include:

- *Minimize operations*: cost savings due to reductions in operating costs as a result of limiting work to only areas specified, such as being able to determine the limits of grading, dredging, or other field work;
- *Reduced fuel costs*: costs of fuel saved by reductions in equipment usage resulting from improved command and control;
- *Reduced costs of chemicals*: reduced costs of chemicals applied in the field by limiting applications to only those areas necessary;
- *Reduced labor costs*: reduced labor costs due to better control of work activities not accounted for in other categories; and
- *Reduced accident clean-up costs*: reduced costs of clean-up of avoided accidents resulting from safety-related applications.

Detailed data does not exist to support analysis of the savings attributable to NDGPS for each of these areas of cost reduction. It is the understanding of the authors of this report that USDOT is conducting an evaluation of the costs and benefits associated with advanced Intelligent Transportation Systems.

9.7 Life Savings

There are a number of applications that directly support safety-of-life functions, such as highway and rail accident prevention. More accurate location information will contribute to reductions of accidents and expediting rescue efforts. Quantifiable benefits from this category include cost of lives saved in:

- Highway;
- Rail;
- Transit; and
- Public safety/first responder operations.

In addition to applications of augmented GPS in safety systems to provide automatic warnings of unsafe conditions (over-speed, unsafe change of lane, not stopping at appropriate point, etc.), augmented GPS can also be used to enable rescue operations by providing accurate location information on the accident by transmitting information on the location of the accident, resulting in quicker emergency response to the right location.

The CICAS program has an ongoing research program to address the benefits associated with intersection collision avoidance, which represents one of the larger contributors to highway deaths. Future VII implementation may also have applications designed to reduce accidents associated with rear-end collisions, lane departure, lane changing, and other situations involving vehicle-vehicle and vehicle-roadside accidents. The railroad industry is implementing Positive Train Control systems, designed to reduce railroad collisions, over-speed operation, and protection of track forces. Many highways are being equipped with signal priority and other systems designed to provide protection for public safety and first-responder vehicles. All of these systems require accurate vehicle location to achieve the design safety benefits. Vehicle positioning is a necessary enabling technology to achieve the significant safety of life benefits associated with these programs, and a high-accuracy ground-level GPS augmentation system is needed to support the positioning requirements of these systems.

There are other Safety of Life (SOL) applications of NDGPS, by Federal and state agencies, and private companies that support public safety and emergency response operations. The applications specifically noted by those NDGPS users include:

- Supporting search and rescue efforts;
- Fire management and mapping fire perimeters;
- Emergency response and operations management;
- Navigation of vehicles and aircraft for fire and emergency response and operations;
- Locating fire hydrants in fighting forest fires in remote areas;
- Hazardous cargo tracking; and
- E911 data collection.

The potential applications of NDGPS for safety-related operations could increase due to the trend in sales of more sensitive GPS receivers. GPS receivers have been developed to operate with very low signal levels to support operations in buildings. The primary target market for these new receivers is emergency response, which by the nature of the application requires more accurate location than un-augmented GPS (e.g., locating a person within a burning building or collapsed structure). NDGPS can provide the accuracy necessary to locate a person within a building under poor visibility or other dangerous conditions; satellite-based augmentation signals would not be able to penetrate within the building.

None of those surveyed were able to identify specific numbers of lives saved as a result of these NDGPS applications, but they indicated that loss of NDGPS would have a detrimental effect on the these safety of life operations, particularly since many of these operations occur in areas where satellite-based augmentation is not reliable.

[Much of the information came from direct discussions with NDGPS user groups, as reported in Sections 4 and 5. Applicable references in Appendix A: 9, 10, 138, 139, 140, 141, 142, 143, 149, 150, 151,152. Applicable references from responses to the Federal Register Notice, Table E-1, entries 0006, 0007, 0010, 0017, 0019, 0022, 0025, 0042, 0045, 0048, 0050, 0063, 0065, 0066, 0068, 0069, 0081, 0082, 0086, 0087, 0088, 00091, 0093, 0099, 0100, 0101, 0103, 0109, 0111.]

9.8 Efficiency Increases

Augmented GPS enables benefits associated with improvements in efficiencies of operations in the field for the various categories of users that have been identified. The benefits to be quantified will include:

- Increased yield with less labor and material input;
- Yield mapping for continuous improvement, by providing measures of the relationships of materials used per unit of work product or output that can be used to support ongoing planning of improvements;
- More efficient use of expensive machinery in terms of more use per unit time and reduced cost per job; and
- Benefits associated with repeatable operations.

Detailed data does not exist to support analysis of the savings attributable to NDGPS for each of these areas of cost reduction. As one example, the state of North Dakota [Appendix E, Table E-1, entry 0042] estimated the following savings attributed to use of NDGPS:

- 81% savings of time and cost for highway project control, representing $60-80,000 per year;
- $75,000 per year for wetlands tree delineation;
- $100,000 per year for wetland mitigation;
- $20-60,000 per year for related to cultural resources field work; and
- $80,000 per year for highway surveys.

A number of organizations responding to the Federal Register Notice identified the efficiencies related to use of NDGPS for field surveys, construction staking, GIS data collection, road construction planning, natural and cultural resource management, inventory and asset management, and other field data collection and mapping applications.

Looking at the economics another way, there are approximately 41,000 NDGPS units in operation. Of these, approximately 8000 units have been sold to Federal Government users and approximately 7500 units have been sold to the private sector in the last 5 years. (There are additional NDGPS-capable units that have been sold that also include capabilities for satellite augmentation, but these are not included in the above numbers since there is no way to determine which augmentation mode is used.) Based on the current $4.6M annual NDGPS Operations and Maintenance budget, the annual O&M cost per unit is ($4,600,000/41,000) = $112 per unit per year.

Based on data from the Bureau of Labor Statistics (BLS) for October 2007 [Bureau of Labor Statistics, USDL-07-1789, “Real Earnings in October 2007.], the average hourly earnings in the construction industry is $21.23 ($42,630 per year based on 2008 hours per year). Assuming a labor burden (benefits, facility, and other overhead costs) rate of 75%, the total cost per hour is ($21.23*1.75) = $37.15. This equates to ($112/$37.15) = 3 hours per year of saved productivity per NDGPS unit per year to pay for the NDGPS O&M costs. The number is likely less than 3 hours, since the hourly earnings for personnel using NDGPS is probably higher than the BLS average.

[Applicable references for in Appendix A: 4, 7, 8, 12, 13, 16, 20, 21, 28, 45, 63, 64, 66, 68, 70, 75, 77, 79, 81, 83, 84, 102, 103, 104, 113, 120, 123, 134, 139. Most of the references from responses to the Federal Register Notice, Table E-1, address various applications of NDGPS and discuss how it increases labor and equipment efficiency.]

9.9 Environmental Impact

The availability of more accurate location of industrial and farm machinery supports:

- Reduced applications of chemicals, resulting in improvements in the environment;
- Reduced environmental impact by minimizing disturbance to the ground or waterways by more accurate machine control;
- Providing “proof of performance” to document that regulatory requirements have been satisfied.

Various studies on precision agriculture have shown a 20-40% reduction in the application of chemicals (fertilizer, pesticides, and herbicides) using GPS-guided farm machinery and precision agriculture methods. This produces two sources of savings – the costs of the chemicals, and the environmental benefits associated with reduced pollution, impact on wildlife and water quality, resource management, and cleanup operations. Various studies put these cost impacts in the billions of dollars, but it is outside the scope of this assessment report to determine how much of these savings could be attributable to NDGPS.

NDGPS users also identified a number of applications relating to environmental monitoring and assessments, documenting environmental violations, planning and executing environmental cleanup, sinkhole monitoring, wetland mapping, hydrographic surveys, and various natural resource conservation activities.

[Applicable references in Appendix A: 16, 31, 32, 34, 38, 63, 64, 65, 68, 75, 77, 79, 81, 84. Applicable references from responses to the Federal Register Notice, Table E-1, entries 0008, 0014, 0016, 0021, 0022, 0024, 0029, 0031, 0034, 0025, 0038, 0039, 0042, 0049, 0052, 0056, 0060, 0066, 0069, 0071, 0076, 0079, 0081, 0082, 0086, 0089, 0091, 0097, 0100, 0103, 0107, 0108, 0113.]

9.10 Weather Data Collection

As discussed in Section 4.3, NDGPS sites are used to collect weather and atmospheric-related data. Data collected at these sites is used to feed NOAA's weather prediction and monitoring models, and to model atmospheric impacts on GPS performance, which are used to improve the accuracy of GPS location measurements and to predict the occurrence of poor GPS performance.

NDGPS is very important to NOAA, particularly its use of the NDGPS sites for weather-related data collection. They consider the NDGPS sites as part of their backbone of data collection sites for weather forecasting and climate modeling. They use the carrier phase measurements from the sites for applications described below. These data are provided as input to weather models, and are also sent to all National Weather Service (NWS) sites, all state DOTs, researchers and others. Since NDGPS sites constitute over 10% of all National CORS sites, NOAA would lose a significant portion of its weather data collection network if NDGPS were shut down. NOAA indicated that enhancing NDGPS sites to provide higher accuracy would provide significant benefits to the real-time positioning community, including surveying and mapping applications.

A recent example of the value of precipitable water vapor data collection at NDGPS and other CORS sites was the demonstrated accuracy of near-term precipitation forecasts related to ice storms in the Eastern US in February 2008.

The 2002 *Weather Information for Surface Transportation, National Needs Assessment* report discusses the value of weather data in surface transportation operations. The impacts of weather on surface transportation include contributions to accidents and the impact on network capacity. The report discusses the potential role of Intelligent Transportation Systems in distributing weather data to users, and the use of surface weather conditions in decision support and traffic management systems. The report addresses an estimate from the National Highway Traffic Safety Administration (NHTSA) from an analysis in 2000 that adverse weather and adverse road conditions contribute directly or indirectly to 800,000 injuries and 7,000 fatalities from vehicular crashes, representing approximately 28 percent of the total crashes and 19 per cent of the total fatalities. The estimated annual economic cost of these weather-related crashes is roughly $42 billion. The report indicates that 544 million vehicle-hours of delay in 1999 could be attributed to the effects of snow, ice, and fog. It is not possible to specifically allocate a portion of these avoidable costs to the weather data collected at NDGPS sites, but the NOAA weather data collection apparatus located at NDGPS sites is part of the overall weather data collection network.

See Section 4.3 for references and detailed descriptions of weather data collection at NDGPS sites.

10. Other Influences on NDGPS Applications

10.1 Other Real-Time GPS Augmentation Systems

There are other real-time GPS augmentation systems in place that support various applications. Some of these systems use commercial and Government geosynchronous L-Band satellite systems to distribute the correction information. These systems do not necessarily work well for surface applications, due to line-of-sight signal blockage caused by foliage or other canopy, terrain, or buildings, particularly for operations on the north side of trees, terrain, or buildings (due to the fact that geosynchronous satellites are over the equator, requiring a clear view of the sky towards the south).

There are also commercial systems that use other satellite means of distribution of GPS correction data, or networks of commercially or individually user-owned reference stations. These commercial systems require annual subscription fees, and the service provider is often a sole-source for receivers using proprietary signal formats; in some cases, the receivers may be available from a GPS supplier, but require a code from the service provider to receive the correction signals. Systems from different commercial augmentation suppliers are not compatible. For ground-based commercial augmentation systems, the geographic coverage may be limited and non-contiguous, such as coverage designed primarily for agricultural applications.

The NASA Global Differential GPS (GDGPS) system uses a large ground network of real-time reference receivers and custom software to develop GPS correction data for locations around the globe. Communications channels such as the internet, dedicated land lines, and satellite links are used to stream raw measurements from the reference sites to GDGPS Operations Centers. The final products from the Operations Centers are available within 5 seconds of data collection at the remote site.

10.2 Impact of GPS Modernization

A GPS Modernization program is underway to replace aging GPS satellites and add new capabilities. Launch of GPS Block II satellites is underway, and design contracts for GPS Block III have been awarded. GPS III will incorporate new orbit determination capability to provide increased accuracy. This capability is currently provided by NGPS, WAAS, and various global monitoring networks independently.

The first GPS III satellite launch is planned for 2013, but recent information indicates that there may be some delay. GPS III satellites will include two new signals for civil use – L2C (L2 Civil) and L5, and an updated L1 civil signal, L1C. Prior to the full deployment of GPS III, the new L2C signal will be available. This new GPS signal provides a more robust code structure to provide enhanced data recovery, will provide a more accurate correction of ionospheric errors, and better carrier tracking than the L1 civilian GPS signal. This should support development of survey grade, more accurate receivers at a lower cost. L2C will also provide an alert flag within six seconds indicating if an individual satellite signal cannot be trusted. Launches of new GPS satellites with L2C capability have begun, with full constellation capability and associated ground control systems projected to be completed in the 2010 - 2012+ time frame. The L2C signal is designed to meet commercial needs. L2C will support operation in challenged environments, such as indoors or in areas of heavy foliage. The L2C signal also facilitates correction of ionospheric effects, and allows more precise ranging measurements due to its wider-bandwidth signal. It will also provide more robustness in the presence of narrowband interference. The higher effective signal power and improved data structure will speed up signal acquisition, enable receiver miniaturization, and may enable indoor use. The L2C signal is currently being implemented on GPS Block IIR-M satellites, whose launch began in September 2005 (without a navigation message capability) and the full constellation of 24 satellites are projected to be available in 2014. The L5 signal is designed to meet safety of life transportation applications, and will operate in the Aeronautical Radio Navigation Service band. L5 will be implemented on the GPS Block IIF satellites, whose first launch is planned for 2007, with the full constellation of 24 satellites projected to be available in 2016. The L1C signal is being designed with international partners to enable GNSS interoperability. The first satellite launch with L1C begins with the first GPS Block III launch, currently projected to be in 2013, with the full constellation of 24 satellites in place in 2021.

The combination of these new civil signals promises to provide real-time, un-augmented 1-meter accuracy. Future integrity warning networks may provide as short as 1 second notification of loss of GPS integrity. However, the time frame for a complete network of modernized GPS will be 2021+. The GPS III program is undergoing some delays.

While at some point in the future, possibly at the point where GPS III is fully deployed, NDGPS can reasonably be transitioned out of service; there is no viable alternative to providing the level of accuracy and integrity at ground level that is available from NDGPS at this time. However, it may be necessary to develop and publish a transition plan covering several years in order to allow NDGPS users time to purchase new equipment, develop new application software, change procedures, and train personnel to avoid significant operational and cost impacts. Even after GPS III deployment and operation, requirements for civilian real-time sub-meter accuracy may require NDGPS or other locally-derived correction information. The ability of GPS III to support ground-level, high accuracy, high integrity applications may require further analysis before NDGPS can be completely phased out of service.

[Applicable references for in Appendix A: 19, 22, 23, 105, 109, 107, 109. Applicable references from responses to the Federal Register Notice, Table E-1, entries 0004, 0008, 0009, 0011, 0016, 0018, 0023, 0032, 0036, 0039, 0040, 0042, 0044, 0045, 0049, 0066, 0069, 0071, 0073, 0080, 0080,0081, 0086, 0091, 0093, 0094, 0096, 0098, 0100, 0102, 0103, 0113, 155, 156, 157, 158, 159, 160.]

10.3 Alternate Sources of PNT Information

NDGPS is designed to provide 1-3 meter accuracy at ground level, in conjunction with standard civil frequency GPS signals. Due to its Medium Frequency beacon transmission, NDGPS performs well in areas of heavy terrain, heavy foliage, man-made obstructions, and in buildings. If the GPS receiver is able to receive sufficient satellite signals to develop a positioning solution, the NDGPS beacon signal is usually able to get through to provide the data for a more accurate solution. In general, current augmentation systems which use satellites to transmit the correction signal do not operate well in these difficult conditions, due to low angle of the user to the satellite providing the correction signal. Due to the spread of GPS satellites across the sky, a user receiver may be able to receive sufficient GPS signals to develop a positioning solution, but not be able to receive the correction signal from a satellite-based augmentation system.

In areas of clear sky coverage, WAAS and commercial satellite augmentation systems can provide equivalent performance to NDGPS, although experience by users indicates that NDGPS provides greater accuracy than WAAS. There have been more WAAS-capable receivers sold than NDGPS-capable receivers, which can primarily be attributed to the fact that WAAS is built in to many commercially-available receivers. WAAS is used by many users who do not operate in wilderness areas or other areas of rugged terrain or heavy foliage. In some cases, users have purchased WAAS-capable receivers, but have not activated reception of the augmentation signal.

Commercial augmentation systems require users to purchase proprietary equipment or software from the service provider, and pay annual subscriptions of up to $2500 per receiver. Claimed accuracy for some services is sub-meter. The precision agriculture industry represents one of the major users of these commercial services. As with WAAS, these services typically use geosynchronous satellites to distribute the correction data, which suffer from loss of the correction signal on the north side of tree lines or terrain, and under heavy foliage cover.

For many current NDGPS users and their applications as defined in other sections of this report, if 1-3 meter accuracy is required at ground level, or if an integrity warning is required, the only viable alternative is RTK or other survey type equipment. The use of this type of equipment requires the user to set up their own local reference station, wait for it to achieve sufficient “lock” with the satellite constellation to achieve high accuracy (typically 20-45 minutes), and begin to use it. These systems have their own wireless link between the reference station and the user receiver, which is typically limited to line-of-sight. If the user moves out of range (radio range or line of sight) of the reference station, the reference station must be re-positioned, and the user must again wait for the reference station to achieve “lock” with the GPS satellites required for high accuracy. Farmers, surveyors, and other field users often use these types of systems. However, many of these users have indicated that there is significant lost time during re-positioning of the reference station. The reference stations also typically cost $15,000 to $20,000. This type of system is not usable for general transportation applications.

[Applicable references for in Appendix A: 39, 106, 107, 135, 136, 137. Applicable references from responses to the Federal Register Notice, Table E-1, entries 0004, 0008, 0009, 0011, 0016, 0018, 0023, 0032, 0036, 0039, 0040, 0042, 0044, 0045, 0049, 0066, 0069, 0071, 0073, 0080, 0080,0081, 0086, 0091, 0093, 0094, 0096, 0098, 0100, 0102, 0103, 0113.]

10.4 PNT Architecture Activities

There is an ongoing activity to develop a next-generation Positioning, Navigation, and Timing (PNT) Architecture, involving a diverse group of military and civilian agencies. This effort was requested by the Assistant Secretary of Defense for Networks and Information Integration, the

Under Secretary of Transportation for Policy, and the National Space-based PNT Executive Committee. The effort was justified on the basis of gaps in current capabilities, and insufficient unity of efforts related to development of future PNT capabilities. The PNT Architecture Group is developing a 20-year outlook to guide near-term and mid-term decisions on PNT capabilities. The PNT capability gaps that were identified included the need for higher accuracy with integrity, and capability to operate in physically impeded environments, which include operation at ground level in areas of signal blockage due to terrain, foliage, and structures. Part of the vision of the group included ensuring stable policies related to PNT capabilities, including commitment to funding, commitment to performance, and advanced notice of changes. The group recognized the future of NDGPS and High Accuracy NDGPS as a near-term issue to be resolved to meet the performance gaps and policy issues addressed by the group.

[Applicable references for in Appendix A: 153.]

11. International Implications of NDGPS Future

Approximately 50 countries have GPS augmentation systems modeled after NDGPS. These countries have spent their own money to put in systems comparable to NDGPS, and shutting down NDGPS in the US may cause these countries to question whether they made good investments. Pulling back from NDGPS could create a confidence issue in the eyes of foreign governments. Countries around the world have looked to the US for leadership in GPS technology. Presidential Decision Directive NSTC-6, "U.S. Global Positioning System Policy", dated March 28, 1996, and the "U.S. Space-Based Positioning, Navigation, and Timing Policy" issued on December 8, 2004, establish requirement for U.S. leadership in GPS technology and its augmentations.

The primary international implication of shutting down the NDGPS system will be one of confidence in US leadership in GPS technology. The primary economic impact would be on US suppliers, due to loss of US market for NDGPS products, and potential loss of international markets for NDGPS products, should other countries develop systems that require US-based GPS product manufacturers to develop new products or cede sales to non-US suppliers.

[Sources include discussions with GPS suppliers. Applicable references for in Appendix A: 1, 6, 105, 108. Applicable references from responses to the Federal Register Notice, Table E-1, entry 0080.]

This page intentionally left blank.

12. Supplier Support to NDGPS

12.1 NDGPS Receiver Sales 2005-2006

Over the last four years, most major GPS manufacturers have reported a decrease in the sale of NDGPS capable receivers. However, for the 2006 market year, preliminary information indicates that CSI and Raven both show small, less that 2%, increases in the sale of NDGPS-capable receivers. It should be noted that this information can be misleading, as the sale of NDGPS capable receivers does not always translate into an increase in NDGPS usage. This is due to the fact that many of these NDGPS capable receivers are also capable of receiving other types of augmentation. Therefore an increase in the sale of NDGPS capable receivers may actually reflect an increase use in some other form of augmentation. However, the 2006 sales data may show an actual increase in NDGPS usage. This is due to the fact that there is a decrease in the number of GPS receivers that are offered with NDGPS as a standard capability as many GPS manufacturers now offer NDGPS as an option only on their GPS products. Other data also supports the belief in the slight increase in NDGPS sales and usage. This supporting data comes from information collected that shows a growing dissatisfaction in the performance of the WAAS, with this dissatisfaction being created by the increased use of WAAS in environments outside of it operational range. This fact could be driving the increase in NDGPS usage.

This information is based on discussions with GPS suppliers.

12.2 Comments from NDGPS Suppliers

On August 20, 2007, *GPS World* magazine conducted an interview with Charles Trimble, Chairman of the US GPS Industry Council and one of the founders of Trimble; and Robert Canty, director of Raytheon's Defense Systems unit. The discussion with Charles Trimble focused on the pending decision whether to continue funding NDGPS. The discussion with Robert Canty focused on the GPS III Operational Control Segment.

During the published interview, Mr. Trimble made the following points:

- NDGPS has become the infrastructure used by local and state governments to support GIS systems;
- A transition is required from the current situation to the availability of GPS III;
- Shutting off NDGPS will save very little money;
- The costs to state, local, and Federal governments will exceed the savings of shutting down NDGPS;
- Shutting off NDGPS before GPS III is in service removes a capability required for civil GIS work without any real alternative;
- Other countries have spent their own money to put in systems comparable to NDGPS, but "for the US to discontinue NDGPS undermines and brings into question whether their investment was a good investment";
- Pulling back from NDGPS creates a confidence issue in the eyes of foreign governments;

- WAAS is a good system, but does not provide the required performance at ground level; and
- It's premature to shut down NDGPS, although it may be the right decision at some point in the future.

This is a synopsis of the magazine article, and does not represent an interview by the authors of this report.

In an email to RITA, Ann Ciganer, Vice President, Strategic Policy at Trimble, indicated Trimble's consistent support to NDGPS, indicated that the US Government should continue to lead in this area, and that GPS users in over 50 countries depend on systems modeled after NDGPS.

13. General Observations and Issues

Activity on this project has produced a number of observations relative to the potential support for NDGPS. It was determined that there is little general knowledge of NDGPS in the user community. Some organizations that are using NDGPS are not aware of it, since they purchased differential receivers but are not aware of what station they receive corrections from. Many organizations contacted had no knowledge of NDGPS, although they were aware of other augmentation systems. When NDGPS was described to these organizations or individuals, they indicated that they could see potential applications, particularly given the shortcomings they had observed with other augmentation systems, related to either ground-level coverage issues or costs. It is the opinion of the authors of this report that the user base for NDGPS could significantly expand if there were a concerted effort to educate a broader potential user base.

A number of states and local governments are deploying stovepipe augmentation systems due to lack of knowledge of NDGPS or lack of confidence in build-out. In many cases, the Federal Government is paying all or part of the costs of these independent networks. While some of these networks provide survey-grade augmentation, this level of correction is not needed for the entire coverage area, and other applications that could be served by NDGPS have been used as the justification for these systems. The result is that costs for multiple augmentation systems will be very high, and there will not be a rationalized coverage plan.

NDGPS (or other) augmentation systems can take advantage of existing/planned radio frequency data links to mobile assets to distribute correction data to vehicles or other mobile assets. For example, future vehicle applications will likely use data radios such as DSRC to communicate with cars, including distribution of GPS augmentation data. There are a number of other new and evolving applications that require real-time correction information, and most of these new applications will be at ground level, where satellite-based augmentation systems suffer from communications disruptions and blockages.

While there are commercial providers who are selling augmentation services, these commercial providers will not accept the liability associated with safety applications. Due to the liability issues and the need for nationwide coverage at ground level for many advanced GPS applications requiring augmentation, a form of Federally-funded and managed GPS augmentation would seem to be warranted.

The NDGPS sites present opportunities for complementary applications. The NDGPS sites include ruggedized towers and equipment shelters, backup power, and sufficient land area for further equipment installation. They are dispersed throughout the nation. With these characteristics, these sites could be exploited for the deployment of other systems, such as emergency communications for homeland security, or for commercial communications.

The potential user base is just starting to realize applications and benefits of augmented GPS. For a number of years, many users did not explore potential applications of GPS beyond that available from the general civilian signal, because of uncertainties related to Selective Availability, or the costs of commercial augmentation (survey grade equipment or augmentation subscription services). As information regarding applications of higher accuracy GPS has begun to spread through conferences, journals, and other means, there are an increasing number of users who see applications for augmented GPS. Few individuals or organizations contacted seem to be familiar with NDGPS unless they are consciously a current user. There are classes of users who are using satellite-based augmentation systems or commercial services who showed significant interest in NDGPS because of issues related to ground level coverage or costs. Because many state and local agencies are not aware of NDGPS or are aware of the uncertainty of future funding, they are planning deployments of their own, more expensive, non-integrated, augmentation systems. It has been noted that there have been more WAAS-capable receivers sold than NDGPS-capable receivers, but no hard data exists to determine whether the WAAS receivers were purchased to obtain higher accuracy than was capable with an un-augmented receiver, if there was a cost or size factor, or if the user was taking advantage of the augmentation capability.

14. Summary of Findings

14.1 NDGPS User Base

The major current users and applications of NDGPS are summarized below. These applications are discussed in previous sections of this report, or were identified from responses to the Federal Register Notice.

<u>Transportation Applications</u>

The following transportation applications were identified by government agencies, transportation operators, construction firms, and surveyors:

- Determining coordinates and elevations of highway control points;
- Construction staking;
- Road centerline locations;
- Road boundary mapping;
- Road construction planning;
- Highway mile marker positioning;
- Developing highway maps;
- Access easements mapping;
- Access route planning;
- Soil bore locations;
- Reforestation and Wildflower Planting along highways;
- National Pollutant Discharge Elimination System data collection;
- Navigating to survey monuments;
- Transportation asset management – signs, culverts, utilities, other road features;
- Accident investigation;
- Collecting information on road jurisdiction;
- Collecting information on road surface condition and pavement ratings
- Conducting traffic studies;
- Roadside environment applications;
- In conjunction with mobile video to map roadside objects and features;
- Identify safe digging areas adjacent to roads;
- Mapping and navigating to wetland locations;
- Mapping snow drift areas;
- Providing wing points for photogrammetric mapping;
- Positive Train Control;
- Railcar tracking;
- Hazardous cargo tracking;
- Location reference for railroad event recorder data;
- Track Defect location;
- Railroad diagnostic tools to identify and remedy safety issues;
- Measure rail longitudinal stress;
- Monitor railroad embankments for landslides;

- Navigate aircraft to road construction sites;
- Truck routing and terminal management;
- Tracking truck hazardous cargo movements; and
- Monitoring truck driver Hours of Service.

NDGPS as Part of CORS Network

The Continuously Operating Reference Station (CORS) network is made up of GPS reference stations that have been installed by various entities. NDGPS sites constitute approximately 14.5% of the current CORS sites. Each CORS site provides GPS carrier phase and code range measurements which are used to calculate GPS corrections to obtain accurate location references. Data from the CORS sites are typically used by GPS professionals, surveyors, engineers, scientists, and others working in the field to obtain local GPS correction information to support a variety of government, academic, commercial, and private applications.

NOAA Data Collection

NOAA is both a user of NDGPS signals and user of the NDGPS sites to house instruments. Their applications include:

- Collection of Integrated Precipitable Water Vapor data at NDGPS sites, which are used in severe and long-term weather models;
- Collection of Total Electron Content data at NDGPS sites, which provide data on expected GPS performance in the area around a site;
- Collection of weather data at sensors at NDGPS sites (GPS Surface Observing System);
- Collection of atmospheric moisture content data at NDGPS sites for input to a tropospheric signal delay model;
- Land surveying;
- GIS mapping;
- Tracking path of aircraft used in remote sensing; and
- Construction support.

Other Federal Agency Applications

A number of other Federal agencies are users of the NDGPS augmentation signal, primarily for use in field work, often in remote and wilderness areas. Applications include:

- Endangered species monitoring;
- Mapping and monitoring historic and cultural sites, including Native American sites, national monuments, and other historic sites;
- Plate tectonic monitoring;
- Earthquake prediction;
- Natural resources management; conservation planning and application; administration of the Farm Bill Program; and locating sensitive resources in the field;
- Mapping sites of interest in detail;
- Mapping and maintenance of roads and trails across Federal land;
- Surveys of changes in sedimentation;

- Hydrographic surveys;
- Conservation planning;
- Conducting surveys: hydrographic, sedimentation, wetlands, dam condition assessments, fire perimeters, glaciers, plate tectonic movement, and other surveys;
- Conducting natural resources inventories, including the Natural Resources, Inventory (NRI); minerals; helium, oil, gas, and coal reserves; endangered species; wilderness areas; grazing areas; public recreational areas; irrigation systems; timber; fisheries; and other mandated inventories;
- Natural resource management, including minerals; helium, oil, gas, and coal reserves; wilderness areas; grazing areas; public recreational areas; irrigation systems; timber; fisheries;
- Mapping land and facilities;
- Law enforcement;
- Park visitor protection and search and rescue;
- Personnel management;
- Fire management and mapping of fire perimeters;
- Measuring glacier movement and limits; and
- Dam condition assessments.

Some of these applications are considered safety-of-life, such as park law enforcement activities, search and rescue, fire management, and aircraft navigation in support of search and rescue and fire management. Most of these applications are in rural environments, with varying land cover and landscape conditions that are significantly more challenging than unobstructed, open-sky environments. Many of these applications are in wilderness or remote areas, often in conditions of heavy foliage cover and heavy terrain, with limited access, and often in dangerous conditions.

State and Local Agency Applications

In addition to many of the transportation applications listed above, state and local government agencies identified the following NDGPS applications:

- General real-time surveying and construction staking;
- Control adjustments on state augmentation networks;
- Locating bounds and monitoring boundaries of conservation parcels;
- Asset inventory and location – signs, storm sewers, sanitary sewers, water mains, utilities, civil defense sirens, curb stops, park assets, park features, tree inventories;
- Feature location;
- Easement mapping;
- Line running in real time;
- Utility Locations;
- Construction staking;
- Crime scene information;
- Emergency response and operations management;
- Accident investigation;
- Mapping natural resource violations;
- Topographic surveys;

- Trail mapping;
- Mining locations;
- Forestry management;
- Fire management;
- Wetland delineation;
- Tree line delineation;
- Project control coordinates;
- Environmental protection mapping;
- Sinkhole monitoring;
- ADA sidewalk compliance;
- E911 mapping and addressing;
- Mapping soil conditions;
- Native American burial ground mapping;
- Cultural resource mapping and monitoring;
- Archeology mapping;
- Monitoring snow-plow operations;
- Mapping glacier limits;
- Mapping natural resource violations to be used for court evidence;
- Herbicide and pesticide application;
- Locating rural fire hydrants for fighting forest fires in remote areas; and
- Lay out soil borings.

Private Industry Applications

Private companies perform many of the same functions as government agencies, in support of private industry, individual private citizens, or government customers. These applications include:

- General surveying, construction staking, and feature location for a variety of applications, including transportation projects;
- Navigating to field locations;
- Project control coordinates;
- Hydrographic surveys;
- Surveys and mapping of wetlands;
- Flood control;
- Navigation and dredging projects;
- Precision agriculture, including land preparation, seeding, fertilizer and pesticide application, and harvesting;
- Waterway dredging;
- Automated agricultural and industrial machine control;
- Agricultural and industrial machine guidance (human operated);
- Delineation of grading plans and survey plans;
- Plat mapping;
- Resource management;
- Conservation service, providing technical services to farmers and ranchers;
- Biological and scientific studies of wetlands, grasslands, and water purification;
- Mapping fish barriers;

- Natural habitat restoration;
- Products that combine NDGPS data and E911 data;
- Utility mapping and asset management; and
- General GIS applications.

Private Citizen Applications

Individual private citizens use NDGPS for precision agriculture, outdoors mapping and navigation, as well as some of the applications previously identified related to travel or locating features in remote areas.

User-Identified High Accuracy NDGPS Applications

A number of responses to the AASHTO survey and the Federal Register Notice identified potential future applications of HA-NDGPS, and encourage further development of this technology. Specific applications for HA-NDGPS that were identified include:

- Vehicle Infrastructure Integration;
- Cooperative Intersection Collision Avoidance;
- More precise asset management;
- More precise utility location;
- Machine control and automation;
- More precise resource and environmental mapping;
- Automated surveying; and
- Positive Train Control.

14.2 Primary Future Applications of NDGPS

The current applications of NDGPS are expected to continue in the future. A number of respondents to the Federal Register Notice indicated that new applications are just being identified, as more users become familiar with NDGPS and as new requirements are being identified, in particular in response to new environmental and other regulatory requirements that require field location measurements and mapping more precise than unaided GPS can provide. The most significant potential future applications of NDGPS are for transportation applications, including command and control and transportation field asset management applications. The ongoing VII Proof of Concept test beds in the Detroit and San Francisco areas are using elements of the High Accuracy NDGPS program to provide enhanced GPS augmentation. The specific location technologies to be used and accuracy requirements for VII and CICAS have not been fully defined at this point.

14.3 Primary Functional Benefits Associated with NDGPS

NDGPS is one of the primary real-time, civilian GPS augmentation systems in operation. The other major systems are WAAS and commercial services, both of which transmit GPS correction information to the user via geosynchronous satellites. Based on information from users, NDGPS provides the following major benefits:

- Provides real-time differential corrections, rather than requiring post-processing to achieve the level of accuracy;
- Signal received better in areas of heavy foliage, terrain or manmade signal blocking structures, or on the north side of tree-lines or terrain;
- Provides 1-3 meter accuracy, at ground level, which is better than other general coverage augmentation systems;
- Provides an integrity warning within six (6) seconds of detecting a fault with the signal from any GPS satellite, protecting against calculation of an erroneous location by the GPS receiver based on bad data;
- NDGPS sites are highly reliable; and

However, there is no NGPS coverage currently deployed for many parts of the Western US, and only single coverage in other areas. A number of users indicated that dual coverage of at least CONUS should be deployed in order to realize the full benefits of NDGPS.

14.4 Economic Benefits Associated with NDGPS

Sufficient data does not exist to accurately calculate the economic benefits associated with all applications of NDGPS at a national level with a high level of confidence, due to lack of well-documented data on the specific utilization of NDGPS for the functions identified by users, and the time or other savings associated with the applications. One over-arching economic benefit of NDGPS that was mentioned by many users was that there was no user fee for the signal. Some specific economic benefits that were identified during this assessment were:

- A potential direct impact on the FHWA Operating Budget of $18-36 million (potentially as high as $106M) per year attributable to NDGPS applications related to highway planning, construction, and maintenance;
- Savings of over $40 million per year associated with NDGPS sites related to CORS applications; and
- Based on the current NDGPS Operation and Maintenance budget and the number of NDGPS receivers in use, a productivity savings of 3 hours or less per year per receiver is equivalent to the O&M cost.

General, non-quantified benefits of NDGPS identified by users are improved labor productivity, reduced equipment to do equivalent work, improvements in environmental controls, increased safety, and scientific and ecological applications.

14.5 Impact of Loss of NDGPS

Users identified the following impacts if NDGPS is shut down:

- Loss of economic benefits;
- Loss of over 10% of the CORS sites;
- No alternative for real-time applications in areas where satellite-based augmentation systems do not work or are not sufficiently reliable, estimated to be 17% of the U.S. land area based on coverage measurements and analysis;
- Have to buy new GPS receivers; would have to buy units costing $5000-6000 each to provide equivalent performance; the National Park Service estimated that it would have to spend $15-18 million for replacement equipment, plus training, software modification, and personnel costs;
- Many new applications require the level of accuracy provided by NDGPS (1-3 meters), particularly for environmental regulations, wilderness management, and to meet court evidence requirements;
- Some users would have to revert to time consuming and costly post-processing, negating the benefits of real-time data collection; others would have to buy significantly more expensive survey grade equipment, which requires a full field crew to operate;
- NOAA would have to develop alternative sites for weather and other data collection;
- Farmers that use NDGPS would have to subscribe to commercial, for-fee, augmentation services; use WAAS, which does work in many areas at ground level; or purchase their own RTK equipment, which requires periodic re-positioning of the reference station.
- Some states may install their own, independent reference station networks, often using partial Federal funds.

14.6 Market Directions

While the recent sales of NDGPS receivers have been fairly flat, there was a slight increase in sales from 2005 to 2006. A potentially significant market trend has been the development of more sensitive GPS receivers, which can receive GPS signals in buildings. A major application of such equipment will be for homeland security and search and rescue applications, which by their nature requirement an augmented GPS solution, and are a natural application for NDGPS, due to the ability of the augmentation signal to penetrate buildings, terrain, and foliage. Current major ITS R&D programs that will provide safety-of-life, congestion mitigation, mobility, productivity, and environmental benefits represent major future potential applications of NDGPS or other systems of enhanced positioning performance. An area where improvements could be made to NDGPS receivers is the size and weight of the units, as compared to GPS receivers with built-in satellite receivers. Satellite-based augmentation receivers tend to be smaller and lighter. In applications where the differential correction information is distributed to the user over a radio frequency data link other than the MF beacon frequency, it should be possible to make NDGPS units that are smaller and lighter. This is already true of NDGPS receivers that do not include the MF beacon receiver.

14.7 USDOT as Civilian Federal Agency Representative for NDGPS

The Federal agencies that were surveyed indicated that they have made investments in NDGPS equipment and built procedures around the use of NDGPS on the belief that the full NDGPS network (CONUS dual coverage) would be constructed and maintained, and that USDOT would represent all Federal agencies on matters related to NDGPS and other GPS policy and funding. Several of the Federal agency personnel who were surveyed indicated that consideration of shutting down NDGPS represented a breach of commitment by USDOT in its role as the civilian Federal agency representative for the program.

14.8 Impact of Uncertainty

There has been a lot of uncertainty over the plans for completing the build-out of NDGPS sites, and continued funding for operation of current sites. This uncertainty in the future of the NDGPS infrastructure has produced uncertainty among current and potential NDGPS users, and among receiver manufacturers. As indicated, some states and local governments have begun deploying or are planning fragmented, costly, independent augmentation networks, often using Federal funds. Receiver manufacturers are not planning new DGPS products until they have a clearer understanding of the future of NDGPS deployment and operation.

14.9 Lack of Knowledge of NDGPS

Discussions with various GPS user communities indicate a general lack of information on NDGPS among potential users, which would suggest that further education of both potential users and equipment suppliers should be conducted in order to solicit informed feedback before a final decision is made regarding future funding profiles.

14.10 Timing of Decision on NDGPS Deployment

A number of individuals and organizations surveyed or who responded to the Federal Register Notice indicated that the decision on future funding for NDGPS should be postponed for a number of years, and that at least the current level of funding should be maintained, if not increased to complete the planned Full Operational Capability. The primary reasons provided for not making any decisions to shut down NDGPS at this time include:

- Many applications of NDGPS are just starting to mature and increase;
- There has not been sufficient outreach to educate potential users about NDGPS;
- Alternatives that provide equivalent capability, such as that planned in the GPS Modernization program, will not be available for many years;
- Many users have no near term alternative to NDGPS;
- Many private users cannot afford commercial, for-fee alternatives to NDGPS.

14.11 Augmentation Rationalization

As discussed in Section 7 of this report, an observation made during the conduct of this assessment is that a number of augmentation networks have evolved to support civilian GPS applications, and the number continues to expand with individual states deploying their own augmentation networks, often with partial Federal funding. However, there is no unified standard of performance or interfaces for these different augmentation networks, although many of the individual sites are part of the CORS network. For real-time applications, the performance characteristics of these different augmentation networks vary, and the communications paths used to deliver the GPS correction data to the user GPS receiver are different. However, it should be possible to rationalize these networks, saving Federal funds, providing more extensive correction coverage, providing a larger and more uniform GPS receiver product market base, and providing more uniform augmentation services to users.

14.12 Impact of GPS Modernization

A GPS Modernization program is underway to replace aging GPS satellites and add new capabilities. It will include three (3) new signals intended to provide improved capabilities for civilian applications. Launch of GPS Block II satellites is underway, and design contracts for GPS Block III have been awarded. GPS III will incorporate new orbit determination capability to provide increased accuracy. It has been suggested that NDGPS may no longer be needed because GPS III will provide the accuracy needed, and have a stronger signal to provide coverage in areas that NDGPS currently serves. The combination of the new civil signals promises to provide real-time, un-augmented 1-meter accuracy. Future integrity warning networks may provide as short as 1 second notification of loss of GPS integrity. However, the time frame for a complete network of modernized GPS will be 2021+. The GPS III program is undergoing some delays, so the actual date of Full Operational Capability cannot be exactly determined.

Prior to the full deployment of GPS III, the new L2C signal will be available. This new GPS signal provides a more robust code structure to provide enhanced data recovery, will provide a more accurate correction of ionospheric errors, and better carrier tracking than the L1 civilian GPS signal. This should support development of survey grade, more accurate receivers at a lower cost. L2C will also provide an alert flag within 6 seconds indicating if an individual satellite signal cannot be trusted. Launches of new GPS satellites with L2C capability have begun, with full constellation capability projected to be in the 2010 - 2012+ time frame.

While at some point in the future, possibly at the point where GPS III is fully deployed, NDGPS can be transitioned out of service, there is no viable alternative to providing the level of accuracy and integrity at ground level that is available from NDGPS. However, it may be necessary to develop and publish a transition plan covering several years in order to allow NDGPS users time to purchase new equipment, develop new application software, change procedures, and train personnel to avoid significant operational and cost impacts. Even after GPS III deployment and operation, requirements for civilian real-time sub-meter accuracy may require NDGPS or other locally-derived correction information. The ability of GPS III to support ground-level, high accuracy, high integrity applications may require further analysis before NDGPS can be completely phased out of service.

There are national-level activities related to future planning for Position, Navigation, and Timing (PNT) systems that cannot be directly addressed in this report, but whose products have indicated that NDGPS and other forms of independent GPS augmentation are necessary until future capabilities render them no longer needed. While at some point in the future, possibly at the point where GPS III is fully deployed, NDGPS can be transitioned out of service, there is no viable alternative to providing the level of accuracy and integrity at ground level that is available from NDGPS.

14.13 General Responses from Surveys

In addition to identifying current and future NDGPS applications, surveys and discussions with NDGPS users and suppliers established the following points:

- NDGPS applications are just starting to take off, as more users become aware of NDGPS, and as more demanding applications become identified. Applications that require higher accuracy are being identified, and in some cases being mandated by security requirements or regulations (such as environmental reporting or government property accounting regulations) that require more accurate location or tracking data.
- The applications of NDGPS are much broader than transportation.
- NDGPS supports real-time applications at ground level, without installing or moving an expensive user-owned base station.
- A number of surface GPS users have WAAS receivers, but recognize that use of WAAS is limited to clear sky areas at ground level.
- The question of whether NDGPS should be decommissioned is premature, in that there is no viable alternative at ground level for many applications at this point in time, and the levels of accuracy to be provided by GPS Modernization is many years in the future.
- A number of users who have tried to use satellite-based augmentation systems at ground level pointed out that these systems did not work well in areas of heavy foliage, heavy terrain, or on the north side of natural or man-made blockage, whereas NDGPS worked in these conditions. In many areas of the most Northern states, NDGPS is the only viable GPS augmentation system. NDGPS also provides higher accuracy than current satellite-based augmentation systems.
- In many cases, it was difficult for individual users to know if they were using NDGPS or WAAS, particularly if their equipment included the ability to receive augmentation data from either source. They simply knew that they were getting the accuracy they needed, and if it was working under their typical operating conditions.
- Many states have a need for augmentation, and a number are or are planning deployment of their own augmentation networks. In some cases, they are putting in survey grade networks, and in other cases are implementing a capability that NDGPS could provide. In some cases, they are using NDGPS and complementing the coverage with their own networks. In many cases, the Federal Government is funding part of these independent augmentation networks.
- As part of the CORS network, NDGPS sites are used for both real-time and post-processing augmentation data sources. The NDGPS sites are generally considered among the most reliable CORS sites, and are the only CORS sites in many areas.
- Operation and maintenance of NDGPS sites should remain with an agency experienced in maintaining geographically dispersed electronic equipment.

Appendix A - References

1. *Presidential Decision Directive NSTC-6, "U.S. Global Positioning System Policy*, March 28, 1996.
2. *Department of Transportation and Related Agencies Appropriations Act*, 1998, Public Law 105–66, Section 346, October 27, 1996.
3. *Memorandum of Agreement for the Establishment and Operation of the Nationwide Differential Global Positioning System (NDGPS)*, February 1999.
4. *Radionavigation Systems: A Capabilities Investment Strategy", A Report to the Secretary of Transportation by the Radionavigation Systems Task Force* (Overlook Systems Technologies, Inc., January 2004).
5. *Code of Federal Regulations, CFR49, Sec. 1.48, Delegations to Federal Highway Administrator*.
6. *2005 Federal Radionavigation Plan*, (Department of Defense, Department of Homeland Security, and Department of Transportation, DOT-VNTSC-RITA-05-12/DoD-4650.5).
7. *Report to Congress, The House and Senate Committees on Appropriations, The Department of Transportation on Civilian Use of the Global Positioning System (GPS): The Nationwide Differential Global Positioning System*.
8. Information on NDGPS on FHWA website at http://www.tfhrc.gov/its/ndgps/.
9. Information on CICAS on RITA website at http://fhwaedl.fhwa.dot.gov/cicas/.
10. Information on CICAS on ITS America website at http://www.its.dot.gov/cicas/index.htm.
11. *Nationwide DGPS Report, Rationale for the Development of a DGPS Policy and Implementation Plan for a Nationwide DGPS Service* (March 24, 1998).
12. *Final Programmatic Environmental Assessment: Nationwide Differential Global Positioning System*, Prepared for: Federal Highway Administration, in cooperation with: U.S. Department of Transportation Office of the Secretary (U.S. Coast Guard, Federal Railroad Administration, September 1999).
13. Richard Snay of the National Oceanic and Atmospheric Administration ,"Report of Surveying, Mapping, and Geosciences Subcommittee", presented by at the CGSIC Meeting, Fort Worth, TX (September 25, 2007).
14. LCDR Jacob Ramos of the US Coast Guard , "Nationwide DGPS Report", presented by at the CGSIC Meeting, Fort Worth, TX (September 25, 2007).
15. Tom Stansell, consultant to the GPS Wing, "Update on GPS L1C Signal Modernization", presented at the CGSIC Meeting, Fort Worth, TX (September 25, 2007).
16. Joseph White of Maryland DOT State Highway Administration, "NDGPS in Maryland", presented at the CGSIC Meeting, Fort Worth, TX (September 25, 2007).
17. Jim Arnold of Federal Highway Administration, "High Accuracy Nationwide Differential Global Positioning System", presented at the CGSIC Meeting, Fort Worth, TX (September 25, 2007).
18. Leonard W. Allen III, Program Manager, Intelligent Railroad Systems, Office of Research and Development, Federal Railroad Administration, "Nationwide Differential Global Positioning System", presented at the Civil GPS Service Interface Committee (May 23, 2006).

19. Thomas Powell of The Aerospace Corporation, "GPS Wing Update", presented at the CGSIC Meeting, Fort Worth, TX (September 24, 2007).
20. CGSIC Presentations and meeting minutes on website http://www.navcen.uscg.gov/cgsic/meetings/default.htm.
21. Various articles in The American Surveyor website http://www.amerisurv.com/index.php, keyword = "ndgps"
22. "GPS III/GPS Block III", article on website. www.globalsecurity.org/space/systems/gps_3.htm.
23. Steven Lazar, "Modernization and the Move to GPS III", article on website www.aero.org/publications/crosslink/summer2002/07.html.
24. Timothy Klein of the USDOT Research and Innovative Technology Administration, "Inland Nationwide Differential GPS Program Status", presented at the CGSIC Meeting, Fort Worth, TX (September 25, 2007).
25. Michael D. Londe, PhD, Information Management and Technology Group, DOI – Bureau of Land Management, "Accuracy Guidelines for GPS Mapping for GIS, Version 1.4".
26. *Standards and Guidelines for Cadastral Surveys using Global Positioning System Method* (United States Department of Agriculture – Forest Service and United States Department of the Interior – Bureau of Land Management, May 9, 2001).
27. D. B. Wolfe, C.L. Judy, A. B. Kritz, J. A. Chop, M.W. Parsons, *Nationwide DGPS: 2003 and Beyond*, (United States Coast Guard Command and Control Engineering Center).
28. Richard Snay of NOAA's National Geodetic Survey, "National CORS: Products and Services", presented at the CGSIC Meeting (May 23, 2006).
29. *National Oceanic and Atmospheric Administration, National Ocean Service Geodetic Support System Operational Analysis*, Document 006-48-01-15-01-3403-00-117-057, (National Oceanic and Atmospheric Administration, 2006, updated February 9, 2007).
30. *The National Geodetic Survey 10 Year Plan – Mission, Vision and Strategy, 2007-2017*.
31. National Park Service web page, www.nps/gov/gis/gps/tech_appl.html and www.nps.gov/gis/gps.
32. Bureau of Land Management web page http://www.blm.gov/nstc/, keyword ="dgps"
33. National Oceanic and Atmospheric Administration web page http://www.noaa.gov/, keyword = "ndgps"
34. Department of Agriculture web page http://www.usda.gov/wps/portal/usdahome, keyword = "ndgps"
35. *Real-Time US Total Electron Content Product Description Document*
36. *USDA Configuration I GPS/NDGPS System,* from USDA website www.ia.nrcs.usda.gov/technical/gis/downloads/config1.pdf
37. National Geodetic Survey website on CORS, www.ngs.noaa.gov/CORS/cors-data.html.
38. USDA Forest Service Remote Sensing Applications Center web site www.fs.fed.us/eng/rsac
39. "Comparing Four Methods of Correcting GPS Data: DGPS, WAAS, L-Band, and Postprocessing", website www.fs.fed.us/database/gps/pubs/htmlpubs/htm04712307/
40. James A. Arnold, "New Applications Make NDGPS More Pervasive", *Public Roads*, (January/February 2001), website www.tfhrc.gov/pubrds/janfeb01/newapps.htm.
41. "Nationwide Differential Global Positioning System Program Fact Sheet", website www.tfhrc.gpv/its/ndgps/02072.htm
42. Richard Snay, Gordon Adams, Miranda Chin, Stephen Frkaes, Tomas Soler, and Neil Weston of the National Geodetic Survey, National Ocean Service, NOAA, "The

Synergistic CORS Program Continues to Evolve", presented at the ION GPS 2002, (24-27 September 2002, Portland Oregon), pp. 2630-2639.
43. "FHWA Working to Improve Weather Forecasting Using NDGPS", *Transporter Magazine* (October 2001).
44. James Arnold, "Nationwide Differential GPS Water Vapor Observations During Hurricane Georgest, New Applications Make NDGPS More Pervasive", *Public Roads* (January/February 2001).
45. James A. Arnold, Rudy Persaud, and David Smallen , "A More Precise Sense of Where We Are", *Public Roads* (January/February 2000).
46. Christopher Wilson, VP, ITS Strategy & Programs, DaimlerChrysler Research and Technology North America Inc., "Vehicle Highway Cooperative Systems", presented at the National IVI Meeting (June 26, 2003).
47. "NDGPS and Weather Applications", *ITS Decision*, http://www.calccit.org/itsdecision/serv_and_tech/Weather_applications/Weather_forecast/weather_forecast_summary.html.
48. Sunil Bisnath, Harvard-Smithsonian Center for Astrophysics, David Dodd, University of Southern Mississippi, Allen Cleveland and Michael Parsons, Command and Control Engineering Center, United States Coast Guard., "Analysis of the Utility of NOAA-Generated Tropospheric Refraction Corrections for the Next Generation Nationwide DGPS Service".
49. Daniel Birkenheuer and Seth Gutman of the NOAA Forecast Systems Laboratory, "A Comparison of GOES Moisture-Derived Product and GPS-IPW Data During IHOP-2002", *Journal of Atmospheric and Oceanic Technology*, Volume 22, 2005).
50. "DOT's National DGPS Improves Local Weather Forecasts for Olympic Events", USDOT press release (February 8, 2002).
51. Yong Won Ahn, et al, DOI, "Analysis of GPS RTK Performance Using External NOAA Tropospheric Corrections Integrated with a Multiple Reference Station Approach", 10.1007/s1091-005-0017-1.
52. Kirk Holub of the NOAA Earth System Research Laboratory, "NOAA Ground-Based GPS Meterology", http://gpsmet.noaa.gov.
53. Tim Fuller-Rowell, et al, "US-TEC: A New Data Assimilation Product From The Space Environment Center Characterizing The Ionospheric Total Electron Content Using Real-Time GPS Data", *RADIO SCIENCE*, VOL. 41, RS6003, doi:10.1029/2005RS003393 (2006).
54. Various topics on GPS Applications, listed on the NOAA website www.oceanservice.noaa.gov/topics/navops/positioning
55. Information on Continuously Operating Reference Stations (CORS) at website http://www.ngs.noaa.gov/CORS/cors-data.html.
56. Tracy Lorraine Smith, Stanley G. Benjamin, Seth I. Gutman, and Susan Sahm of the NOAA Research, Earth System Research Laboratory, Global Systems Division, "Short-Range Forecast Impact from Assimilation of GPS-IPW Observations into the Rapid Update Cycle".
57. Section 3, DOT 159, Federal Highway Administration Section.
58. *Evaluation of the High Accuracy-Nationwide Differential Global Positioning System (HA-NDGPS) for the California PATH Program, Final Report*, (Bournes College of Engineering, Center for Environmental Research and Technology, University of California, November 2006).
59. "VII California Team Meeting" presentation to the Metropolitan Transportation Commission (August 4, 2006).
60. *Institute of Navigation (ION) GPS Conference, Including 42nd CGSIC Meeting Notes*, (Portland, OR, September 8-12, 2003).

61. US Coast Guard Navigation Center website on NDGPS, www.navcen.uscg.gov/ndgps.
62. Richard Snay & Neil Weston of NOAA's National Geodetic Survey, and Gavin Schrock, Washington State Reference Network, "Exploring the Relationship Between the CORS Program and Regional Real-Time GNSS Networks", presented at Trimble's GPSNet User Group Meeting (Westminster, CO, May 9, 2006).
63. Michael Rasher and Gary Hallbauer, USDA Natural Resources Conservation Service, National Cartography & Geospatial Center, "Autonomous Navigation & Positioning for Inventorying Natural Resources",.
64. Michael Rasher, USDA Natural Resources Conservation Service, "The Use of GPS and Mobile Mapping for Decision-Based Precision Agriculture".
65. USDA website www.usda.gov, keyword = "ndgps".
66. "Precision Agriculture – NRCS Support for Emerging Technologies", (Agronomy Technical Note No. 1, June 2007).
67. "Automatic Vehicle Location – Successful Transit Applications, A Cross-Cutting Study" (ITS Joint Program Office, August 2000).
68. Roz Buick, Ph.D., Agriculture Division, Trimble, "GPS Guidance and Automated Steering Renew Interest in Precision Farming Techniques".
69. Brendan Cook, "The United States Nationwide Differential Global Positioning System", *Communications System International* (January 14, 2000).
70. DeLane R. Meier, North Dakota Department Of Transportation, "Why Do We Want NDGPS in North Dakota?", presented at the CGSIC (San Juan, Puerto Rico May 23, 2006).
71. Mark D. Roper, GIS Specialist, *GPS to GIS Procedural Handbook & Reference Guide, VERSION 7.0, Includes GPS Analys*", (Prepared and Compiled for the USDA Forest Service, San Juan National Forest, 5/31/2006).
72. Website www.precisionag.org.
73. Garmin web site www.garmin.com.
74. *GPS User Magazine*, online at www.gpsuser.com.
75. "GPS in the Field: Precision Agriculture", *GPS User Magazine*, Volume 1, Number 2, (Fall 2003).
76. M. Reza Ehsani-Assistant Professor, The Ohio State University Extension, Matthew Sullivan-Extension Program Specialist, "GPS Guidance Systems – An Overview of the Components and Options".
77. Various articles on precision agriculture at http://precisionag.osu.edu/resources/index.html#c and http://precisionag.osu.edu/.
78. "Fact Sheet – AgGPS Receiver Series", Trimble web site http://trl.trimble.com/docushare/dsweb/Get/Document-3360/.
79. "GPS for Precision Agriculture, Trimble web site www.trimble.com/ag_gps.shtml.
80. "GPS Tutorial", Trimble web site www.trimble.com/gps/index.shtml, refer to section on "Why We Need Differential GPS".
81. Stephen W. Searcy, Texas Agricultural Extension Service, Texas A&M University, "Precision Farming: A New Approach to Crop Management".
82. Thomas Marek, Texas A&M University, "Precision Agriculture Initiative: Summary of the Amarillo/Bushland/Etter Efforts".
83. Jeffrey L Willers, et al, "Development of Precision Agricultural Systems for Cotton Production", (Applied Statistics in Agriculture Conference Proceedings, 2005).
84. Various papers on precision agriculture on the University of Georgian College of Agriculture and Environmental Sciences web site http://nespal.cpes.peachnet.edu/precisionag/papers.asp.

85. "Accuracies of Common Agricultural GPS Units and Sources of Differential Correction", University of Georgian College of Agriculture and Environmental Sciences web site http://nespal.cpes.peachnet.edu/precisionag/pdfs/AccuracyofGPS.pdf.
86. "Precision Ag Guide" (University of Georgian College of Agriculture and Environmental Sciences, November 2006).
87. Pi-Ming Chang, et al, "Evaluation of NDGPS for Assessing Road User Charges", (Transportation Research Board, 2004).
88. M. Sergi, et al, "Dynamic Evaluation of High Accuracy Differential GPS", (Institute of Navigation GPS Conference, 2003).
89. Product Descriptions on Raven website www.ravenprecision.com, , keyword = "dgps".
90. Product Descriptions on AutoFarm website www.gpsfarm.com.
91. Product Descriptions on Case International Harvester website www.caseih.com.
92. Product Descriptions on Fieldstar website www.fieldstar.com.
93. Product Descriptions on Micro-Trak Systems website http://www.micro-trak.com.
94. Product Descriptions on Hemisphere GPS website http://www.hemispheregps.com/.
95. Product Descriptions on Trimble website http://www.trimble.com/agriculture.shtml.
96. Product Descriptions on Magellan website http://pro.magellangps.com.
97. Product Descriptions on Leica Geosystems website http://www.leica-geosystems.com.
98. Product Descriptions on Novatel website http://www.novatel.com.
99. Dr. Robert Mann and Dr. Barry Fehl, "Monitoring Steel Cell Placement Using Differential GPS at Lock and Dam 24, Mississippi River", http://crunch.tec.army.mil/information/publications/Lock_Dam24/cell.htm.
100. Amr A. Oloufaa, Masaaki Ikeda, and Hiroshi Oda, Department of Civil and Environmental Engineering, University of Central Florida, "Situational Awareness Of Construction Equipment Using GPS, Wireless and Web Technologies",.
101. "Using Differential GPS Positioning for Elevation Determination" (Department of the Army Technical Letter No. 1110-1-183).
102. "GPS-Based Earthmoving's Awesome Technology", *Construction Equipment* (April 2004).
103. Lynn Landberg, "Lasers/GPS Enhance Machine Control: Applying the latest Technology, Machine-Control Systems Can Pinpoint Machine Location and Performance for Precise Grading", *Construction Equipment* (July 1, 2002), .
104. Francois Peyret, David Betaille, Gaetan Garcia, Aubert Carrel, "Precision on a Roll: DGPS Solutions For Heavy Machinery - Design challenge", *GPS World*, (January 2004).
105. Charles Trimble, "Expert Advice — NDGPS Cut-off Premature", *GPS World* (Oct 1, 2007).
106. Alan Cameron, "Perspectives — August 2007", *GPS World* (Aug 20, 2007).
107. "The System — September 2007", *GPS World* (September 1, 2007).
108. Various articles and letters to the editor in GPS World magazine, www.gpsworld.com, keyword = "ndgps".
109. Mr. Hank Skalski, U.S. Department of Transportation, "GPS Civil Augmentations: Status and Future", (UN/USA International Meeting on GNSS, December, 2004).
110. " Leonard W. Allen, Program Manager, Intelligent Railroad Systems, Office of Research and Development, Federal Railroad Administration, "Nationwide Differential Global Positioning System, Presented to National Transportation Research Board's Positive Train Control Symposium (March 3, 2005).
111. *Weather Information for Surface Transportation (WIST) Initiative Document* (Office of the Federal Coordinator for Meteorological Services and Supporting Research, September 2005).
112. *Railroad Safety Advisory Committee (RSAC)*, Minutes of Meeting (May 18, 2005).

113. Zinn, Jeffery, *CRS Report for Congress*, Precision Ag. (1997).
114. Bongiovanni, R, and Lowenberg-DeBoer, *Precision Agriculture and Sustainability*, (2004).
115. Mannel, Sylvio, “How to Set up a GIS program at Tribal College” (2000).
116. *U.S. Space-Based Positioning, Navigation and Timing Policy Fact Sheet* (2004).
117. *Jurisdiction of the Committee on Transportation and Infrastructure*, (U.S. Congress. 2007).
118. *Information Technology Resource Management Guideline: GPS* (Commonwealth of Virginia, 2000).
119. *GPS Data Accuracy Standard* (U.S. Forest Service, 2003).
120. *Support Sustainable Agriculture and Forestry* (Technical Reference Document, 2002).
121. Pugh. Nathan. 2006. Trimble. Scalable GPS Infrastructure: The building Block of Tomorrow.
122. Timmons, Richard, America Short Line and Regional Railroad Association, testimony at U.S. House of Representatives, Committee on Transportation and Infrastructure (2006)
123. *An Investigation of the Use of GPS Systems Technology and it Augmentations within State and Local Transportation Departments* (U.S. Department of Transportation. Publication No. FHWA-RD-00-093, 2000).
124. *Smart Construction. Using Cutting-Edge Technology to Maximize Public Investment in America’s Transportation Network*, American Road and Transportation Builders Association, 2006).
125. Buechner, William, *An Analysis of the DOT 2006 Report on Conditions and Performance and Mass Transit System* (ARTBA, 2006).
126. Buechner, William, *Number of Contracts, Value of Contracts Awards* (ARTBA, 2007).
127. Buechner, William, Analysis *of the Bush Administration’s FY 2008 Budget Proposal for Transportation* (ARTBA, March 30, 2007).
128. *Views and Estimates of the Committee on Transportation and Infrastructure* (U.S. Congress, 2007).
129. *Freight Rail Infrastructure Capacity Expansion Act* (Association of America Railroads, 2007).
130. *The Nation’s Freight Rail Challenge*, (Association of America Railroads, 2007).
131. *A Vision of America’s Transportation Future*, (Huston Institute, 2004).
132. *Annual Energy Outlook: 2006 Projections* Department of Energy, 2006).
133. *High Accuracy – Nationwide Differential Global Positioning System Test and Analysis: Phase II Report* (US Department of Transportation, Federal Highway Administration, Publication No. FHWA-HRT-05-034).
134. Sean Fernandez, Utah Department of Transportation, “GPS and DOT”, presented at the AASHTO Implementation Group.
135. Information on the Global Differential GPS system at http://www.gdgps.net/.
136. Information on WAAS at http://www.faa.gov/about/office_org/headquarters_offices/ato/service_units/techops/navservices/gnss/.
137. *Wide-Area Augmentation System Performance Analysis Report*”, Report #17, (FAA/William J. Hughes Technical Center, July 2006).
138. *Benefits and Costs of Positive Train Control, Report in Response to Request of Appropriations Committees* (U.S. Department of Transportation, Federal Railroad Administration, August 2004).
139. *Quantification of the Business Benefits of Positive Train Control*, Prepared for the Federal Railroad Administration (Zeta-Tech Associates, March 15, 2004).
140. Information on VII on the RITA website http://www.its.dot.gov/vii/.

141. Information on National VII Coalition website http://www.vehicle-infrastructure.org/.
142. Information on VII California website http://www.viicalifornia.org/.
143. Information on VII on the FHWA website http://ops.fhwa.dot.gov/travelinfo/infostructure/aboutinfo.htm.
144. NHTSA report on VII on website http://www-nrd.nhtsa.dot.gov/pdf/nrd-01/NRDmtgs/2005Honda/Resendes_VII.pdf.
145. Information on Michigan VII Test Program on website http://www.michigan.gov/mdot/0,1607,7-151-9621_11041_38217---,00.html.
146. "Primer on Vehicle Infrastructure Integration" on ITS America website http://www.itsa.org/itsa/files/pdf/VIIPrimer.pdf.
147. Product descriptions on website www.agnav.com.
148. *Real Earnings in October 2007*, (Bureau of Labor Statistics, USDL-07-1789).
149. *VII Architecture and Functional Requirements – Version 1.1* (ITS Joint Program Office, July 20, 2005).
150. *Cooperative Intersection Collision Avoidance System Limited to Stop Sign and Traffic Signal Violations (CICAS-V), System Architecture Description*, *Final Preliminary Release v1.03* (CAMP Vehicle Safety Communications 2, August 24, 2007).
151. *Cooperative Intersection Collision Avoidance System Limited to Stop Sign and Traffic Signal Violations (CICAS-V), Concept of Operations, Interim Release v1.03,* (June 29,3007).
152. *Vehicle Safety Communications Project, Task 3 Final Report* (DOT HS 809 859, March 2005).
153. Karen Van Dyke, DOT/RITA/Volpe Center, "Navigational Positioning Navigation and Timing Architecture Update", presented by, at the CGSIC Meeting (Fort Worth, TX, September 24, 2007).
154. *FY 2006 Annual Report, Minnesota Governor's Council on Geographic Information.*
155. Alan Cameron, "Wing Commander", *GPS World* (March 2007).
156. "Satellite Receiver is Designed for Agriculture Applications", www.thomasnet.com (February 20, 2007).
157. Eric Gakstatter, "L2C – Not Just Vanilla GPS Anymore", *GPS World* (April 24, 2006).
158. Philip Mattos, "Acquiring Sensitivity to Bring New Signals Indoors", *GPS World* (May 1, 2004).
159. "Understanding L2C (L2) GPS", www.gpsreview.net.
160. "GPS Signals", *Wikipedia* web site.

This page intentionally left blank.

Appendix B - Case Studies

B.1 State of Maryland

Maryland has several users within the state and local governments. NDGPS users in the state of Maryland include:

- Department of Transportation;
- Department of Environment;
- Department of Natural Resources; and
- local agencies.

B.1.1 Applications

The Maryland State Highway Administration (SHA) uses NDGPS for several mapping and asset management projects. They are currently building new programs to collect data on all assets along the roadways that are maintained by SHA. They continue to purchase GPS receivers that use the NDGPS signal, as well as developing applications for data inventory that are being connected to these receivers. SHA uses NDGPS to:

- inventory all publicly maintained roads in Maryland;
- map roadway centerlines;
- collect data for the Road Inventory Data Entry (RIDE) system;
- maintain a database of the roadway characteristics;
- verify County and Municipal yearly updates in the field;
- Monitor state-maintained sidewalks for ADA compliance; and
- Support asset management for light poles, guardrails, signs, and other roadside assets, including identification of the location, condition, attributes of each asset, and entry of the data in the SHA Asset Data Warehouse.

The Maryland Department of the Environment and Maryland Environmental Services uses NDGPS for:

- Environment Digital Floodplain Mapping;
- Custom application development;
- Field support;
- Custom data integration;
- Data management and quality assurance;
- Technology integration;
- Data delivery; and
- Field verification of GIS data.

The Maryland Department of Natural Resources (DNR) uses NDGPS for:

- Collecting vegetation samples along the Appalachian Trail;

- Mapping endangered and protected species areas;
- Supporting geological surveys and a cooperative study of sinkholes between the Department of Natural Resources and the State Highway Administration;
- DNR Police use NDGPS to get a location for violations. The location is required for court hearings. In 2006, DNR Police had over 16,000 incidents.

The Montgomery County Fire & Rescue Service relies on NDGPS to provide accurate GPS locations for field collected data and apparatus location.

B.1.2 Benefits and Cost Impacts of Loss of NDGPS

Benefits of the use of NDGPS identified by the state of Maryland include:

- Reduced field data collection time;
- Reduced state re-inventory cycle;
- Increases productivity in collecting and processing data; and
- Improved quality of data.

If NDGPS is decommissioned, state agencies would have to possibly buy new receivers as well as new software. Any new receivers would have to be capable of getting the accuracy the different agencies within the state require for their applications. Software programs would have to be redeveloped.

NDGPS provides higher accuracy that Satellite-Based Augmentation Systems, and the signal can be received in wooded or urban areas where other augmentation systems do not work reliably.

[The information for this case study came from papers and presentations, information provided by the Maryland Department of Transportation, and responses to the NDGPS Federal Register Notice from organizations operating within the state. Applicable references in Appendix A: . Applicable references from responses to the Federal Register Notice, Table E-1, entries 0018, 0024, 0095.]

B.2 State of North Dakota

There are a number of government and private entities in North Dakota that use the NDGPS network in North Dakota for a variety of applications.

Within the state government, the organizations using NDGPS include:

- North Dakota National Guard;
- North Dakota State University (Division of Transportation);
- North Dakota Department of Transportation;
- State Water Commission; and
- State Engineer's Office.

Federal Government agencies operating within North Dakota that use NDGPS include:

- Bureau of Reclamation;
- Garrison Diversion (water management);
- Theodore Roosevelt National Park;
- US Air Force in Grand Forks;
- US Corps of Engineers;
- US Fish & Wildlife; and
- US Forest Service.

North Dakota counties that use NDGPS include:

- Barnes County;
- Bottineau County;
- Dickey County;
- Richland County;
- Stutsman County; and
- Billings County.

A number of private companies and user groups (17) were also identified by state officials as regular users of NDGPS. These companies include land surveyors and engineers, mapping companies, environmental protection groups, farmers, Native American tribes, and others. These organizations consider NDGPS an essential tool, used in everyday work. There are several NDGPS stations within or in usable range of North Dakota.

B.2.1 Applications

Information from organizations within North Dakota indicated a number of applications of NDGPS, including:

- highway project control;
- land surveying;
- wetlands and tree field delineations;
- precision agriculture;

- water resource project planning, investigation, construction, and issuance of water use permits;
- flood plain management;
- engineering;
- dam safety efforts;
- inventory;
- archeology;
- utility location;
- environmental planning and assessment;
- environmental management, including mapping wetlands, managing resources, indexing wetlands, wetland construction, and habitat restoration;
- biological and scientific studies of wetlands, grasslands, water purification filtration, flood control, and fish barriers;
- water management;
- cultural resources;
- meeting regulatory requirements; and
- emergency operations.

The Department of Transportation also uses the NDGPS network for determining the coordinates and elevations of highway projects control points (static surveys), roadway centerlines for planning purposes, wetland and tree field delineations, and cultural resources.

The use of NDGPS includes both real-time data collection and post-processing using data from CORS sites, which include NDGPS sites.

The requirements for the location accuracy supported by NDGPS, enhancements to NDGPS, and other precision GPS systems are increasing. For planning of roadway centerlines, the current requirement is three feet or less, but will be one foot or less in the future. For roadway surveys (highway control), the requirement is two centimeters now, two centimeters in the future. For applications related to mapping cultural resources, the location accuracy requirement is about one foot now, and will be less than one foot in the future. For environmental mapping applications, the current requirement is three feet or less now, one foot or less in the future. For real-time surveys, the need will be 0.4 feet in the future, which could be satisfied with High Accuracy NDGPS.

B.2.2 Benefits and Cost Impacts of Loss of NDGPS

The fundamental benefits of NDGPS identified by organizations in North Dakota include:

- Time savings;
- Vehicle miles savings;
- Operational efficiency;
- More accurate surveys; and
- Use of current technology.

Highway Applications

The savings of using NDGPS for highway work was identified as follows:

- Reduction of staff hours needed to do the work;
- Reduction of GPS receivers needed to complete the work;
- Reduction of vehicles needed to do the work; and
- Reduction in cost to do the work.

Surveying Applications

For highway project control, North Dakota personnel use the following NDGPS stations: Billings (Montana), Pine River (Minnesota), Clark (South Dakota), and Medora (North Dakota), plus CORS stations BSC (Bismarck, ND) and Minot AFB (Minot, ND). To properly determine the coordinates and elevation of an unknown point, three known points must be used. If the NDGPS stations are removed, there would only be two CORS stations left in the area, which are insufficient to accurately determine the coordinates and elevation of unknown points.

Without the NDGPS stations, North Dakota surveyors would have to revert to the use of concrete monuments (if they are still there), with a potential cost impact up to $80,000/year. In addition to the cost impact, they project that it will also take longer to complete the surveys. Setting up their own RTK systems is also expensive, requiring the purchase of base stations, rovers with a data collector, radio links between the base stations and rovers, and appropriate software. Some project sites also require the use of additional personnel to guard the base, to protect it from being stolen or otherwise moved, or interrupted in any way during the survey. This requires the use of additional surveying personnel that increases the cost of the field data collection. NDGPS allows state personnel to do more work in less time and at a lower cost.

ND personnel indicated that environment work would be greatly affected by the loss of NDGPS. The Environmental Section uses a GPS unit for wetland and tree field delineations, and the degree of accuracy, after correction, is less than 1 meter. Before correction the degree of accuracy can be up to 10 meters, but is usually less than 5 meters. Without correction, the data collected is not reliable for design or construction. With the removal of this accuracy, the Environmental Section would have to spend more time in the field and would be required to employ surveying equipment.

ND personnel estimated that it would cost at least $30,000/year more in total field operations, travel, and personnel time for wetland and tree delineations without NDGPS, not including the time for a engineer/draftsman to take the paper delineation and draft onto plans. The total estimated costs for all aspects of this function are approximately $75,000. The estimated additional costs without the use of NDGPS associated with wetlands mitigation is $100,000, based on the error rate of manual methods.

Survey benchmarks are also sparse in many parts of the state, are regularly destroyed, and are seldom replaced. Work is often conducted in remote areas, with no geodetic networks nearby.

Cultural Resource Mapping

For the Cultural Resource Section, NDGPS has become an integral part of the survey process. Field-derived GPS data is post-processed with NDGPS base data. They recently purchased new GPS equipment with plans to post-process using data from NDGPS sites. If these NDGPS sites were decommissioned, they would be required to purchase GPS equipment upgrades to accommodate real-time correction, or duplicate current equipment and operate their own local base station for every field project. The estimated cost impact is $20,000 - $30,000+ for equipment/software updates.

The staff time cost impact of loss of NDGPS would depend largely on the solution to correction without NDGPS. Post-processing would involve downloading individual files for the entire time period of each rover file, instead of the current automated method. ND personnel indicate that a conservative estimate of the additional time necessary to prepare each file for use in their GIS system would be 40 - 100 man-hours, based on an estimate of 40 - 100 sites, with an hour added to process each. Having to establish a local base at each project location would effectively double the man-power required for field work, likely requiring adding additional staff, which is very difficult. The estimated cost impact for these operations is estimated to be up to $50,000, depending on the solution selected to replace use of signals from NDGPS sites.

Overall, ND officials estimate that the additional costs to the Cultural Resource Section associated with the loss of NDGPS between $20,000 and $60,000+, with the likely costs projected to be from the middle to upper end of this range.

Need for High Accuracy NDGPS

North Dakota officials indicate that adding High Accuracy capability to NDGPS sites is needed to meet the demands of surveying, engineering, environmental, and cultural resources applications. This would improve efficiency and produce time and cost savings for completing projects. Adding High Accuracy capability would provides better control triangles, provide the ability to occupy each control point for a very short time, provide accurate project control, and produce accurate real time data.

[The information for this case study came from papers and presentations, information provided by the North Dakota Department of Transportation, and responses to the NDGPS Federal Register Notice from organizations operating within the state. Applicable references in Appendix A: 70. Applicable references from responses to the Federal Register Notice, Table E-1, entries 42, 51, 53, 76, 97.]

B.3 National Park Service

The US Department of the Interior National Park Service (NPS) has many of the same applications as other Federal agencies that operate in the field (including the Department of Interior Bureau of Land Management, Department of Interior Bureau of Indian Affairs, the Department of Agriculture Natural Resource Conservation Service, and the Department of Agriculture US Forest Service), which requires use of GPS in an environment of often having to operate under foliage canopy or in areas of significant blockage of parts of the sky due to terrain.

NPS estimates that it has 3000 NDGPS users. They do not consider the ground-level coverage of satellite-based augmentation systems to be sufficiently reliable for most of their applications. They do some post-processing, but try to avoid it because of an estimated two to four times increase in costs. In general, NPS does not consider GPS augmentation methods other than NDGPS to be cost-effective or practical for their applications.

Most of the current NPS applications of NDGPS are based on the need for accurate, real-time location data for navigation and mapping applications. Their applications require a stable augmentation source that can penetrate rough terrain and heavy vegetation. New laws require increasing levels of location accuracy in managing wilderness areas. They need 1-2 meter accuracy, but operate with 5-10 meter accuracy when necessary. They indicated a need for improved NDGPS signal coverage, and deployment of a higher accuracy augmentation system in the future.

B.3.1 Applications

Some specific NPS applications of NDGPS include:

- Mapping cultural and historic resources;
- Mapping and managing natural resources, including endangered species;
- Hydrology surveys;
- Mapping roads and trails;
- Mapping land and facilities;
- Law enforcement;
- Visitor protection and search and rescue;
- Personnel management;
- Fire management and mapping of fire perimeters;
- Measuring glacier movement; and
- Facility management.

Some applications are considered safety-of-life, such as park police law enforcement activities, visitor search and rescue, and fire management, including helicopter navigation in fire areas.

Applications identified by specific Parks include:

- *California National Parks (Redwood National Park, Yosemite National Park, Devil's Post Pile National Monument, Joshua Tree National Park, Lassen Volcanic National Park, Whiskeytown-*

Shasta-Trinity National Recreation Area, Sequoia National Park, Manzanar National Historic Site, and Mojave National Preserve):
  - Mapping;
  - Natural resource management;
  - Fire management;
  - Emergency services; and
  - Transportation mapping.

- *National Parks in Southeast Region:*
  - Data collection;
  - Mapping park resources and features;
  - Natural resource protection;
  - Cultural resource protection;
  - Facilities management;
  - Wildland fire management;
  - Law enforcement; and
  - Visitor protection, search and rescue.

- *Glacier National Park:*
  - GIS;
  - Precision mapping; and
  - Navigation.

- *Lake Roosevelt National Recreation Area*:
  - Archeological surveys.

- *Grand Canyon National Park*:
  - Mapping of roads, buildings, fire hydrants.

- *Sequoia & Kings Canyon National Parks:*
  - Mapping locations of roads, buildings, fire hydrants, and other features.

- *Blue Ridge Parkway*:
  - All aspects of park management; and
  - Visitor search and rescue.

- *Southern Colorado Plateau Network*:
  - Natural resource management.

- *Saguaro National Park*:
  - Set survey controls.

- Flagstaff Area National Monuments:
  - Natural resource management;
  - Cultural resource management;
  - Park management planning and operations; and
  - Wildlife fires and hazard trees.

- *Rock Creek Park*:
  - Track and map wildlife;

  - Monitor and spatially analyze changing environs; and
  - Create and publish maps.

- *Zion National Park*:
  - Utilities management;
  - Archeological surveys;
  - Rare plant inventories;
  - Aerial application of herbicide on exotic vegetation; and
  - Fire management.

- *Midwest Region*:
  - Map park features and resources;
  - Fire planning;
  - Incident management;
  - Rehabilitation operations; and
  - Search and rescue.

- *Crater Lake National Park:*
  - Collect spatial data for input to GIS database.

- *Lewis and Clark National Historic Trail*:
  - Mapping entire Lewis and Clark Trail.

- Yellowstone National Park:
  - Data collection on exotic plants, and noxious and invasive weeds; and
  - Navigation and mapping.

B.3.2 Benefits and Cost Impacts of Loss of NDGPS

The benefits of NDGPS to NPS are:

- the level of location accuracy;
- the ability to work in areas of foliage and heavy terrain;
- the ground-hugging nature of the NDGPS signal;
- the fact that NDGPS provides real-time GPS augmentation;
- good repeatability;
- notification of loss of integrity; and
- NDGPS automatically puts data on the NAD-83 data set as required for Federal Government applications.

Many of the applications of NDGPS include direct automatic location data entry into GIS applications. For many of its applications, NPS needs to be able to quickly get back to a specific field site.

Experience has shown that Satellite Based Augmentation systems are not accurate enough or not always available in the areas where NPS personnel work. NPS personnel rely on the precision and integrity of NDGPS and CORS data, and use NDGPS for both real-time and post-processing applications. NDGPS is critical for many real-time applications, such as navigating back to a specific site in the wild. For many surveying, mapping, and GIS applications, the ability to accurate locate natural features, plants, and wildlife is a significant benefit of NDGPS. NPS works closely with other land management agencies, which have similar missions and location requirements.

NDGPS is particularly valuable in the Western states, because there is little satellite coverage in many areas. There is no incentive for private companies to set up reference stations to maintain quality of service, as is done with NDGPS sites. In much of this area, NDGPS sites constitute the majority of CORS sites, which are necessary for post-processing data to achieve necessary levels of accuracy for many GIS applications, and to satisfy environmental and asset management regulatory requirements.

NPS considers NDGPS critical to national geospatial location capabilities. Loss of sites would impair ability to provide accurate data and detrimental to scientific integrity. Loss of NDGPS would increase costs by requiring the agency to hire survey crews, and would cost many of the individual parks tens of thousands of dollars each. Loss of NDGPS would increase costs and decrease productivity across NPS and other Government agencies, making data collection take longer and cost more.

Without NDGPS, NPS would have to set up its own augmentation system, otherwise it would lose the ability to collect higher resolution data sets in areas of rough terrain where satellite-based augmentation does not work. Replacement of existing NDGPS receivers (that cost $1500-$1700) with other GPS units that would provide the required accuracy is estimated to be $5000-6000 each. Not counting the sunk cost of existing NDGPS receivers, this translates into $15-18M of new investment for replacement equipment. They would also incur costs related to training, application software, and personnel costs.

B.4 State of Minnesota

Various government (state, county, city) agencies and private companies within the state of Minnesota use NDGPS. Organizations within Minnesota are very active in using NDGPS and other GPS technologies in combination with Geographic Information Systems (GIS) to manage state resources. The Minnesota Governor's Council on Geographic Information coordinates GIS activities among all levels of government in the state; there are 23 members representing state agencies, Federal and local government, higher education, and the private sector. The Council promotes the effective use of GIS by coordinating investments; developing standards, policies, and guidelines; promoting stewardship of geographic data; and minimizing duplication of effort and public expenditure (reference 154). The Council endorses NDGPS as an integral part of the state's GIS infrastructure.

B.4.1 Applications

There are a number of public and private organizations in Minnesota that use NDGPS for a variety of applications, including:

- Accurate mapping of transportation, other infrastructure, and buildings;
- Precision navigation systems for agriculture and transportation;
- Delineation of landscape features such as wetlands;
- Scientific applications, such as tracking weather, monitoring soil conditions, and monitoring endangered species; and
- Public safety uses related to crime and emergency response.

The Minnesota Governor's Council on Geographic Information has stated that planned NDGPS enhancements would result in greatly improved accuracy. They indicated that with nationwide availability of 10-centimeter navigation accuracy or better, collision avoidance, lane keeping, and other applications could become available on a widespread basis, saving countless lives every year. Enhancement of NDGPS to include High Accuracy capability would also meet requirements for real-time applications that include locating underground utilities, automatic vehicle control, and automated surveying for locating and managing bridges and other public assets.

The paragraphs below identify applications by selected specific NDPGS users in the state.

The Minnesota Department of Transportation (MnDOT) uses survey grade receivers in conjunction with the NDGPS system for a number of applications, including:

- MnDOT Soils department uses NDGPS on their auger truck to navigate the proposed alignment and locate test holes;
- MnDOT Hydraulics department uses NDGPS for locating and inventorying culverts;
- MnDOT Preliminary Design department uses NDGPS to locate wetlands;
- MnDOT Maintenance department uses NDGPS for locating snow drift areas; and
- MnDOT Environmental Services uses NDGPT to locate Native American burial mounds.

MnDOT applications rely upon the NDGPS to support either the construction or maintenance of the Transportation Infrastructure.

Sherburne County, Minnesota, Public Works uses NDGPS for both real-time and CORS post-processing for:

- GIS and mapping applications;
- Road centerline locations;
- utility locations;
- trail mapping;
- asset inventories;
- gravel mining locations;
- civil defense siren locations;
- crime scene information;
- topographic surveys; and
- construction staking.

Itasca County, Minnesota, uses NDGPS for:

- Environmental Services uses NDGPS for E911 mapping and addressing;
- County Highway Department uses NDGPS for mapping and management of road centerlines, and collecting information on road jurisdiction, surface type, and location; and
- County Land Commissioner uses NDGPS for location of Section and Quarter Corners for management of timber lands, trail mapping, easement mapping, and line running in real time.

The City of Woodbury, Minnesota, uses NDGPS for:

- Sign inventory;
- Field location of storm sewer, sanitary sewer, and water main structures;
- Curb stop location;
- Recording park trail alignments; and
- Inventory of park assets.

The City of Eagan, Minnesota, uses NDGPS for:

- Mapping and locating sewer and water utilities, streets, trail networks;
- Documenting pavement ratings;
- Conducting traffic studies; and
- Conducting inventories of park infrastructure and natural resources.

Private land surveyors identified the following applications of NDGPS:

- establishing base stations for real-time surveys
- mapping road locations, access easements, and access routes, often under heavy foliage canopy; and
- providing support to state transportation operations.

B.4.2 Benefits and Cost Impacts of Loss of NDGPS

Minnesota relies on NDGPS stations for controlling adjustments to the state's Virtual Reference Station/CORS system and ensuring stability of the network and reduction of discrepancies in GIS references. Loss of NDGPS would require state NDGPS users to replace their current receivers with ones that would achieve the same accuracies at a much higher cost and potentially have to add more reference stations to their network.

[The information for this case study came from articles and presentations from state of Minnesota NDGPS users, and responses to the NDGPS Federal Register Notice by organizations within Minnesota. Applicable references in Appendix A: 154. Applicable references from responses to the Federal Register Notice, Table E-1, 0011, 0012, 0015, 0020, 0025, 0029, 0031, 0037, 0064.]

This page intentionally left blank.

Appendix C - States Implementing or Considering Own Augmentation Networks

1. Virginia
2. Maryland
3. New Jersey
4. North Carolina
5. South Carolina
6. Georgia
7. Florida (Under Construction)
8. California (Under Construction)
9. Washington
10. Maine
11. Connecticut
12. Alabama
13. Louisiana
14. Kentucky
15. Tennessee
16. Illinois
17. Indiana
18. Ohio
19. North Dakota
20. South Dakota
21. Mississippi
22. Arkansas
23. Iowa
24. Texas
25. Vermont
26. Rhode Island
27. Massachusetts
28. Pennsylvania

This page intentionally left blank.

Appendix D - Copy of Federal Register Notice

burden of the collection of information on respondents, including the use of automated collection techniques or other forms of information technology.

All responses to this notice will be summarized and included in the request for OMB approval. All comments will also become a matter of public record.

Issued in Washington, DC on July 25, 2007.

Todd M. Homan,

Director, Office of Aviation Analysis.

[FR Doc. E7–14885 Filed 7–31–07; 8:45 am]

BILLING CODE 4910–9X–P

DEPARTMENT OF TRANSPORTATION

Research and Innovative Technology Administration

[RITA–2007–28836]

Nationwide Differential Global Positioning System (NDGPS) Program

AGENCY: Research and Innovative Technology Administration, DOT.

ACTION: Notice; request for public comments.

SUMMARY: The Research and Innovative Technology Administration (RITA), on behalf of the U.S. Department of Transportation (DOT), is assessing the current user needs and systems requirements of the inland (terrestrial) component of NDGPS. This assessment is in preparation for making a recommendation to the National Space-Based Positioning, Navigation and Timing (PNT) Executive Committee (*http://www.pnt.gov*) on the need to continue to operate the inland component of the NDGPS system, and to make a decision on funding the NDGPS. The assessment may recommend other funding sources for future maintenance or enhancement of NDGPS, or shared sponsorship with other Federal and non-Federal agencies and entities, including the private sector. If no transportation requirements or other federal user requirements are identified as a result of the needs assessment, and if there are no other Federal or other funding sources willing to sponsor or partner in sponsoring NDGPS, DOT would develop a decommissioning plan for NDGPS.

DATES: Comments and related material must reach the Docket Management Facility on or before October 1, 2007. Late filed comments will be considered to the maximum extent practicable.

ADDRESSES: You may submit comments identified by RITA docket number RITA–2007–28836 to the Docket Management Facility at the U.S. Department of Transportation. To avoid duplication, please use only one of the following methods:

(1) *Web site: http://dms.dot.gov* (electronic submission).

(2) *Mail:* U.S. Department of Transportation, Docket Operations, M–30, Room W12–140, 1200 New Jersey Avenue, SE., Washington, DC 20590.

(3) *Fax:* 202–493–2251.

(4) *Delivery:* Room W12–140 in the West Tower of the U.S. Department of Transportation Headquarters Building, 1200 New Jersey Avenue, SE., Washington, DC, between 9 a.m. and 5 p.m., Monday through Friday, except Federal holidays. The telephone number is 202–366–9329.

FOR FURTHER INFORMATION CONTACT: If you have questions on this notice, call Mr. Timothy A. Klein, Department of Transportation, Research and Innovative Technology Administration, 202–366–0075, or e-mail *NDGPS@dot.gov.*

If you have questions on viewing or submitting material to the docket, call Renée V. Wright, Program Manager, Docket Operations, 202–493–0402.

You may obtain a copy of this notice by calling RITA's Office of Governmental, International and Public Affairs, 202–366–9664, or read it online at *http://dms.dot.gov.*

SUPPLEMENTARY INFORMATION:

Background

In 1997, the Department of Transportation and Related Agencies Appropriations Act of 1998 (Pub. L. 105–66, section 346 (111 Stat. 1449)) authorized the implementation of the inland component of NDGPS. Federal agencies, states, and scientific organizations have been cooperating to complete the inland NDGPS component throughout the U.S. If completed as originally envisioned, NDGPS will provide coverage of the conterminous U.S., Hawaii, and Alaska, regardless of terrain, man-made obstructions, or other surface obstructions. This coverage is achieved by using a robust medium frequency broadcast optimized for surface applications. NDGPS currently meets all of the Maritime Differential GPS performance requirements.

The completed NDGPS system would provide an accurate, highly-reliable, dynamic, nationwide real-time differential GPS location and integrity function to users that could enable multiple surface transportation, other civil, commercial, scientific and homeland security applications. More information is available at: *http://www.navcen.uscg.gov/ndgps/default.htm.*

The Department of Transportation is evaluating the user needs and system requirements of the NDGPS system. DOT is examining whether it would be in the public interest to continue operations of the inland component of the NDGPS system, or to invest in completing and enhancing NDGPS by:

1. Completing the planned NDGPS Initial Operational Capability (IOC); or
2. Completing the planned NDGPS Full Operational Capability (FOC).

If further investment is not in the public interest and there are no other funding sources, DOT is evaluating whether to decommission the inland component of NDGPS.

DOT is also seeking information about potential NDGPS sponsor partnerships with other Federal, state and local agencies, universities, and the private sector.

Future operations and investment decision scenarios might include:

1. Sharing sponsorship (program operations, maintenance and funding responsibilities) across interested Federal, state and local agencies, which may lead to completing the planned NDGPS Initial Operating Capability (IOC) of providing users with coverage by at least one NDGPS site over the conterminous United States (CONUS), as defined in the 2005 Federal Radionavigation Plan (2005 FRP), available at: *http://www.navcen.uscg.gov/pubs/frp2005/2005%20FRP%20WEB.pdf;*
2. Sharing sponsorship (program operations, maintenance and funding responsibilities) across interested Federal, state and local agencies, which may lead to completing the planned NDGPS Full Operating Capability (FOC) of dual coverage over CONUS, as defined in the 2005 FRP;
3. Transferring system funding and/or operations to the private sector through a public-private partnership or similar mechanism; or,
4. If user requirements are not identified, decommissioning the inland component of NDGPS.

In all scenarios, the Coast Guard will continue to operate, maintain, and manage the Maritime Differential GPS system to meet maritime safety, navigation and security mission requirements.

Contributing factors to these decisions are:

1. Whether there are sufficient number of current and projected NDGPS transportation users, and/or other civil sector users (e.g., civil Federal, state and local agencies, commercial and scientific interests) to justify continued system operation, or build-out to FOC completion;
2. Whether there are sufficient safety, mobility, efficiency, economic,

environmental, and other benefits to justify the costs of FOC completion and future operations;

3. Whether there are other GPS augmentation or PNT services currently available to meet NDGPS requirements; or if such services are in development, when nationwide real-time deployment is expected;

4. Whether the private sector has or is developing the capability to provide services equivalent to or better than NDGPS requirements, or whether the private sector has an interest in assuming funding and/or operations of the inland component of NDGPS;

5. Whether there are international considerations to the decision concerning the future of the inland component of NDGPS; and

6. Whether there are interoperability or radio frequency spectrum considerations to the decision concerning the future of the inland component of NDGPS.

Specific to the DOT decision on future NDGPS sponsorship by the Department, contributing factors include:

7. Whether there are any transportation operational requirements for the inland component of NDGPS;

8. Whether there are existing uses of NDGPS by Federal, state and local transportation agencies, other transportation authorities, or private transportation and logistics providers and shippers, and if these uses are critical to transportation safety, operations and efficiency;

9. Should there be existing uses, whether another PNT or GPS augmentation service could meet the user requirement; and the cost of switching to another system, should that system meet the user requirements; and

10. Whether there are transportation safety, mobility or efficiency applications currently in research, development, or early deployment which are dependent upon the NDGPS for successful application; whether another PNT or GPS augmentation service could meet the projected application(s); and the cost of switching to another system, should that system meet the projected requirement.

The Department of Transportation seeks public input on the various decisions currently under consideration, with an emphasis on NDGPS user requirements and sponsorship opportunities. The Department of Transportation also will solicit real-time navigation and positioning requirements from Federal civil agencies and quantify any mission impacts of conducting public business without the availability of NDGPS. For more information on NDGPS, you may visit: *http://www.navcen.uscg.gov/ndgps/default.htm.*

Request for Comments

All comments received will be posted, without change, to *http://dms.dot.gov* and will include any personal information you have provided. Please see DOT's "Privacy Act" paragraph below.

Submitting Comments: If you submit a comment, please include your name and address, identify the docket number for this notice (RITA–2007–28836) and give the reason for each comment. You may submit your comments by electronic means, mail, fax, or delivery to the Docket Management Facility at the address under **ADDRESSES**; but please submit your comments by only one means. If you submit comments by mail or delivery, submit them in an unbound format, on white paper no larger than 8½ by 11 inches, suitable for copying and electronic filing. If you submit comments by mail and would like confirmation they reached the Facility, please enclose a stamped, self-addressed postcard or envelope. We will consider all comments received during the comment period.

Viewing Comments and Documents: To view comments, go to *http://dms.dot.gov* at any time, click on "Simple Search," enter the last five digits of the docket number for this notice (RITA–2007–28836), and click on "Search." You may also visit the Docket Management Facility in Room W12–140 in the West Tower of the U.S. Department of Transportation Headquarters Building, 1200 New Jersey Avenue, SE., Washington, DC, between 9 a.m. and 5 p.m., Monday through Friday, except Federal holidays.

Privacy Act: Anyone can search the electronic form of all comments received into any of our dockets by the name of the individual submitting the comment (or signing the comment, if submitted on behalf of an association, business, labor union, etc.). You may review the Department of Transportation's Privacy Act Statement in the **Federal Register** published on April 11, 2000 (65 FR 19477), or you may visit *http://dms.dot.gov.*

Next Steps for this Project

At this time, the Department of Transportation seeks public input on the various options currently under consideration. The Department of Transportation also will inventory Federal civil agencies on any mission requirements that may require NDGPS, and identify mission impacts of conducting business without NDGPS. After considering all comments, the Department of Transportation will make a recommendation to the National Space-Based PNT Executive Committee (*http://www.pnt.gov*) on the need to continue to operate or to invest in completion or enhancement of the inland component of the NDGPS system, and on proposed sponsors and funding partners; and will inform the public of the agreed course of action with respect to future investment in NDGPS.

Issued in Washington, DC, on July 25, 2007.

Thomas O'Donoghue,

Chief Counsel, Research and Innovative Technology Administration.

[FR Doc. E7–14905 Filed 7–31–07; 8:45 am]

BILLING CODE 4910–HY–P

This page intentionally left blank.

Appendix E – Summary of NDGPS Federal Register Responses

Table E-1. Summary of NDGPS Federal Register Notice Responses			
Docket Ref. RITA-2007-28836-	**Affiliation**	**NDGPS Applications Referenced**	**Other Comments**
0001		FRN Notice	
0002	Unknown		
0003			
0004	Patriot II R&D		• Current augmentation systems need to remain in operation until new systems are proven • Current augmentation systems need to be improved
0005	Unknown	• Hunters • Lumberman • Drivers delivering cargo	• NDGPS critical in West and Midwest
0006/0077	South Carolina Geodetic Survey	• Critical component of NGS CORS network • Use data for NGS Height Modernization • Enable surveyors and mappers to obtain sub-meter accuracy • Train control applications still valid	• Should consider all uses of NDGPS and NDGPS sites
0007	South Carolina Citizen	• NDGPS part of CORS network • Surveying and mapping • Positive Train Control • NGS Height Modernization activities	• Coast Guard service only along the coast
0008	Mass. Conservation Commission	• Locating bounds and monitoring boundaries of conservation parcels • Allows personnel to quickly re-locate objects	• Works in rough and wooded terrain • NDGPS should remain with agency experienced in maintaining dispersed electronic equipment
0009	City of Ashland, Wisconsin	• Used to inventory assets for required GASB34 reporting	• No other augmentation options in northern rural areas • Can't afford own reference stations
0010	Private Pilot	• Off-airways navigation	
0011	Minnesota Department of		• Did use NDGPS, now use WAAS • Should combine NDGPS and WAAS

Table E-1. Summary of NDGPS Federal Register Notice Responses			
Docket Ref. RITA-2007-28836-	**Affiliation**	**NDGPS Applications Referenced**	**Other Comments**
	Agriculture		
0012	MN Private Land Surveyor	• Use NDGPS to establish base stations for real-time surveys in northern Minnesota	• Also use OPUS data
0013	Federal Govt GIS Worker		• Need data from NDGPS sites for real-time corrections in Western states
0014	Private Hydrographic Surveyor	• Hydrographic surveys for state, federal, local, and private entities • Navigation and dredging projects	
0015	Sherburne County, MN, Public Works	• GIS and mapping applications • Road centerline locations, utility locations, trail mapping, asset inventories, gravel mining locations, civil defense siren locations, crime scene information, topographic surveys, construction staking	• Use both real-time NDGPS data and CORS post-processing
0016	Unknown	• Resource mapping, including wetlands	• Area heavily forested; WAAS of limited use due to tree cover and low angle of satellite • Commercial service not viable; 90% Federal land
0017	Unknown	• NDGPS part of CORS network • Surveying and mapping	• Homeland security needs accurate maps for flood control and emergency response • Urged continuation of system
0018	Maryland Dept. of Natural Resources		• Marine and urban/wooded applications • Use both NDGPS and MDGPS sites • NDGPS accuracy better than WAAS • NDGPS provides distributed backup augmentation
0019	Bureau of Land Mgmt, Idaho	• Manage 600,000 acres of public land, including fire management	• Use real-time NDGPS data and CORS post-processing
0020	Minnesota Private Land Surveyor	• Uses NDGPS for road locations, access easements, and cartway access routes • Often under heavy foliage canopy	• Supports Cook County, MN transportation operations
0021	Iowa Dept of Transportation	• Use NDGPS for locating soil bore holes, wetland delineation, and project design	• Need NDGPS accuracy

Table E-1. Summary of NDGPS Federal Register Notice Responses			
Docket Ref. RITA-2007-28836-	**Affiliation**	**NDGPS Applications Referenced**	**Other Comments**
		control coordinates	
0022	National Governors Association	• Referenced applications for economic development, safety and security, mobility, environmental protection, global competitiveness, and other critical aspects of transportation, agriculture, and public safety	• NDGPS support part of Policy Position dated 7/24/07 • Support completion of construction of NDGPS, make modernization improvements, and provide reliable funding for ongoing operations
0023	North Carolina State University	• Precision farming and forestry applications	• Need NDGPS capabilities at ground level, WAAS not suitable • Need NDGPS accuracy • Farmers cannot afford commercial augmentation services
0024	Maryland Dept. of Natural Resources	• State Highway Administration uses NDGPS for mapping and asset management • DNR Police use NDGPS for location of violations, required for court hearings • Other state and local applications, including ADA sidewalk compliance and sinkhole monitoring	• Would have to replace NDGPS receivers, develop new software, and redevelop programs
0025	Itasca County, Minnesota	• Environmental Services uses NDGPS for E911 mapping and addressing • County Highway Department uses NDGPS for mapping and management of road centerlines, and collecting information on road jurisdiction, surface type, and location. • County Land Commissioner uses NDGPS for location of Section and Quarter Corners for management of timber lands, trail mapping, easement mapping, and line running in real time.	
0026	Unknown		• Used by surveyors and software developers • Urge expansion of NDGPS program
0027	Vermont Agency of	• Use NDGPS in Video-Log van to correlate safe digging areas to highway locations, and	• Need accurate, real-time corrections

Table E-1. Summary of NDGPS Federal Register Notice Responses			
Docket Ref. RITA-2007-28836-	**Affiliation**	**NDGPS Applications Referenced**	**Other Comments**
	Transportation	to relate objects captured on video to a GIS system. • Use NDGPS in Roadware van to analyze pavement surface condition	
0028	Retired MN DOT Survey Engineer		• Contacting Minnesota congressional representatives to urge continuation of funding and attention
0029/0041	Minnesota Governor's Council on Geographic Information	• Use NDGPS for: o Accurate mapping of transportation, other infrastructure, and buildings; o Precision navigation systems for agriculture and transportation; o Delineation of landscape features such as wetlands; o Scientific applications such as tracking weather, soil conditions, and endangered species monitoring; o Public safety uses related to crime and emergency response.	• Support enhancement of NDGPS to 10 centimeter accuracy for: o Collision avoidance, lane keeping, and other highway applications; o Locating underground utilities, automatic vehicle control, automated surveying for locating bridges and other public assets.
0030	South Dakota DOT	• Use NDGPS for road project surveys without having to use post-processing	
0031	Minnesota DOT	• Use NDGPS to locate: o soil bore trucks o culverts o wetlands o snow drift areas o Native American burial grounds	• Order of magnitude cost impact to replace NDGPS receivers with others of equivalent accuracy • Use NDGPS to control adjustments on state Virtual Reference System network; loss of NDGPS would reduce stability of network and causing variability of surveys • Loss of NDGPS would increase costs of transportation infrastructure development
0032	North Carolina State University	• On verge of rapid expansion of precision agriculture	• NDGPS corrections among preferred options for augmentation; NDGPS superior performance compared to satellite-based augmentation • No fee service important to maintain

Table E-1. Summary of NDGPS Federal Register Notice Responses			
Docket Ref. RITA-2007-28836-	**Affiliation**	**NDGPS Applications Referenced**	**Other Comments**
			• Consider NDGPS to be an essential utility • Loss of NDGPS would create obstacles to development of user applications
0033	California DOT	• Transportation Surveyors use NDGPS for navigating to find survey monuments, obtain resource grade mapping, and targeting wing points for photogrammetric mapping	• High Accuracy NDGPS would support more applications for asset management, utility location and inventory, more accurate resource and environmental mapping, and machine control and automation • Suggested that more effort should go into promoting NDGPS
0034	Byrum Family Farms, Inc. (VA)	• Depend on NDGPS for precision agricultural guidance system • Guidance system has made farm more efficient, including reduced use of fertilizers and pesticides	• Other options are limited and cost prohibitive for small farms
0035	Private Surveyor	• Resource mapping and surveying	• NDGPS critical in rural areas
0036	CEH Precision Crops	• Sell guidance systems on fertilizer spreaders and spray machines	• WAAS does not work well next to woods • Having to pay for commercial subscription would reduce use of automated guidance systems • 20% savings from reduced application of chemicals and fertilizer, contributing to health of environment
0037	City of Woodbury, MN	• Sign inventory • Field location of storm sewer, sanitary sewer, and water main structures • Curb stop location • Record park trail alignments • Inventory park assets	
0038	Private Surveyor	• Wetland boundary mapping, accepted by state and Federal agencies due to accuracy • Delineation of grading plans, survey plans, and plat mapping • Navigate back to wetland boundaries	• NDGPS allows one person to do work that would otherwise require a survey crew

Table E-1. Summary of NDGPS Federal Register Notice Responses			
Docket Ref. RITA-2007-28836-	**Affiliation**	**NDGPS Applications Referenced**	**Other Comments**
0039	Kunde Consultants (Environmental Consultants)	• Sub-meter delineation of wetlands, as required by Army Corps of Engineers	• WAAS not able to operate in many surface level conditions
0040	South Dakota Resident		• Use of NDGPS just beginning to be realized • WAAS not reliable in SD • Need NDGPS accuracy
0041	Minnesota Governor's Council on Geographic Information	• Duplicate of 0029	

0042/0054	North Dakota DOT	• ND DOT uses NDGPS for determining coordinates and elevations of highway control points, roadway centerlines, wetland and tree field determinations, and cultural resources.
		• Other agencies use NDGPS for surveying, engineering, inventory, archeology, utility location, environmental, cultural resources, and emergency operations. Letter lists 8 Federal agencies, 9 surveying and engineering companies, 3 state government agencies, 5 county governments, and 7 other organizations known to use NDGPS within North Dakota.
			• Identified future applications for High Accuracy NDGPS
			• RTK is expensive to buy, and the base station has to be guarded, increasing costs of field data collection
			• Estimate 81% savings of time and cost for highway project control using NDGPS, representing $60-80,000 per year
			• Identified the following savings related to use of NDGPS:
			  o Reduction of staff hours
			  o Reduction of GPS receivers required
			  o Reduction of vehicles to do the work
			  o Reduction in cost to do the work
			• Estimate increase in Environmental Section costs of $75,000 per year for wetland tree field delineations if NDGPS is lost.
			• Estimate additional costs of $100,000 per year for wetlands mitigation due to errors in wetlands delineations if NDGPS is lost.
			• Estimate additional costs of $20-60,000 per year in Cultural Resources Section if NDGPS is lost due to

Table E-1. Summary of NDGPS Federal Register Notice Responses			
Docket Ref. RITA-2007-28836-	**Affiliation**	**NDGPS Applications Referenced**	**Other Comments**
			additional manpower required to do field work and data processing. • ND invested $300,000 in NDGPS site Medora. • Estimate up to $80,000 per year to complete highway surveys if NDGPS is lost, due to requirement to go back to concrete monuments. • Without NDGPS sites, ND would only have data from two CORS sites, which is insufficient to accurately determine coordinates and elevation of survey points.
0043	Alliant Engineering	• Use NDGPS for survey of property corners and physical features.	• Feel NDGPS potential just beginning to be realized. • Identified ITS as major future application of NDGPS.
0044/0047	Advanced Research Corporation	• Identified range of applications of NDGPS and NDGPS sites.	• NDGPS superior to WAAS at ground level • Recommended enhancements to NDGPS: o High Accuracy o Improved Integrity o Incorporation of non-US GNSS services
0045	Former Railroad Official	• NDGPS Users – surveyor, snow plows, railroad track inspection cars, emergency responders, earthmoving equipment, weather forecasters, forest rangers, precision farmers • Railroad applications – Positive Train Control, Work Order reporting systems, railcar tracking, hazardous cargo tracking, event recorder location data, track defect location, precision surveys	• WAAS not certified below 200 feet, LAAS in development and limited range • Included several Transportation Research Board recommendations from 2000 to 2007 recommending completion of the NDGPS network • Included paper on “Network-Centric Railroading Utilizing Intelligent Railroad Systems”
0046	Scruggs Equipment Company, Inc.	• Referenced precision farming	• Loss of NDGPS would pose financial burden on farmers
0047	Advanced Research Corporation	• Duplicate of 0044	
0048	Association of American	• Need NDGPS for Positive Train Control to ensure interoperability and consistency of	• Recommend completion of NDGPS network and upgrade to High Accuracy NDGPS

Table E-1. Summary of NDGPS Federal Register Notice Responses			
Docket Ref. RITA-2007-28836-	**Affiliation**	**NDGPS Applications Referenced**	**Other Comments**
	Railroads	quality and integrity • NDGPS supports development of new diagnostic tools to identify and remedy safety issues • Can use NDGPS to locate track defects to needed accuracy, measuring rail longitudinal stress, monitor embankments for landslides	
0049	North Carolina DOT	• Searching for property corners • Staking out proposed roadway centerlines for geotechnical evaluations and boring • Guiding potential highway construction contractors along proposed centerlines • Wetlands and species habitat monitoring • Pavement mapping and analysis • Maintenance activities • Vehicle tracking	• Benefits: o Reduced need for walking property line, reduced need for cutting brush, more efficient use of personnel o Reduced need for survey crews o Rapid location of geotechnical points o Easier evaluation and estimating of highway projects • Increased use of electronic plans will increase use of NDGPS surveying • NDGPS more accurate than WAAS • High Accuracy NDGPS would increase benefits
0050	US Department of Agriculture, Farm Service Agency	• More than 3500 FSA staff members use NDGPS • Area measurements of planted acreage for programmatic assessments • Field investigative work for compliance • Disaster recovery assessments • Record accurate farm structure point data/location for credit program property inventory, maintenance, and security	• FSA has invested millions of dollars in NDGPS equipment and training • Decommissioning of NDGPS will negatively impact FSA's ability to carry out mission critical activities in 2400 offices nationwide and impact thousands of farmers and ranchers
0051	Ultieg Engineers		• General support and objection to privatization
0052	Ducks Unlimited	• Use NDGPS daily for mapping wetlands; managing resources; indexing wetlands; biological and scientific studies of wetlands,	

Table E-1. Summary of NDGPS Federal Register Notice Responses			
Docket Ref. RITA-2007-28836-	**Affiliation**	**NDGPS Applications Referenced**	**Other Comments**
		grasslands, and water purification filtration in shallow lakes; flood control; mapping fish barriers; wetland construction; habitat restoration	
0053	Holleybeck Surveying	• Use NDGPS for survey control, boundary surveys, construction staking, horizontal and vertical control for transportation projects and private clients	• Use of NDGPS saves time and money and repeatability
0054	North Dakota DOT	• Duplicate of 0042	
0055	Alaska Regional NPS GIS Coordinator	• As part of CORS network, NDGPS needed to provide common geodesy reference frame • Mapping glacier limits	• Presented comments as private citizen
0056	North Carolina Geodetic Survey	• Transportation applications in NC o Road construction planning o Preliminary construction staking o Mapping proposed road corridors o Roadside environment applications • Surveying and mapping applications o Preliminary reconnaissance o Feature location o Preliminary site location • Precision agriculture o Efficient application of pesticides and fertilizers o Harvest yield monitoring o Navigation of farm equipment • Geographic Information System applications o Inventory mapping o Mapping o GIS Maintenance	• NDGPS used for precision agriculture, saving money, fuel, and chemicals, and reducing pollution runoff • As part of CORS network, NDGPS used by land surveyors, professional engineers, scientists, educators, government agencies, construction, mining • NDGPS part of CORS network
0057	GPNS		• Propose integration of NDGPS with Land Based

Table E-1. Summary of NDGPS Federal Register Notice Responses			
Docket Ref. RITA-2007-28836-	**Affiliation**	**NDGPS Applications Referenced**	**Other Comments**
	Corporation		Location Services for video phones for public safety application • Propose public-private partnership to develop a national public safety Video 911 System
0058/0061	Chris Coles Holdings		• Support GPNS proposal Video 911 System
0059	Unknown	• Federal, state, county, and local agencies and private entities use NDGPS to provide high quality products to the public	• Discontinuation of NDGPS would be a costly step backward
0060/0072/0075	Washington State DOT	• WSDOT uses NDGPS for: o Video logging o Roadside Feature Inventory Program data collection o Wetlands and other environmental feature data collection o Collecting data on traffic related features o Navigate aircraft to sites and produce geodetic survey control for highway project construction • Use NDGPS and other CORS sites for datum references to Washington State Reference System	
0061	Chris Coles Holdings Inc.	• Duplicate of 0058	
0062	Unknown, Jackson County, WS	• Forestry department uses NDGPS to manage 125,000 acre county forest	• Local agency not award of proposed NDGPS discontinuation • Many users nationwide not aware of how NDGPS funded or operated, but rely on it
0063	Advocates for Highway and Auto Safety	• Referenced use of DGPS nationwide for fleet management applications: o Routing efficiency o Terminal location o Real-time tracking of sensitive/hazardous	• Major emphasis on use of NDGPS to verify Hours of Service

Table E-1. Summary of NDGPS Federal Register Notice Responses			
Docket Ref. RITA-2007-28836-	**Affiliation**	**NDGPS Applications Referenced**	**Other Comments**
		shipments o Monitoring and verifying commercial driver Hours of Service per 49 CFR § 396.8	
0064	City of Eagan, Minnesota	• Use NDGPS for: o Mapping and locating sewer and water utilities, streets, trail networks, pavement ratings o Conducting traffic studies o Park feature and tree inventories	• No alternative to Alma, WI NDGPS reference station
0065	Washington State E911	• NDGPS can support improved Medical Services and rapid accident scene management related to response to E911 calls.	
0066	US GPS Industry Council	• Referenced applications for farming, Positive Train Control, waterway dredging, resource management, GIS, plate tectonic monitoring, earthquake prediction, and weather forecasting, as well as maritime uses.	• Referenced President's 2004 Policy Statement on PNT directing operation and maintenance of terrestrial augmentation. • Discussed need for NDGPS at ground level • Benefits – improved productivity, improvements to environmental controls, increased safety of ground and marine navigation, and scientific and ecological applications.
0067		• No posting	
0068	Alliance of Automotive Manufacturers	• "NDGPS has the potential to contribute to cooperative highway-vehicle applications as well as autonomous safety applications" • Discussed CICAS and VII applications	• Members include BMW Group, Chrysler, Ford Motor Company, General Motors, Mazda, Mitsubishi, Toyota, and Volkswagen • Need High Accuracy NDGPS for lane-level accuracy for many safety applications •
0069	National States Geographic	• Emergency response (fire, police, HAZMAT spill, E911 calls, search and rescue) • Crop dusting	• NSGIC is association of state geographic information managers and other representatives that use GIS • NSGIC originally supported implementation of

Table E-1. Summary of NDGPS Federal Register Notice Responses			
Docket Ref. RITA-2007-28836-	**Affiliation**	**NDGPS Applications Referenced**	**Other Comments**
	Information Council	• Resource monitoring (archeological sites, environmentally sensitive areas, crop production, water quality) • Fleet management • Rural 911 services • Correct data in GIS systems • Geodetic survey operations • Fire and emergency management • Law enforcement navigation and mapping • Facilities management • Monitoring Integrated Precipitable Water Vapor • Commerce and coastal navigation • Post processing	NDGPS in 1999 • Many communities use NDGPS for real-time activities • NDGPS does not conflict with private sector since, by law, only Federal government can provide radio-navigation services • NDGPS is a Federal radio-navigation service, assuring public of adherence to published accuracy and availability specifications • NDGPS more robust than WAAS • WAAS uses different datum than GIS systems • Support deployment of High Accuracy NDGPS • Referenced Public Law 105-66 that states that DOT responsible for NDGPS funding • Request Congress to reconsider FY08 budget and fully fund NDGPS, and request funding to begin implementation of High Accuracy NDGPS
0070		• No posting	
0071	Murphy-Brown LLC	• Soil sampling • Measure accurate field acreage • Mark irrigation hydrants • Spraying and fertilizing crops	• Other augmentation likely not to work as well as NDGPS because many fields surrounded by trees • Precision agriculture will be more widely used • Access to NDGPS critical to make precision agriculture work
0072	Washington State DOT	• Duplicate of 0060	
0073	Ohio State University		• Recommended combining NDGPS and WAAS reference stations into integrated network, and using both NDGPS MF and satellite transmission • Discussed that land-based transmitters (as used in NDGPS) provide more robust delivery of augmentation than higher frequency methods • Discussed that some states are deploying their own reference stations, and that “NDGPS should take

Table E-1. Summary of NDGPS Federal Register Notice Responses			
Docket Ref. RITA-2007-28836-	**Affiliation**	**NDGPS Applications Referenced**	**Other Comments**
			over this role and provide consistence, as well as cost savings across the states".
0074	NPS, George Washington Memorial Parkway		• Important tool for NPS • NDGPS only source of real-time augmentation in many interior US locations • NDGPS operations not a major expense
0075	Washington State DOT	• Duplicate of 0060	
0076	North Dakota State Water Commission and State Engineer's Office	• Use of GPS surveys increasing • Water resource planning • Water system investigations • Construction • Flood management • Regulatory matters • Dam safety efforts • Issuance of water use permits	• NDGPS sites part of CORS network • Survey bench marks disappearing • Not possible to commit cooperate state funding at this time due to biennial budget cycle • Critical to keep NDPGS in operation
0077	Crop Production Services, Southern Illinois Division	• Use NDGPS on 26 crop application rigs, covering 150,000 acres	
0078	Crop Production Services, Precision Ag Specialist	• Precision agriculture • Managing tree farms for large paper companies	• Only NDGPS provides a reliable source to farmers with tree borders, and for forestry applications • Farmers rely on NDGPS • Support expansion of NDGPS to nationwide coverage
0079	Crop Production Services, NC-VA Division	• Precision application of nutrients and fertilizer • Yield monitors on harvesting equipment • Machine guidance systems	• Other systems are expensive or not as accurate in fields surrounded by trees
0080	Charles	• GIS • Precision agriculture	• NDGPS cut-off premature • Decision would undermine world confidence in US

Table E-1. Summary of NDGPS Federal Register Notice Responses			
Docket Ref. RITA-2007-28836-	**Affiliation**	**NDGPS Applications Referenced**	**Other Comments**
	Trimble		commitment to maintaining or improving GPS service • Zeroing out the NDPGS budget would save very little money; would cost state, local, and Federal governments more than the $10M budget • Need transition to GPS III • NDGPS provides better accuracy than WAAS
0081	NPS, Point Reyes National Seashore	• Mapping • Natural resource management • Fire management • Emergency services • Transportation mapping	• Writing in support on inland parks not covered by MDGPS • In California, Redwood National Park, Yosemite National Park, Devil's Post Pile National Monument, Joshua Tree National Park, Lassen Volcanic National Park, Whiskeytown-Shasta-Trinity National Recreation Area, Sequoia National Park, Manzanar National Historic Site, and Mojave National Preserve all rely on NDGPS • WAAS not accurate enough or not available in these areas • Loss of NDGPS would increase costs to hire survey crews • Shutting off NDGPS probably 10 years premature
0082	NPS, Southeast Region	• Data collection • Mapping park resources and features • Natural resource protection • Cultural resource protection • Facilities management • Wildland fire management • Law enforcement • Visitor protection, search and rescue	• NDGPS and CORS essential to meeting Congressional mandate to preserve parks providing national park visitor services • In FY2007, 50 search and rescue missions conducted in national parks
0083	NPS, Glacier National Park	• GIS • Precision mapping • Navigation	• Discussed precision and integrity of NDGPS and CORS data
0084	NPS, Lake Roosevelt	• Archeological surveys	• Real-time differential correction more accurate than post-processing

Table E-1. Summary of NDGPS Federal Register Notice Responses			
Docket Ref. RITA-2007-28836-	**Affiliation**	**NDGPS Applications Referenced**	**Other Comments**
	National Recreation Area		
0085	NPS, Grand Canyon National Park	• Mapping of roads, buildings, fire hydrants	• Use data from Flagstaff site for real-time and post-processing applications • Loss of Flagstaff NDGPS site would cost them tens of thousands of dollars

0086	US Civil GPS Service Interface Committee, US State and Localities Subcommittee	• Survey – land, road, hydrological and environmental location, assessment, management, and maintenance.
		• Inventory – infrastructure and natural resource location, assessment, management, maintenance, and protection.
		• Archaeology – historic resource location, assessment, management, and protection.
		• Utilities – location, management, and maintenance.
		• Emergency Operations – real-time location, positioning and assessment for firefighting, hurricane response and recovery, and similar activities.
		• Agriculture and roadside management – precision application of pesticides, runoff minimization, avoidance of protected species, soil quality mapping, and crop yield estimates.
		• Law enforcement – incident location and reporting, and emergency response.
		• Automated systems – automated road survey, construction and maintenance equipment, snowplow operations, and mowing systems.
			• Recommended:
			  o "completion of the Full Operational Capability (FOC) of NDGPS;
			  o Recapitalization of existing inland NDGPS equipment to ensure full functional equivalence with the U.S. Coast Guard's Maritime DGPS;
			  o 100 percent deployment of the proven High Accuracy NDGPS capability;
			  o Completion of a second NDGPS station in Puerto Rico to provide redundancy; and
			  o Completion of the proposed complement of NDGPS stations in Alaska."
			• NDGPS provides public access to:
			  o "sub-meter accuracy in multiple terrestrial applications;
			  o Accurate real-time positioning in all surface environments, including impeded environments (mountains, valleys, tunnels, urban canyons);
			  o Post-processed data for increased accuracy for resource management and mapping."
			• Could not do detailed cost and time savings estimates, but indicate that an ROI calculation should show substantial return in state and local areas.
			• ROI and cost avoidance would exceed annual Federal investment in NDGPS. Costs being avoided are often in Federally-mandated and funded programs, such as Federal Aid Highway and State

Table E-1. Summary of NDGPS Federal Register Notice Responses			
Docket Ref. RITA-2007-28836-	**Affiliation**	**NDGPS Applications Referenced**	**Other Comments**
			Planning and Research programs. • Letter provides examples of how NDGPS is used to allow states and localities to meet Federal regulatory and reporting requirements. • A number of states have invested in NDGPS sites. • Letter identified Federal agencies that work in concert with states and localities in applications that require NDGPS. • Discussed value of NDGPS as part of CORS network, and that CORS is a Federal-state-university-private sector partnership. • Discussed implementation of state RTK networks due to uncertainty over NDGPS future, and that this represents a waste of taxpayer dollars. • Referenced September 24, 2007, CGSIC presentation by the National PNT Architecture Team that identified gaps in PNT capabilities that would be met by completed deployment of inland NDGPS and High Accuracy upgrade. • Indicated that required investment in NDGPS a small investment compared to other national PNT investments. • Requested that “should a decision be made to continue inland NDGPS, that National Space-Based PNT Executive Committee direct all member Federal agencies to develop and implement a long-term funding plan to secure the future of the NDGPS, and of the critical user applications that rely upon it.”
0087	NPS, Sequoia & Kings Canyon National Parks	• Mapping locations of roads, buildings, fire hydrants, and other features	

Table E-1. Summary of NDGPS Federal Register Notice Responses			
Docket Ref. RITA-2007-28836-	**Affiliation**	**NDGPS Applications Referenced**	**Other Comments**
0088	NPS, Blue Ridge Parkway	• All aspects of park management • Visitor search and rescue	• Requested building of additional NDGPS sites
0089	NPS, Southern Colorado Plateau Network	• Natural resource management	• Depend heavily on GPS units for field crews, many use DGPS, and nearly all CORS data for post-processing • Loss of NDGPS would increase costs and decrease productivity across many government agencies
0090	NPS, Saguaro National Park	• Set survey controls	• Rely on CORS data for post-processing • NDGPS critical for real-time applications
0091	US Department of Interior, Bureau of Land Management	• General resource mapping • Detailed site mapping • Location of roads and trails • Law enforcement • Fire mapping • Surface area disturbances associated with energy development • Relocation of mapped points • Mapping of mineral leases	• BLM responsible for management of 260 million surface acres in lower 48 states and Alaska, plus 700 million acres of Federal surface and sub-surface mineral estate lands • GPS is predominant data collection and navigation tool in the field; use both WAAS and NDGPS receivers; have approximately 200 NDPGS receivers • WAAS signals often blocked in areas of canopy and rugged terrain • WAAS receivers take a long to start up or reacquire after augmentation signal loss; not observed in NDGPS receivers • NDGPS in standard National Reference System and NAD 1983 datum • NDGPS stations part of national CORS network, and are among the most dependable CORS sites; NDGPS sites critical part of CORS network in the West • Loss of NDGPS sites will reduce accuracy of position data and result in insufficient number of CORS sites for accurate baselines • Funding and operational responsibility should be transferred to another agency if USDOT will not continue funding NDGPS

Table E-1. Summary of NDGPS Federal Register Notice Responses			
Docket Ref. RITA-2007-28836-	**Affiliation**	**NDGPS Applications Referenced**	**Other Comments**
0092	High Plains Underground Water Conservation District No. 1	• Use Summerfield, TX NDGPS beacon daily	• Lubbock, Texas – 10,000 square mile area
0093	Society of American Foresters	• Real-time positioning • CORS operations needed to maintain a national spatial reference frame • Surveying and mapping • Forestry management • Fire protection and mapping • Search and rescue • Weather data collection • Law enforcement and police support, including E911	• NDGPS works in mountain forests, canopy areas, north slopes and other areas of limited sky visibility where WAAS does not work • LAAS should augment National Spatial Reference System • NDGPS and CORS are part of critical infrastructure
0094	OmniSTAR	• Agriculture	• Functions of NDGPS have been superseded • Alternate options available from commercial and government sources • NDGPS funding should be discontinued unless user base willing to cover costs is found
0095	Montgomery County, MD, Fire & Rescue Service	• Field data collection and apparatus location	• Support continuation of funding for Hagerstown, MD, NDGPS site.
0096	NPS, Intermountain Region		• Intermountain Region includes parts of Montana, Wyoming, Colorado, Utah, New Mexico, Arizona, Texas, and Oklahoma • Many users of CORS data • No incentive for privately owned reference stations to maintain quality of service, as is done with NDGPS sites • No WAAS coverage in many areas of this region

Table E-1. Summary of NDGPS Federal Register Notice Responses			
Docket Ref. RITA-2007-28836-	**Affiliation**	**NDGPS Applications Referenced**	**Other Comments**
			• Intermountain Region would suffer disproportionately from closure of NDGPS sites; map included to show impact • Need additional planned NDGPS sites
0097	Ducks Unlimited	• Mapping wetlands • Managing resources • Indexing wetlands • Biological and scientific studies of wetlands, grasslands, water purification in shallow lakes, flood control, fish barriers, construction of wetland, habitat restoration	• Chief Surveyor of Ducks Unlimited • NDGPS needed to accomplish goals and missions • No alternative to NDGPS for geodetic control in many remote areas • Support full funding and future funding for NDGPS
0098	Bureau of Land Management, Alaska State Office		• Support completion of planned NDGPS Full Operational Capability • Completion of NDGPS network would complete coverage in Alaska, needed for real-time and post-processing applications • Space Based Augmentations limited in Alaska • Commercial augmentation systems too expensive for most users • Need terrestrial base stations to transmit GPS corrections
0099	Idaho Transportation Department	• Collision avoidance • Land departure • Vehicle tracking • Improve data collection and accuracy	• Support continued development and operations of NDGPS to provide safety, efficiency, economic, and environmental benefits to Idaho
0100	NPS, Flagstaff Area National Monuments	• Natural resource management • Cultural resource management • Park management planning and operations • Wildlife fires and hazard trees	• NPS units have made significant investments in GPS technology • Rely on signal from Flagstaff 1 NDGPS/CORS site • Need alternative before NDGPS site decommissioned
0101	Transportation Research	• Positive Train Control	• Committee for Review of FRA Research, Development, and Demonstration Programs

Table E-1. Summary of NDGPS Federal Register Notice Responses			
Docket Ref. RITA-2007-28836-	**Affiliation**	**NDGPS Applications Referenced**	**Other Comments**
	Board		• Referenced various letter reports of the committee from 2002-2007 that supported completion of the NDGPS network • Support completion of the NDGPS network • NDGPS uncertainty leading to proprietary designs, and loss of PTC interoperability • Urge USDOT to see other agency partners for completion and maintenance of the NDGPS network
0102	Unknown		• Recommendations: o Change NDGPS to a wide band broadcast of GPS, eLORAN, and High Accuracy corrections, and weather and other data o Build out NDGPS to Full Operational Capability o Maintain NDGPS as a backup to WAAS o Retain NDGPS to supplement WAAS where WAAS signal is not available
0103	Federal Geodetic Control Subcommittee	• Fire and Emergency operations • Law Enforcement/Visitor Protection • Natural and Cultural Resource Management • Facilities Management • Monitoring precipitable water vapor • Monitoring distribution of fee electrons • Source of post-processing data	• Support continued operation of NDGPS • NDGPS provides level of augmentation unavailable with any other existing system • NDPGS independent of other infrastructure and can provide position augmentation despite catastrophic loss of other assets • Encourage high accuracy and integrity information broadcasting
0104	US Department of Agriculture, Forest Service	• Source of CORS data • Surveying • Mapping wildfire perimeters • Roadkill Observation Collection System • Update mapping information • Precise navigation • Navigation back to plot centers on Forestry Inventory and Analysis research projects	• No CORS alternatives in southeast Alaska • Need real-time capability for many applications
0105	Unknown		• Support continuation of NDGPS

Table E-1. Summary of NDGPS Federal Register Notice Responses			
Docket Ref. RITA-2007-28836-	**Affiliation**	**NDGPS Applications Referenced**	**Other Comments**
			• Have invested heavily in NDPGS systems
0106	NPS, GIS Coordinator	• NPS uses NDGPS and CORS data for administering national parks, historic areas, natural landmarks, and preserves	• Support continuation of NDGPS
0107	NPS, Rock Creek Park	• Track and map wildlife • Monitor and spatially analyze changing environs • Publish maps	• Support continuation of NDGPS • Loss of sites would impair ability to provide accurate data and detrimental to scientific integrity
0108	NPS, Zion National Park	• Utilities management • Archeological surveys • Rare plant inventories • Aerial application of herbicide on exotic vegetation • Fire management	• Support continuation of NDGPS • Loss of Flagstaff, AZ, NDGPS site would impair operations
0109	NPS, Midwest Region	• Map park features and resources • Fire planning • Incident management • Rehabilitation operations • Search and rescue	• Support continuation of NDGPS • Loss of 4 NDGPS sites in North Dakota, South Dakota, Nebraska, and Minnesota would impact operations in 12 National Park units in the Midwest Region • Impact of loss of NDGPS sites not limited to park boundaries
0110	NPS, Crater Lake National Park	• Spatial data	• Expressed general support for NDGPS and impact of loss on NDGPS on GIS database
0111	National Association of State Departments of Agriculture	• "The National Differential Global Positioning System (NDGPS) program is a valuable asset in anticipating and responding to natural, infrastructure and intentional disasters, and making major contributions to weather predicting, rescue and recovery, and agriculture. NASDA supports the completion of the terrestrial component of the NDGPS."	• Statement represents consolidated opinion of every state-appointed Agricultural Commissioner in the US

Table E-1. Summary of NDGPS Federal Register Notice Responses			
Docket Ref. RITA-2007-28836-	**Affiliation**	**NDGPS Applications Referenced**	**Other Comments**
0112	NPS, Lewis and Clark National Historic Trail	• Mapping entire Lewis and Clark Trail	• NDGPS critical to national geospatial location capabilities • Impact of loss of NDGPS would be critical in Idaho, Montana, and the Dakotas
0113	NPS, Yellowstone National Park	• Data collection on exotic plants, and noxious and invasive weeds • Navigation and mapping	• Many areas do not have satellite coverage • Loss of NDGPS sites would make data collection take longer and cost more • Requested building of additional NDGPS sites in the West
0114	NPS, North Coast and Cascades Network	• Prairie vegetation monitoring • Facilities mapping	• Need to be able to return to unmarked long-term monitoring sites • Work in rugged mountainous terrain • Use NDGPS data for post-processing • Loss of NDGPS sites would degrade positional accuracy of applications • GPS program was built around ability to obtain high-accuracy post-processed data
0115	NPS, Kenai Fjords National Park, Alaska	• Emergency response – fires, storms, floods, disaster response and recovery • Scientific investigations • Navigation	• Current unified system saves time and Government money, provides unified data source, covers large area, and spurs private sector innovation • NDGPS supports rapid response to emergencies and does not require additional training due to consistent system design • Decommissioning sites would affect provision of public services; should complete original build out of sites
0116	US Forest Service, Missouri	• Incident management • Fire management, GIS Fire Incident Command System	• Sites critical to incident management and Forest Service operation
0117	US Forest Service, Land Surveying and	• Post-processing and real-time navigation of fire perimeters • Generating maps of fire lines	• Safety issue of providing real-time data for fire-line leaders to plan escape routes and strategy • Able to navigate directly along boundary lines without locating old section corners

Table E-1. Summary of NDGPS Federal Register Notice Responses			
Docket Ref. RITA-2007-28836-	**Affiliation**	**NDGPS Applications Referenced**	**Other Comments**
	Fire Suppression		• Use of NDGPS in real time saves thousands of dollars per year by avoiding post-processing and returning to site the next day to set markers
0118	US Forest Service, Gallatin National Forest	• Field surveys	• Regularly use NDGPS/CORS station data
0119	Unknown	• Fire operations • GIS mapping	• Timeliness of CORS data important to applications
0120	NPS, Great Lakes Network	• Ecological monitoring, changes in natural resources	• Use data for post-processing • Supports increasing number of CORS stations
0121	US Forest Service	• GPS mapping • Mapping boundaries between Federal and private properties	• Loss of signal makes existing equipment obsolete • Loss of signal will reduce skills and accuracy of results • More difficult and time consuming to do data collection if signal lost, with less accurate results
0122	North Dakota DOT Survey Manager	• Preliminary surveys for highway reconstruction •	• Strong support to continue NDGPS • NDGPS also used by other government agencies, business, and individuals • Limited number of NGS survey markers in region, rely on NDGPS
0123	US Department of Agriculture	• More than 7000 receivers in daily use throughout the US • NDGPS enables USDA to provide higher quality, more timely service to its customers and partners	• USDA chose to use NDGPS for real-time navigation and positioning requirements because of improved accuracy, precision, and integrity monitoring • Recommends NDGPS be completed with dual coverage throughout the contiguous US • "Decommissioning the inland component of NDGPS would leave 42 percent of the contiguous United States without Differential Global Positioning System coverage. This would affect 41 States, 1,189 counties, 1,482 Soil and Water Conservation Districts, 1.5 million square miles, 74 percent of

Table E-1. Summary of NDGPS Federal Register Notice Responses			
Docket Ref. RITA-2007-28836-	**Affiliation**	**NDGPS Applications Referenced**	**Other Comments**
			Tribal lands, 1,244 watersheds, 448,107 miles of streams, 20 percent of family farms, and 1,388 wetland easements as well as countless rural communities. Decommissioning also would mean the loss of the associated Continuous Operating Reference Stations, which would have a severe impact on high accuracy positioning."
0124	Unknown	• Daily data collection and navigation by forest land managers in Mendocino National Forest	
0125	USDA Forest Service, Laramie, WY	• Real-time search for section corners for cadastral surveys • Mark lines for Fuel Reduction Projects (timber thinning)	
0126	Professional Land Surveyors of Wyoming, Southeast Chapter		• Support Option 1 and 2 of November 26, 2007 Memorandum (Paul Brubaker); strongly oppose Option 3 • Site spacing of CORS stations in Western US less dense than other parts of the country • Western CORS network vital to performing high accuracy and correctly positioned geodetic and ground based surveys • Decommissioning of 18 CORS sites will result in significantly positioning quality, impacting the professional land surveying community • Loss of CORS stations will result in longer observation times to achieve same level of accuracy as currently achieved • Longer observation times will result in higher survey costs to public and private entities.
0127	Land Surveying Incorporated	• Surveying • Mapping	• Surveying industry relies on current services • Industry would suffer significantly losses from loss of NDGPS data

Table E-1. Summary of NDGPS Federal Register Notice Responses			
Docket Ref. RITA-2007-28836-	**Affiliation**	**NDGPS Applications Referenced**	**Other Comments**
0128	US Forest Service, Lassen National Forest	• Post-process GPS data on daily basis using NDGPS data	• Use Chico, CA, station • Station also used by Eagle Lake Ranger District, Almanor & Hat Creek Ranger Station, and Supervisors Office

This page intentionally left blank.

Appendix F - NDGPS Memorandum of Agreement

MEMORANDUM OF AGREEMENT

FOR THE ESTABLISHMENT AND OPERATION OF THE

NATIONWIDE DIFFERENTIAL GLOBAL POSITIONING SYSTEM (NDGPS)

THIS AGREEMENT IS MADE AND ENTERED INTO BY AND AMONGST:

HEADQUARTERS U.S. AIR FORCE AIR COMBAT COMMAND AND THE U.S. ARMY CORPS OF ENGINEERS OF THE U.S. DEPARTMENT OF DEFENSE;

THE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION OF THE U.S. DEPARTMENT OF COMMERCE; AND

THE FEDERAL RAILROAD ADMINISTRATION, THE FEDERAL HIGHWAY ADMINISTRATION, THE U.S. COAST GUARD, AND THE OFFICE OF THE SECRETARY OF TRANSPORTATION OF THE U.S. DEPARTMENT OF TRANSPORTATION

I. PURPOSE:

A. This Memorandum of Agreement (MOA), and such supplements as may be agreed to, provide the basis for cooperative efforts among the U.S. Air Force (USAF), the U.S. Army Corps of Engineers (USACE), the National Oceanic and Atmospheric Administration (NOAA), the Federal Railroad Administration (FRA), the Federal Highway Administration (FHWA), the U.S. Coast Guard (USCG), and the Office of the Secretary of Transportation (OST) in the establishment of the U.S. Department of Transportation's (USDOT) Nationwide Differential Global Positioning System (NDGPS) radionavigation service.

B. This agreement provides for the maximum use of existing infrastructure and resources within each agency to the mutual benefit of all agencies and the general public. Specifically, this agreement establishes the overall policies, relationships, and responsibilities guiding interagency activities necessary to establish, operate, and manage the NDGPS as authorized by Section 346 of Public Law 105-66 of October 27, 1997 (Attachment A) including the temporary and permanent transfer of mutually selected USAF Ground Wave Emergency Network (GWEN) sites and equipment to USDOT.

II. BACKGROUND:

A. In Presidential Decision Directive NSTC-6, U.S. Global Positioning System Policy, (March 28, 1996), the President designated the USDOT as the Nation's, "lead agency for all Federal civil GPS matters." In addition, the President directed the USDOT to "develop and implement U.S. Government augmentations to the basic GPS for transportation applications." The USCG established the Maritime DGPS Service, a GPS augmentation providing service for coastal coverage of the continental U.S., the Great Lakes, Puerto Rico, portions of Alaska and Hawaii, and portions of the Mississippi River Basin. This service meets the requirements of U.S. harbor entrance and approach areas defined in the current version of the Federal Radionavigation Plan. Differential GPS (DGPS) corrections are broadcast on long-established international marine radiobeacon frequencies (285-325 kHz). The USCG Maritime DGPS Service is operated in cooperation with the USACE and the National Geodetic Survey.

B. The Technical Report to the Secretary of Transportation on a National Approach to Augmented GPS Services (December 1994) recommended implementation of a Coast Guard-like system for use in land navigation and positioning applications in those sections of the nation not currently covered by the USCG Maritime DGPS Service. To accomplish this, the USDOT formed the DGPS Policy and Implementation Team under an Executive Steering Group. The NDGPS Policy and Implementation Team found that the current most viable GPS augmentation option which could satisfy most surface applications needs is the DGPS operated to the USCG DGPS Navigation Service Broadcast Standard, Commandant Instruction M16577.1.

C. During its study, the NDGPS Policy and Implementation Team learned of the USAF plans to decommission the Ground Wave Emergency Network (GWEN). GWEN provides emergency communications using fifty-three transmitter sites located across the continental U.S. The Single Channel Anti-Jam Man Portable (SCAMP) is to replace GWEN. The GWEN sites operate on frequencies near the USCG DGPS radiobeacon frequencies. During 1997, the USAF loaned the GWEN site located near Appleton, Washington, to the FRA and USCG to be converted to a USCG DGPS station as a proof of concept. The Appleton station provided DGPS coverage to the navigable portions of the Columbia and Snake Rivers and the Positive Train Separation test-bed supported by the FRA. Based on the successful results of this prototype, the NDGPS Policy and Implementation Team determined that conversion of GWEN sites to civil DGPS use provided a cost-avoidance opportunity in the establishment of the NDGPS. The team presented its results to the Executive Steering Group on August 14, 1997. The consensus of the Executive Steering Group was to expand the Coast Guard's DGPS into a nationwide system.

D. On October 27, 1997, Section 346 of Public Law 105-66 (Attachment A) authorized the USDOT to establish, operate, and manage the NDGPS including taking receipt of necessary GWEN sites and equipment. A coverage plan was developed to meet FRA requirements for use in its train-control initiatives. To complete the required coverage under this plan, many of the GWEN sites will be converted at their current locations, from other GWEN sites the equipment will be moved to locations better suited for optimum coverage to the nation, and some non-GWEN stations will be established.

E. The NDGPS project plans to install 65 to 75 sites under the scope of this agreement. The final NDGPS will have 125 to 135 sites, including the current Coast Guard and Army Corps of Engineers sites and the sites installed under this MOA. These sites will be compatible with, and integrated into, the Maritime DGPS Service operated by the Coast Guard and the Continuously Operating Reference Station (CORS) network of the National Geodetic Survey. Plans based upon historical Congressional appropriations for the NDGPS project a completion date in Calendar Year 2003. The expected system life cycle is fifteen years.

III. IMPLEMENTATION AND FUNDING:

A. Implementation of this MOA will be performed by the appropriate elements of the USAF, USACE, NOAA, and participating USDOT agencies. For the USAF the responsible organization is the USAF Headquarters Air Combat Command. For NOAA the responsible organization is the National Geodetic Survey (NGS). For the USACE the responsible organizations are the individual field offices in coordination with their chain of command. For the FRA the responsible organization is the Office of the Associate Administrator for Railroad Development. For the FHWA the responsible organization is the Office of the Associate Administrator for Research and Development. For the USCG the responsible organization is the Director of Operations Policy.

B. The NDGPS Policy and Implementation Team will conduct overall coordination of the NDGPS. The functions of the NDGPS Policy and Implementation Team are: to coordinate interagency actions affecting the NDGPS; to serve as a forum to raise, discuss, and resolve issues concerning the NDGPS; to monitor compliance with interagency memoranda of agreement regarding the NDGPS; and to advise agencies as appropriate. The team will consist of members from each of the organizations that are signatories to this agreement. Members will be designated in writing and each will be responsible for coordinating his or her organization's activities and reporting those activities to the team. The team chairman will be the representative from the USDOT OST.

C. The FRA, in coordination with the NDGPS Policy and Implementation Team and the USCG, will submit and defend funding requests for the full cost of providing the NDGPS. These requests are to include implementation, operation, maintenance, and eventual decommissioning, including but not limited to real property disposal and environmental remediation, and the execution of the specified activities below. Agencies with funding requirements are required to submit their requirements and cost estimates to the FRA in sufficient time to enter the Congressional budget cycle. The FRA shall specify submission dates as necessary.

D. No fund transfers are required to or from the USAF under this MOA. Agencies will ensure adequate funding is available via direct appropriation, transfer, or reimbursable agreement prior to undertaking work associated with their responsibilities under this MOA. The Coast Guard will ensure adequate funding is available from all other agencies and/or Departments via direct appropriation, transfer, or reimbursable agreement prior to undertaking work associated with their responsibilities under this MOA. Agencies shall be responsible for compliance with all laws, regulations, and federal policies for obligation and management of funds as applicable.

E. The Secretary of Transportation's authority to establish, operate, and manage the NDGPS pursuant to Section 346 of Public Law 105-66 is delegated to the USCG in a Federal Regulation issued to Part I of Title 49 of the Code of Federal Regulations (CFR). The delegation to the USCG does not include responsibility for determining the Federal requirements for the NDGPS. This authority is delegated to the FRA. The delegation to the USCG also does not include the responsibility for acting as lead USDOT agency for matters relating to the National Environmental Policy Act (NEPA). The FHWA is delegated authority for matters relating to NEPA and the NDGPS. Neither the delegation addressed here nor this MOA requires the Coast Guard to fund the NDGPS; rather the FRA is responsible for funding the NDGPS as per paragraph III.C.

F. The parties agree that the FHWA will be the lead agency, as defined in 40 CFR 1501.5, for NEPA compliance related to the establishment of the NDGPS. The parties agree to use the FHWA implementing regulations (23 CFR 771) for environmental impact analysis and procedural compliance with NEPA. The FHWA will prepare NEPA documents for the entire NDGPS program as well as for specific sites and will distribute copies of all NEPA documents to the cooperating agencies participating in NDGPS deployment. The FHWA may request that cooperating agencies provide information and analysis in areas of the cooperating agencies special expertise. The FHWA will give the technical and environmental reviewers of each of the cooperating agencies the opportunity to review and comment on the programmatic and site-specific NEPA documents for technical accuracy and adequacy at the preliminary draft stage (i.e., prior to release of the draft document to the public) and at the preliminary final document stage (i.e., prior to release of the final document to the public).

IV. <u>RESPONSIBILITIES OF THE PARTIES</u>:

The parties agree that they will carry out their respective responsibilities listed herein and those which they subsequently agree to be responsible for in any supplements to this agreement.

A. **OFFICE OF THE SECRETARY OF TRANSPORTATION** will perform, or arrange to have performed, the following actions:

1. Designate a representative to serve as chairperson of the NDGPS Policy and Implementation Team.

2. Coordinate interagency funding and seek transfer authority as appropriate as determined through the budget process.

3. Resolve issues, as required, including those associated with the early termination of a party's participation in this agreement, if need be, as indicated in Section V.

4. Coordinate the decommissioning of the NDGPS at the appropriate time.

B. **UNITED STATES AIR FORCE, HEADQUARTERS AIR COMBAT COMMAND (HQ ACC)** will perform, or arrange to have performed, the following actions:

1. Provide two points of contact, a primary and an alternate, to provide for a GWEN Program liaison to the NDGPS Policy and Implementation Team.

2. Continue as the lead command within the USAF for coordination of GWEN and GWEN-related issues.

3. Identify specific GWEN sites and spare hardware available for transfer during the GWEN decommissioning phases. The NDGPS project will bear the cost of deinstallation, shipping and storage of spare hardware for installation at new NDGPS broadcast locations. NDGPS may utilize the following GWEN hardware components:

   a) 299-foot guyed antenna with hazard lighting system,

   b) Backup Power Group (BUPG),

   c) Electronics equipment shelter, and

   d) Antenna Tuning Unit (ATU)

4. Coordinate with U.S. Strategic Command (STRATCOM) on issues concerning total GWEN system performance as a result of removing sites from the network.

5. Remove and dispose of the GWEN equipment not required for NDGPS use at an existing GWEN broadcast site prior to site transfer for NDGPS use. The U.S. Coast Guard, as advised by the NDGPS Policy and Implementation Team, will identify GWEN equipment not required.

6. Coordinate with the USACE for the transfer to the USDOT of real property accountability for the GWEN sites that will be converted to NDGPS broadcast sites.

7. Retain responsibility for all GWEN properties and equipment not transferred for use by the NDGPS service.

8. Complete baseline environmental assessments for each GWEN site being transferred for NDGPS use. The assessments will include a survey that identifies the potential for contamination of the properties and an inventory of any protected areas or species located at or adjacent to the GWEN site. Provide one copy of the baseline environmental assessment reports to the USDOT OST representative.

C. **U.S. ARMY CORPS OF ENGINEERS** will perform, or arrange to have performed, on a reimbursable basis and subject to the availability of funds made available via a separate written agreement between the USACE and the FRA, the following actions:

1. Provide two points of contact, a primary and an alternate, to provide for agency liaison on real estate and other engineering or construction management services to the NDGPS Policy and Implementation Team.

2. Provide real-estate services and property-management services including, but not limited to, real property, planning, appraisal, acquisition, leasing, management, and disposal requested by the USCG or the NDGPS Policy and Implementation Team. Site locations for any new NDGPS broadcast sites will be identified by the NDGPS Policy and Implementation Team with such input from the USACE as may be requested.

3. Provide engineering, design, environmental assessment, maintenance, or construction management services requested by the USCG or the NDGPS Policy and Implementation Team.

D. **FEDERAL RAILROAD ADMINISTRATION** will perform, or arrange to have performed, subject to the availability of funds, the following actions:

1. Designate two agency representatives, a primary and an alternate, for participation on the NDGPS Policy and Implementation Team.

2. Provide liaison to U.S. railroad owners and operators regarding the NDGPS and provide their documented NDGPS requirements to the NDGPS Policy and Implementation Team.

3. Coordinate with the USCG to develop NDGPS notification methods and lists to notify NDGPS users of any service outages and planned service outages.

4. Complete the NDGPS operational requirements document (ORD) and submit it to the NDGPS Policy and Implementation Team for review prior to final approval by the FRA Administrator.

5. In coordination with the NDGPS Policy and Implementation Team and the USCG, submit and defend funding requests for implementation, operation, maintenance, and decommissioning of the NDGPS.

6. Verify that NDGPS broadcast coverage and performance is meeting the requirements of railroad users.

7. Acquire commercial engineering services as required to complement the USCG's installation responsibilities. Commercial services may also be used to deinstall, ship, store, and refurbish, as needed, spare GWEN hardware which is moved to a new location for reuse as a NDGPS site.

E. **FEDERAL HIGHWAY ADMINISTRATION** will perform, or arrange to have performed, on a reimbursable basis and subject to the availability of funds made available via a separate written agreement between FHWA and the FRA, the following actions:

1. Identify an agency representative for participation on the NDGPS Policy and Implementation Team. The total staff months shall not exceed four per year.

2. Complete the appropriate NEPA environmental impact analyses and documentation and any environmental requirements identified during the NEPA process for the NDGPS service. NEPA-process documentation will be submitted to the NDGPS Policy and Implementation Team.

3. Provide liaison to state transportation agencies regarding the NDGPS.

4. Coordinate with the USCG to develop NDGPS notification methods and lists to notify NDGPS users of any service outages and planned service outages.

5. Refine the design for the broadcast site network to provide for the required service coverage. This specifically involves:

   a) Selecting approximate site locations based on signal coverage needs.

   b) Selecting a candidate broadcast frequency in the marine radiobeacon band and broadcast range for each site.

   c) Providing preliminary coordination of the selected candidate frequencies and ranges with the radiobeacon frequency managers of the Federal

Aviation Administration (FAA) and Canada to ensure noninterference. Formal coordination will be performed by the USCG.

d) Coordinating with the FAA to move interfering aerobeacons to new frequencies. Formal coordination will be performed by the USCG. Funding for the cost of changing aerobeacon frequencies will be in accordance with Section III of this MOA.

6. Assist in coordination efforts with state and local governments to identify candidate sites suitable to support NDGPS broadcast facilities in the approximate locations selected that do not have existing GWEN broadcast facilities. Generic NDGPS site selection criteria will be provided by the USCG.

7. Provide management for the coverage measurement of each NDGPS broadcast site after each site becomes operational. If there are any unexpected coverage gaps or localized interference problems, provide OST with data, supporting rationale, and recommendations on how to resolve the issue.

F. **U.S. COAST GUARD** will perform, or arrange to have performed, on a reimbursable basis and subject to the availability of funds made available via a separate written agreement between USCG and the FRA, the following actions:

1. Designate two agency representatives, a primary and alternate, for participation on the NDGPS Policy and Implementation Team.

2. Acquire administrative control over and maintain real property, including land and improvements, as may be necessary to establish, maintain, and operate the NDGPS.

3. Provide maritime safety requirements for NDGPS to the NDGPS Policy and Implementation Team.

4. Furnish technical expertise and support as required to ensure that each NDGPS broadcast site installation will meet USCG DGPS broadcast signal specifications. This may include, but is not limited to, providing:

   a) Generic DGPS broadcast site selection criteria;

   b) Engineering specifications, drawings, and instructions for the installation of the same type of DGPS equipment and broadcast transmitter as used in the USCG's Maritime DGPS service;

   c) Technical advice on alternative engineering solutions to environmental concerns that may be found during site assessments;

d) Quality assurance reviews of site design and installation plans;

e) Engineering teams to visit candidate sites as required for final site selection;

f) Engineering team visits to the NDGPS sites as required to select and mark the placement of the two required GPS antenna mast locations;

g) Installation quality assurance visits to check and certify the NDGPS broadcast sites prior to initial operation.

5. Procure additional DGPS equipment to support installations at NDGPS broadcast sites. Equipment procurement by the USCG will be standard USCG DGPS equipment; i.e., GPS reference stations with antennas, DGPS integrity monitors with antennas, radiobeacon transmitter, network interface unit, and uninterruptible power supply. This equipment would be stored and maintained by the USCG DGPS Depot until issued for installation.

6. Arrange for construction and/or equipment installation as required at the NDGPS control station and at each NDGPS broadcast site.

7. Provide operational control and monitoring of NDGPS transmissions. This would require the following actions:

a) Staff the NDGPS control station with trained personnel;

b) Establish control communication service between the NDGPS control station and each NDGPS broadcast site;

c) Initiate requests for immediate and priority technical responses as necessary to meet site operations to USCG DGPS Broadcast Standards;

d) Coordinate with FRA and FHWA to develop NDGPS notification methods and lists;

e) Notify NDGPS users of any service outages and planned service outages;

f) Coordinate with OST, FRA, FHWA, NOAA, and USACE, on any issues or concerns affecting the operations, maintenance, or safety of the NDGPS;

g) Develop the NDGPS Concept of Operations to meet the NDGPS operational requirements and submit it to the NDGPS Policy and Implementation Team for approval.

8. Provide depot support of the GPS reference stations, DGPS integrity monitors, radiobeacon transmitters, network interface units, and uninterruptible power supplies. The USCG ability to provide this depot support would be dependent on NDGPS use of standard USCG DGPS equipment.

9. Provide electronics system life-cycle support through the USCG DGPS System Management and Engineering Facility (SMEF). The USCG ability to provide SMEF support is dependent on NDGPS use of standard USCG DGPS equipment.

10. Contract or provide organizational/intermediate level support which includes casualty response and preventive maintenance for NDGPS broadcast sites.

11. As frequency manager:

a) Obtain frequency and range authorization for NDGPS transmissions for each broadcast site. USCG action to gain authorization will be advised by a network frequency plan from the NDGPS Policy and Implementation Team.

b) Develop radio frequency interference protection standards for NDGPS.

12. In cooperation with the Department of Defense, ensure that the use of the NDGPS is denied to any enemy of the United States.

13. In cooperation with industries, universities, and state governments, develop standards for the NDGPS.

14. At the request of OST, develop plans and prepare funding estimates required to perform the following additional provisions of Public Law 105-66, Section 346:

a) In cooperation with industries, universities, and state governments:

(1) Investigate improvements to the NDGPS;

(2) Sponsor the development of new applications for the NDGPS.

b) Provide for the continual upgrading of the NDGPS to improve the performance of the system and to address the needs of the federal, state and local governments and the general public.

15. At the end of the life of the system, or as necessary, dispose of standard USCG DGPS equipment; i.e., GPS reference stations with antennas, DGPS integrity monitors with antennas, radiobeacon transmitter, network interface unit, and uninterruptible power supply.

G. **NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION (NOAA)** will perform, or arrange to have performed, on a reimbursable basis and subject to the availability of funds made available via a separate written agreement between NOAA and the FRA, the following actions:

1. Identify two agency representatives, a primary and an alternate, for participation on the NDGPS Policy and Implementation Team.

2. Provide surveying and shipping industry requirements for NDGPS to the NDGPS Policy and Implementation Team.

3. Establish and maintain coordinates in the official datum of the United States for each NDGPS broadcast site's reference station. The official datum, at the time of this MOA is North American Datum of 1983 (NAD 83).

4. Integrate each NDGPS reference station into the Continuously Operating Reference Stations (CORS) system.

5. Coordinate the investigation of the use of NDGPS reference stations in the Integrated Precipitable Water Vapor System with NOAA's Forecast Systems Laboratory. If successful, add Integrated Precipitable Water Vapor System equipment to NDGPS reference stations as necessary.

V. MODIFICATION AND TERMINATION:

A. This MOA will be reviewed as deemed necessary by any party. It is subject to modification at any time upon joint written approval of all parties. Supplements to this MOA are allowed between all or some of the parties to further clarify agreements made herein or to address additional aspects of the project not foreseen in this MOA. Signatory level may be as deemed appropriate by the participants in the supplement. At a minimum, the points of contact of the agencies participating in this MOA must be informed of the supplement and given a copy when it is made effective. The Chairman of the Policy and Implementation Team shall maintain this MOA and any of its supplements.

B. The participation in this agreement by any agency may be terminated by written notice to the other parties 180 days prior to the desired termination. Agencies seeking termination that have unfulfilled responsibilities under the MOA, such as disposal of equipment or property, must arrange for those responsibilities to be completed, to the reasonable satisfaction of all the remaining parties in the agreement. In the event that an agency wishes to terminate their participation in this agreement, but cannot reasonably satisfy one or more of the remaining parties, the agency seeking termination may forward an appeal to the Deputy Assistant Secretary for Transportation Policy for resolution.

VI. OTHER PROVISIONS:

A. Any activities undertaken by the parties pursuant to this MOA are subject to the availability of appropriated funds and proper authorization.

B. Nothing herein is intended to conflict with current directives of any participating agency. If the terms of this MOA are inconsistent with existing directives of any of the parties entering into the MOA, then those portions of the MOA which are determined to be inconsistent shall be invalid. The remaining terms and conditions that are not affected by inconsistency shall remain in full force and effect. At the first opportunity for review of the MOA, such changes as deemed necessary will be accomplished by either an amendment to this MOA or by entering into a new agreement, whichever is deemed expedient and in the interests of all parties.

VII. EFFECTIVE DATE:

A. The effective date of this agreement shall be the last date of the last signature affixed on the following page.

VIII. EXECUTION OF AGREEMENT:

A. This agreement is being executed in seven (7) counterpart originals.

Appendix G – Assessment Study Statement of Work

Background:

The NDGPS system was developed to provide an extension of the Coast Guard Maritime DGPS network in order to achieve nationwide GPS differential signal coverage for inland applications. The NDGPS was authorized in Public Law 105-66 § 346. The planned network of NDGPS sites has not been completed.

Although there are no concrete estimates of the number NDGPS users by function, there are existing private and government sector users of NDGPS, representing a variety of applications that provide economic, productivity, safety and security, environmental, and other benefits. Users also may be planning new applications that will rely on NDGPS. The different user groups reflect a number of segments of government and industry, including public and private users in transportation, public safety, agriculture, construction, and other industrial and commercial sectors.

A comprehensive review is required to provide decision-makers with updated information on the NDGPS system, its current and potential applications, and the associated benefits and costs of continuing NDGPS build-out and operations, in order to make informed decisions on the future direction of the Federal NDGPS program.

Task Objective:

The objective of this task is to develop an objective assessment of:

- the current status of the NDGPS system;
- current and projected NDGPS user base and applications, with the primary emphasis on assessing transportation system requirements; and
- economic costs and benefits associated with continued NDGPS deployment and operations.

This assessment must also assess the potential impact of ceasing NDGPS operations on current and projected NDGPS users and applications, and the costs and benefits of ceasing operations.

Scope of Work:

The contractor shall perform the following tasks:

- Task 1 – Document Private Sector Users and Applications
- Task 2 – Document Government Sector Users and Applications
- Task 3 – Document Supplier Base and Other Factors Affecting Future Directions
- Task 4 – Document NDGPS Benefits
- Task 5 – Prepare Final Assessment Report

These tasks are described below.

Task 1 – Document Private Sector Users and Applications

The contractor shall be provided an overview that documents the NDGPS system. The contractor shall document current private sector users and their applications of NDGPS signals, and known or proposed future applications. Future technology that will make use of NDGPS within the private sector shall also be documented. In addition to a survey of cross-sector applications, transportation systems requirements for NDGPS shall be fully scoped and highlighted. The contractor shall document the PNT needs/requirements of the identified users and applications, and identify the characteristics and attributes of NDGPS that make it ideal for those applications, vs. alternate PNT information sources. The contractor shall determine if NDGPS meets the user requirements, or if NDGPS systems improvements will be needed to meet requirements.

Task 2 – Document Government Sector Users and Applications

The contractor shall document current and proposed Government sector users of NDGPS and their applications. This task shall address Federal, state, and local agencies. The contractor shall interview selected Government agencies and provide specific case studies of NDGPS applications, benefits associated with the applications, and potential mission impacts of the loss of this capability. Again, in addition to documenting other governmental applications, transportation systems requirements shall be fully scoped and highlighted. The contractor shall document the PNT needs/requirements of the identified users and applications, and identify the characteristics and attributes of NDGPS that make it ideal for those applications, vs. alternate PNT information sources. The contractor shall determine if NDGPS meets the user requirements, or if NDGPS systems improvements will be needed to meet requirements.

Where state and local government users are consulted, the contractor shall document potential financial instruments that could support cost sharing.

As part of this effort, the contractor shall document:

- System user expectations in reference to U.S. Government commitments in providing NDGPS;
- Modernization of GPS and its effect on the need for NDGPS;
- Alternative sources of Positioning, Navigation and Timing (PNT) information that may meet user requirements for applications currently served by NDGPS.

Task 3 – Document Supplier Base and Other Factors Affecting Future Directions

The contractor shall research other entities that are affected by the NDGPS program, including product suppliers. Because of American technological leadership in PNT, various worldwide public and private sector entities base applications development and production planning on U.S. Government planning; therefore. the international economic implications of NDGPS technology and product base decisions will also be identified in brief.

Task 4 – Document NDGPS Benefits

The contractor shall identify and document the productivity, economic, quality of life, safety of life, and other benefits associated with NDGPS that cannot be foregone or otherwise met by other cost effective means. Various categories of benefits shall be identified relevant to the private and government user applications identified in Tasks 2 and 3. Estimates of the dollar values associated with these benefits will be developed. The international economic implications of NDGPS technology and product base will also be identified.

Task 5 – Prepare Final Assessment Report

The contractor shall prepare a final assessment report, described below, that documents the results of Tasks 1 through 5, plus other factors identified during the course of the project that contribute to an overall assessment of the status of the NDGPS project, the current and projected applications of NDGPS, and issues associated with further NDGPS implementation and operation, as well as issues associated with ceasing NDGPS operations. The Final Assessment Report must address:

- whether critical verified transportation requirements exist for the NDGPS system, and
- which user base among all sectors is the primary beneficiary of the NDGPS system.

GFI:

The Government will provide a system overview for incorporation into the final report that addresses:

- The mission of the NDGPS program;
- NDGPS system architecture;
- Original site deployment plan and current deployments;
- System performance requirements;
- Organizational responsibilities.

Key points of contact within the Federal government for this information will be provided.

Deliverables:

The deliverable for this project is an NDGPS assessment report. This report shall document:

- Private sector users and applications;
- Government sector users and applications;
- NDGPS benefits; and
- Summary assessment of NDPGS applications, future requirements, and impact of loss of system.

Timeline

- Kickoff within two weeks of task establishment.
- Periodic project review briefings every six to eight weeks.
- Interim project report due April 1.
- Final project review at completion of effort (date to be negotiated).

Appendix H – 2004 PNT Policy Fact Sheet

U.S. SPACE-BASED POSITIONING, NAVIGATION, AND TIMING POLICY

December 15, 2004

FACT SHEET

The President authorized a new national policy on December 8, 2004 that establishes guidance and implementation actions for space-based positioning, navigation, and timing programs, augmentations, and activities for U.S. national and homeland security, civil, scientific, and commercial purposes. This policy supersedes Presidential Decision Directive/National Science and Technology Council-6, U.S. Global Positioning System Policy, dated March 28, 1996.

I. Scope and Definitions

This policy provides guidance for: (1) development, acquisition, operation, sustainment, and modernization of the Global Positioning System and U.S.-developed, owned and/or operated systems used to augment or otherwise improve the Global Positioning System and/or other space-based positioning, navigation, and timing signals; (2) development, deployment, sustainment, and modernization of capabilities to protect U.S. and allied access to and use of the Global Positioning System for national, homeland, and economic security, and to deny adversaries access to any space-based positioning, navigation, and timing services; and (3) foreign access to the Global Positioning System and United States Government augmentations, and international cooperation with foreign space-based positioning, navigation, and timing services, including augmentations.

For purposes of this document:

- "Interoperable" refers to the ability of civil U.S. and foreign space-based positioning, navigation, and timing services to be used together to provide better capabilities at the user level than would be achieved by relying solely on one service or signal;

- "Compatible" refers to the ability of U.S. and foreign space-based positioning, navigation, and timing services to be used separately or together without interfering with each individual service or signal, and without adversely affecting navigation warfare; and

- "Augmentation" refers to space and/or ground-based systems that provide users of space-based positioning, navigation, and timing signals with additional information that enables users to obtain enhanced performance when compared to the un-augmented space-based signals alone. These improvements include better accuracy, availability, integrity, and reliability, with independent integrity monitoring and alerting capabilities for critical applications.

II. Background

Over the past decade, the Global Positioning System has grown into a global utility whose multi-use services are integral to U.S. national security, economic growth, transportation safety, and homeland security, and are an essential element of the worldwide economic infrastructure. In the year 2000, the United States recognized the increasing importance of the Global Positioning System 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 the Global Positioning System have continued to multiply and their importance has increased significantly. Services dependent on Global Positioning System 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 U.S. critical infrastructure.

While the growth in civil and commercial applications continues, the positioning, navigation, and timing information provided by the Global Positioning System remains critical to U.S. national security, and its applications are integrated into virtually every facet of U.S. military operations. United States and allied military forces will continue to rely on the Global Positioning System military services for positioning, navigation, and timing services.

The continuing growth of services based on the Global Positioning System presents opportunities, risks, and threats to U.S. national, homeland, and economic security. The widespread and growing dependence on the Global Positioning System of military, civil, and commercial systems and infrastructures has made many of these systems inherently vulnerable to an unexpected interruption in positioning, navigation, and/or timing services. In addition, whether designed for military capabilities or not, all positioning, navigation, and timing signals from space and their augmentations provide inherent capabilities that can be used by adversaries, including enemy military forces and terrorist groups. Finally, emerging foreign space-based positioning, navigation, and timing services could enhance or undermine the future utility of the Global Positioning System.

The United States must continue to improve and maintain the Global Positioning System, augmentations, and backup capabilities to meet growing national, homeland, and economic security requirements, for civil requirements, and to meet commercial and scientific demands. In parallel, we must continue to improve capabilities to deny adversary access to all space-based positioning, navigation, and timing services, particularly including services that are openly available and can be readily used by adversaries and/or terrorists to threaten the security of the United States. In addition, the diverse requirements for and multiple applications of space-based positioning, navigation, and timing services require stable yet adaptable policies and management mechanisms. The existing management mechanisms for the Global Positioning System and its augmentations must be modified to accommodate a multi-use approach to program planning, resource allocation, system development, and operations. Therefore, the United States Government must improve the policy and management framework governing the

Global Positioning System and its augmentations to support their continued ability to meet increasing and varied domestic and global requirements.

III. Goals and Objectives

The fundamental goal of this 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. To achieve this goal, the United States Government shall:

- Provide uninterrupted access to U.S. space-based global, precise positioning, navigation, and timing services for U.S. and allied national security systems and capabilities through the Global Positioning System, without being dependent on foreign positioning, navigation, and timing services;

- Provide on a continuous, worldwide basis civil space-based, positioning, navigation, and timing services free of direct user fees for civil, commercial, and scientific uses, and for homeland security through the Global Positioning System and its augmentations, and provide open, free access to information necessary to develop and build equipment to use these services;

- Improve capabilities to deny hostile use of any space-based positioning, navigation, and timing services, without unduly disrupting civil and commercial access to civil positioning, navigation, and timing services outside an area of military operations, or for homeland security purposes;

- Improve the performance of space-based positioning, navigation, and timing services, including more robust resistance to interference for, and consistent with, U.S. and allied national security purposes, homeland security, and civil, commercial, and scientific users worldwide;

- Maintain the Global Positioning System as a component of multiple sectors of the U.S. Critical Infrastructure, consistent with Homeland Security Presidential Directive-7, Critical Infrastructure Identification, Prioritization, and Protection, dated December 17, 2003;

- Encourage foreign development of positioning, navigation, and timing services and systems based on the Global Positioning System. Seek to ensure that foreign space-based positioning, navigation, and timing systems are interoperable with the civil services of the Global Positioning System and its augmentations in order to benefit civil, commercial, and scientific users worldwide. At a minimum, seek to ensure that foreign systems are compatible with the Global Positioning System and its augmentations and address mutual security concerns with foreign providers to prevent hostile use of space-based positioning, navigation, and timing services; and

- Promote the use of U.S. space-based positioning, navigation, and timing services and capabilities for applications at the Federal, State, and local level, to the maximum practical extent.

IV. Management of Space-Based Positioning, Navigation, and Timing Services

This policy establishes a permanent National Space-Based Positioning, Navigation, and Timing Executive Committee. The Executive Committee will be co-chaired by the Deputy Secretaries of the Department of Defense and the Department of Transportation or by their designated representatives. Its members will include representatives at the equivalent level from the Departments of State, Commerce, and Homeland Security, the Joint Chiefs of Staff, the National Aeronautics and Space Administration, and from other Departments and Agencies as required. Components of the Executive Office of the President, including the Office of Management and Budget, the National Security Council staff, the Homeland Security Council staff, the Office of Science and Technology Policy, and the National Economic Council staff, shall participate as observers to the Executive Committee. The Chairman of the Federal Communications Commission shall be invited to participate on the Executive Committee as a Liaison. The Executive Committee shall meet at least twice each year. The Secretaries of Defense and Transportation shall develop the procedures by which the Committee shall operate.

The Executive Committee shall make recommendations to its member Departments and Agencies, and to the President through the representatives of the Executive Office of the President. In addition, the Executive Committee will advise and coordinate with and among the Departments and Agencies responsible for the strategic decisions regarding policies, architectures, requirements, and resource allocation for maintaining and improving U.S. space-based positioning, navigation, and timing infrastructures, including the Global Positioning System, its augmentations, security for these services, and relationships with foreign positioning navigation, and timing services. Specifically, the Executive Committee shall:

- Ensure that national security, homeland security, and civil requirements receive full and appropriate consideration in the decision-making process and facilitate the integration and deconfliction of these requirements for space-based positioning, navigation, and timing capabilities, as required;

- Coordinate individual Departments' and Agencies' positioning, navigation, and timing program plans, requirements, budgets, and policies, and assess the adequacy of funding and schedules to meet validated requirements in a timely manner;

- Ensure that the utility of civil services exceeds, or is at least equivalent to, those routinely provided by foreign space-based positioning, navigation, and timing services;

- Promote plans to modernize the U.S. space-based positioning, navigation, and timing infrastructure, including: (1) development, deployment, and operation of new and/or improved national security and public safety services when required and to the maximum practical extent; and (2) determining the apportionment of requirements between the Global Positioning System and its augmentations, including consideration of user equipment;

- Review proposals and provide recommendations to the Departments and Agencies for international cooperation, as well as spectrum management and protection issues; and

- Establish a space-based Positioning, Navigation, and Timing Advisory Board. The board shall be comprised of experts from outside the United States Government, and shall be chartered as a Federal Advisory Committee.

The Executive Committee shall establish the National Space-Based Positioning, Navigation, and Timing Coordination Office. This office shall provide the staff functions for the Executive Committee. It shall be led by a full-time Director chosen by, and reporting to the Executive Committee, and shall include a cadre of full-time staff provided by Departments and Agencies represented on the Executive Committee. The Executive Committee shall determine the resources for the National Space-Based Positioning, Navigation, and Timing Coordination Office, including funding, location, staffing, and composition, consistent with the direction of this policy.

The National Space-Based Positioning, Navigation, and Timing Coordination Office shall serve as the Secretariat for the Executive Committee and shall perform those functions delegated by the Executive Committee. Departments and Agencies shall provide appropriate information to the National Space-Based Positioning, Navigation, and Timing Coordination Office to ensure interagency transparency about positioning, navigation, and timing programs, policies, budgets, and activities that might affect mutual interests or interagency dependencies. The Interagency Global Positioning System Executive Board is hereby disestablished, and the Executive Committee or the National Space-Based Positioning, Navigation, and Timing Coordination Office, as appropriate, shall assume its functions as defined in the Positioning, Navigation, and Timing Executive Committee Charter, consistent with the direction provided in this policy.

The Executive Committee shall advise and coordinate the interdepartmental resource allocation for the Global Positioning System and it augmentations on an annual basis. The Secretary of Defense shall have primary responsibility for providing resources for development, acquisition, operation, sustainment, and modernization of the Global Positioning System. The Secretary of Transportation shall provide resources to the Secretary of Defense for assessment, development, acquisition, implementation, operation, and sustainment of additional designated Global Positioning System civil capabilities beyond the second and third civil signals already contained in the current Global Positioning System program. Global Positioning System civil signal performance monitoring, augmentations, and other unique positioning, navigation, and timing capabilities will be funded by the agency or agencies requiring those services or capabilities, including out-year procurement and operations costs. Any new technical features proposed and funded by the civil agencies shall not degrade or displace existing or planned national security functions of the system. If the Executive Committee recommends that the availability of Global Positioning System capabilities should be accelerated, the Executive Committee will make recommendations regarding the resources required to accelerate those capabilities. Resource issues will be resolved during the regular budget process.

The details of the cost sharing between: (1) the Department of Defense and the Department of Transportation, for the Global Positioning System; and (2) Departments and Agencies sponsoring augmentations, and/or unique or accelerated capabilities, shall be outlined in a Five-Year National Space-Based Positioning, Navigation, and Timing Plan, consistent with the guidance provided in this policy.

V. Foreign Access to U.S. Space-based Positioning, Navigation, and Timing Capabilities

Any exports of U.S. positioning, navigation, and timing capabilities covered by the United States Munitions List or the Commerce Control List will continue to be licensed pursuant to the International Traffic in Arms Regulations or the Export Administration Regulations, as appropriate, and in accordance with all existing laws and regulations.

As a general guideline, export of civil or other non-United States Munitions List space-based positioning, navigation and timing capabilities that are currently available or are planned to be available in the global marketplace will continue to be considered favorably. Exports of sensitive or advanced positioning, navigation, and timing information, systems, technologies, and components will be considered on a case-by-case basis in accordance with existing laws and regulations, as well as relevant national security and foreign policy goals and considerations. In support of such reviews, the Secretary of State, in consultation with the Secretaries of Defense, Commerce, and Energy, the Administrator of the National Aeronautics and Space Administration, and the Director of Central Intelligence, shall modify and maintain the Sensitive Technology List directed in U.S. Commercial Remote Sensing Space Policy, dated April 25, 2003, including those technology items or areas deemed sensitive for positioning, navigation and timing applications. The Secretaries of State and Commerce shall use the list in the evaluation of requests for exports.

VI. Agency Roles and Responsibilities

Departments and Agencies shall allocate the resources required to fulfill the objectives of this policy. Nothing in this policy shall diminish the operational and budgetary authorities of the Departments and Agencies.

The Secretary of Defense shall:

- Have responsibility for development, acquisition, operation, security, and continued modernization of the Global Positioning System, while facilitating appropriate civil and homeland security Department and Agency representation and participation in these activities, and any decisions that affect civil and homeland security equities;

- Develop, acquire, operate, realistically test, evaluate, and maintain navigation warfare capabilities and other capabilities required to:

    - Effectively utilize the Global Positioning System services in the event of adversary jamming or other interference;

  - Deny to adversaries position, navigation, and timing services from the Global Positioning System, its augmentations, and/or any other space-based position, navigation, and timing systems without unduly disrupting civil, commercial, and scientific uses of these services outside an area of military operations, or for homeland security purposes; and

  - Identify, locate and mitigate, in coordination with Departments and Agencies, as appropriate, any interference on a global basis that adversely affects use of the Global Positioning System for military operations;

- Ensure the earliest operational availability for modernized military and navigation warfare capabilities;

- Train, equip, test, and exercise U.S. military forces and national security capabilities in operationally realistic conditions that include denial of the Global Positioning System. In cooperation with the Secretaries of Transportation and Homeland Security, and as appropriate, with the Secretary of State, develop guidelines that facilitate these activities and Navigation Warfare training, testing, demonstrations, and exercises without unduly disrupting or degrading homeland security and civil services and operations, either internationally or domestically;

- Promote use of Global Positioning System national security services to allied military forces to facilitate interoperability between U.S. and allied forces and capabilities, and to maintain their use as the pre-eminent military space-based positioning, navigation, and timing capability;

  - Consistent with the guidance in Section V of this policy, make Global Positioning System national security services, user equipment, information, and technology available for use by allied military forces; and

  - Work with allies to monitor access to national security services and user equipment, in order to limit the potential for adversaries to use these capabilities against U.S. and allied military forces;

- Maintain the commitment to discontinue the use of the feature known as Selective Availability designed to degrade globally the Standard Positioning Service of the Global Positioning System;

- Facilitate access to appropriate levels of national security services and user equipment at the Federal level to meet critical requirements for emergency response and other homeland security purposes, and, on an exceptional basis, for civil purposes, including state or local emergency response;

- Develop improved, dedicated national security positioning, navigation, and timing capabilities, including but not limited to more diverse, flexible, and capable signals and services;

- Maintain lead responsibility for negotiating with foreign defense organizations any cooperation regarding access to or information about Global Positioning System military services; and
- In cooperation with other Departments and Agencies, assess the utility and feasibility of hosting secondary payloads on Global Positioning System satellites, including, but not limited to those intended to enhance global search and rescue capabilities for all users. No secondary payload may adversely affect the performance, schedule, or cost of the Global Positioning System, its signals or services. Resources required for the assessment, development, acquisition, integration, and operation of secondary payloads shall be the responsibility of the sponsoring agency or agencies.

The Secretary of Transportation shall:

- Have lead responsibility for the development of requirements for civil applications from all United States Government civil Departments and Agencies;
- Ensure, in cooperation with the Secretary of Defense and the Secretary of Homeland Security, the performance monitoring of U.S. civil space-based positioning, navigation, and timing services;
- Consistent with the guidance in Section V of this policy, and in coordination with the Secretary of Commerce and the Secretary of State, facilitate: (1) foreign development of civil positioning, navigation, and timing services and systems based on the Global Positioning System; and (2) international participation in the development of civil applications for U.S. space-based positioning, navigation, and timing services;
- Ensure, in coordination with the Secretary of Defense, that space-based positioning, navigation, and timing public safety services meet or exceed international performance standards, including but not limited to those used for these services in aviation and/or maritime applications;
- In cooperation with other Departments and Agencies, promote the use of U.S. civil space-based positioning, navigation, and timing services and capabilities for transportation safety;
- Represent the civil Departments and Agencies in the development, acquisition, management, and operations of the Global Positioning System;
- Develop, acquire, operate, and maintain Global Positioning System space or terrestrial augmentations for civil transportation applications;
- Ensure the earliest operational availability for modernized civil signals and services on the Global Positioning System and its augmentations, in coordination with the Secretary of Defense;
- In coordination with the Secretary of Homeland Security, develop, acquire, operate, and maintain backup position, navigation, and timing capabilities that can support critical

transportation, homeland security, and other critical civil and commercial infrastructure applications within the United States, in the event of a disruption of the Global Positioning System or other space-based positioning, navigation, and timing services, consistent with Homeland Security Presidential Directive-7, Critical Infrastructure Identification, Prioritization, and Protection, dated December 17, 2003; and

- In cooperation with the Secretary of Defense, assess and assist, as appropriate, in the international acceptance for using the military positioning, navigation, and timing services of the Global Positioning System for operations in civil airspace.

The Secretary of Commerce shall:

- Represent U.S. commercial interests with other Departments and Agencies in the requirements review of the Global Positioning System and related space-based augmentations;

- In coordination with the Secretaries of State, Defense, and Transportation and the National Aeronautics and Space Administration, seek to protect the radio frequency spectrum used by the Global Positioning System and its augmentations through appropriate domestic and international spectrum management and regulatory practices;

- In coordination with the Secretaries of Defense and Transportation, and the Administrator of the National Aeronautics and Space Administration, facilitate cooperation between the United States Government and U.S. industry as appropriate to identify mutually acceptable solutions that will preserve existing and evolving uses of space-based positioning, navigation, and timing services, while allowing for the development of other technologies and services that depend on use of the radio frequency spectrum;

- In cooperation with the Administrator of the National Aeronautics and Space Administration, develop and provide to the Secretary of Transportation requirements for use of the Global Positioning System and its augmentations to support civil space systems; and

- In cooperation with other Departments and Agencies, promote the use of U.S. civil space-based positioning, navigation, and timing services and capabilities for applications at the Federal, State, and local level, to the maximum practical extent.

The Secretary of State shall:

- In cooperation with the Secretary of Defense, the Secretary of Transportation, and other Departments and Agencies promote the use of civil aspects of the Global Positioning System and its augmentation services and standards with foreign governments and other international organizations;

- Take the lead for negotiating with foreign governments and international organizations regarding civil and, as appropriate and in coordination with the Secretary of Defense, military positioning, navigation, and timing matters, including but not limited to coordinating interagency review of:

  - Instructions to U.S. delegations for bilateral and multilateral consultations relating to the planning, management, and use of the Global Positioning System and related augmentation systems; and

  - International agreements with foreign governments and international organizations regarding the planning, operation, management, and/or use of the Global Positioning System and its augmentations; and

- Modify and maintain, in coordination with the Secretaries of Defense, Commerce, and Energy, the Director of Central Intelligence, and the Administrator of the National Aeronautics and Space Administration, the Sensitive Technology List created by U.S. Commercial Remote Sensing Space Policy, dated April 25, 2003. In particular, include sensitive technology items and/or information related to positioning, navigation, and timing applications.

The Secretary of Homeland Security shall:

- Identify space-based positioning, navigation, and timing requirements for homeland security purposes to the Secretary of Transportation, and coordinate the use of positioning, navigation, and timing capabilities and backup systems for homeland security purposes by Federal, State, and local governments and authorities;

- In coordination with the Secretary of Transportation, and with other Departments and Agencies, promote the use of the Global Positioning System positioning and timing standards for use by Federal agencies, and by State and local authorities responsible for public safety and emergency response;

- In coordination with the Secretary of Defense, and in cooperation with the Secretaries of Transportation and Commerce, ensure:

  - Mechanisms are in place to identify, understand, and disseminate timely information regarding threats associated with the potential hostile use of space-based positioning, navigation, and timing services within the United States; and

  - Procedures are developed, implemented, and routinely exercised to request assistance from the Secretary of Defense should it become necessary to deny hostile use of space-based position, navigation and timing services within the United States;

- In coordination with the Secretaries of Defense, Transportation, and Commerce, develop and maintain capabilities, procedures, and techniques, and routinely exercise civil contingency responses to ensure continuity of operations in the event that access to the Global Positioning System is disrupted or denied;

- In coordination with the Secretaries of Transportation and Defense, and in cooperation with other Departments and Agencies, coordinate the use of existing and planned Federal capabilities to identify, locate, and attribute any interference within the United States that adversely affects use of the Global Positioning System and its augmentations for homeland security, civil, commercial, and scientific purposes; and

- In coordination with the Secretaries of Transportation and Defense, and the Director of Central Intelligence, and in cooperation with other Departments and Agencies: (1) develop a central repository and database for reports of domestic and international interference to the civil services of the Global Positioning System and its augmentations for homeland security, civil, commercial, and scientific purposes; and (2) notify promptly the Administrator, National Telecommunications and Information Administration, the Chairman of the Federal Communications Commission, the Secretary of Defense, the Director of Central Intelligence, and other Departments and Agencies in cases of domestic or international interference with space-based positioning, navigation, and timing services to enable appropriate investigation, notification, and/or enforcement action.

The Administrator of the National Aeronautics and Space Administration, in cooperation with the Secretary of Commerce, shall develop and provide to the Secretary of Transportation requirements for the use of the Global Positioning System and its augmentations to support civil space systems.

The Director of Central Intelligence shall identify, monitor, and assess the development of foreign threats to the use of the Global Positioning System positioning, navigation, and timing architectures and related services; provide information to assist the Secretary of Defense in development of countermeasures;

Departments and Agencies detecting interference, or receiving reports of domestic or international interference adversely affecting the performance of U.S. space-based positioning, navigation, and timing services shall provide timely reports to the Secretary of Homeland Security, the Secretary of Defense, and the Director of Central Intelligence. Upon notification by the Secretary of Homeland Security:

- The Secretary of Commerce, in cooperation with other Departments and Agencies, and with the Chairman of the Federal Communications Commission shall take appropriate and legally permissible actions required to mitigate interference to U.S. space-based positioning, navigation, and timing services within the United States; and

- The Secretary of State shall, as appropriate, notify and/or coordinate the notification of foreign governments and international organizations in cases of interference with U.S. space-based positioning, navigation, and timing services caused by foreign government or commercial activities.

######

This page intentionally left blank.

Appendix I – Surface Transportation R&D Programs

Vehicle Infrastructure Integration (VII) Program

The VII program is a cooperative effort between the U. S. Department of Transportation (USDOT), State departments of transportation, and the automobile industry, to develop and test an information infrastructure that uses advanced communications technologies to exchange real-time information between the roadside and vehicles to improve safety and mobility. There are three general categories of VII applications:

- Safety;
- Mobility; and
- Private.

Specific applications are being developed to test a broad variety of potential safety and mobility uses of the VII system including:

- Warning drivers of unsafe conditions or imminent collisions;
- Warning drivers if they are about to run off the road or speed around a curve too fast;
- Informing system operators of real-time congestion, weather conditions and incidents;
- Providing operators with information on corridor capacity for real-time management, planning and provision of corridor-wide advisories to drivers.

One group of VII safety applications is to enable reductions in collisions at signalized intersections, stop signs, highway/rail intersections, and between vehicles in the same lane. Another grouping of safety applications, referred to as Roadway Assistance applications, will provide warnings to drivers related to the position of a vehicle relative to other vehicles, curves, work zones, and road features, and provide in-vehicle signage to display information to the driver in advance of the roadway feature of interest and when visibility may be impaired.

VII mobility applications are those that address improving the flow of traffic to reduce congestion, improve roadway capacity, or otherwise enhance driving or flow management. Examples of mobility applications electronic toll collection, probe data collection and dissemination, and distribution of traveler information, traffic advisories, weather data, and other applications to improve traffic flow and congestion management.

The specific list of potential applications continues to evolve. The most recent information can be found at the following web sites:

- The Research and Innovative Technology Administration (RITA) website: www.its.dot.gov/vii;
- The ITS America website: www.itsa.org, search word "VII".

The location accuracy and integrity requirements for these applications are still being defined, but in general vary from knowing which road a vehicle is on, which lane it is in, to knowing location within very tight limits (e.g., locations of cars in adjacent lanes). VII applications requiring knowledge of vehicle location at the lane level lane or better for its location will require augmentation of the basic position accuracy possible with unaided commercial GPS. Research also continues on determining whether vehicle position must be known on an absolute (vehicle position relative to a standard earth reference) or relative (vehicle positions relative to each other) basis. Position integrity requirements for VII applications have not been developed at this time, nor have the mechanisms by which the integrity information will be generated or used by on-vehicle systems.

Development of automotive applications are being based on an assumption of loss of primary GPS signals and loss of augmentation signals in certain situations, such as traveling in tunnels, deep cuts, and urban canyons. While the final applications will be developed at some point in the future, the general principles being applied during the current VII Proof of Concept program include:

- Use of Dead Reckoning technology to provide a positioning solution during short periods of loss of primary GPS satellite signals. Cost-effective dead reckoning devices such as Micro-Electronic Motion Sensors (MEMS) have a high drift rate, so a usable solution can currently only be provided for a short period. More expensive gyroscopic devices can provide a usable dead reckoning input for a significantly longer time. Improvement of MEMS or other dead-reckoning technologies has been identified by the GPS Federal community as an area of needed investment.
- Providing quality of solution (quantified through level of accuracy and confidence level) and integrity parameters from the vehicle Positioning Service software to the VII applications software. From these parameters, the individual applications will be able to determine if the current positioning solution is within pre-defined parameters, and may respond as determined by automotive OEM, Federal, or other guidelines (to be established). Responses to loss of positioning solution or reduction in accuracy (loss of augmentation data, extended dead reckoning, etc.) may include turning off a function and notifying the driver, increasing the warning or response times, or increasing the protection zone around the affected vehicle. Details of the potential positioning failure modes and response mechanisms have not been identified at the time of writing of this report, nor have the specific positioning integrity requirements.

For the VII Proof of Concept (POC) test bed in the Detroit area, a reference station is creating enhanced differential correction data, formatting standard RTCM correction messages, converting the messages to Internet Protocol (IP) packets, and sending the correction messages through an IP network to the network of Dedicated Short-Range Communications (DSRC) radios in the test bed area. These DSRC roadside radios then communicate with DSRC-equipped vehicles which have been equipped for the POC program. This demonstrates the ability to use multiple RF paths to transmit GPS augmentation data from a differential GPS reference station to the ultimate user. While many applications, particularly in remote field locations, may use the Medium Frequency NDGPS beacon transmission, other applications may utilize a different radio system to transmit the augmentation data to the end user.

Table I -1 summarizes the VII positioning requirements as defined for the VII POC demonstration program, to be conducted in the Detroit, Michigan, area in early 2008. This table, extracted from the positioning framework document developed for the VII POC program, does not include all of the VII applications that are envisioned, but addresses only those applications planned for the POC program. In general, VII applications (distinct from the CICAS and VII vehicle-vehicle applications, which are primarily safety applications) require knowledge of which road the vehicle is on for general information provided to vehicles, but require knowledge of which lane of a road the vehicle is for applications that relate to a specific target point, such as a stop line, turn, road feature (e.g., curve), or specific point (such as toll or fee collection). Which lane is generally defined as 1 meter accuracy at 95% confidence, and which road is defined as 3 meter accuracy. Integrity requirements were not defined for the POC program. For both VII and Cooperative Intersection Collision Avoidance System (CICAS) applications (described below), determination of whether the positioning requirements are absolute (earth referenced) or relative (reference to other nearby vehicles or local roadside infrastructure) has not been finalized.

Table I-1. Preliminary VII Positioning Requirements			
Application Name	**Positioning Needs Description**		**Reference Point on Vehicle**
	Accuracy	**Condition**	
Emergency Brake Warning	Which Lane	All conditions	Front/rear bumper of vehicle
Traffic Signal Violation Warning	Which Lane	Within 300 m of intersection	Center of vehicle
Stop Sign Violation Warning	Which Lane	Within 300 m of intersection	Center of vehicle
Curve Speed Warning	Which Lane	Within 300 m of the entrance of the curve	Center of vehicle
In Vehicle Signage	Which Lane	Within the activation zone for certain signage items. (e.g., work zone warning, next exit services)	Center of vehicle
Off-Board Navigation	Which Lane	Within the notification zone for maneuvers	Center of vehicle
Electronic Payments: Parking	Which Lane	When the parking facility announcement is received and the driver selects parking	Front bumper of vehicle
Electronic Payment: Toll Roads	Which Lane	When toll collection announcement is received	Center of vehicle
Traveler Information	Which Lane	Within the activation zone for certain signage items. (e.g., work zone warning, next exit services)	Center of vehicle
Signal Timing Optimization	Which Lane	Within 300 m of intersection	Center of vehicle
Pothole Maintenance	Which Road	All conditions	Center of vehicle
Corridor Management Planning	Which Road	All conditions	Center of vehicle
Corridor Management Load	Which Road	All conditions	Center of vehicle
Weather Information	Which Road	All conditions	Center of vehicle

Cooperative Intersection Collision Avoidance System (CICAS)

Another program related to VII is the Cooperative Intersection Collision Avoidance System, or CICAS. Like VII, this program is currently in the Research and Development phase, lead by the US Department of Transportation, in partnership with state agencies, universities, and private industry.

The CICAS program is focused on reducing accidents at intersections. Each year intersection-related crashes take a heavy toll on lives, productivity, and the economy. In 2003 alone, 8,569 people died and more than 1.4 million suffered injuries as a result of intersection-related crashes. Intelligent intersection systems offer a significant opportunity to improve safety by enhancing driver decision-making at intersections that will help drivers avoid crashes.

Intersection collision avoidance systems use both vehicle-based and infrastructure-based technologies to help drivers approaching an intersection understand the state of activities within that intersection. Cooperative intersection collision avoidance systems (CICAS) have the potential to warn drivers about likely violations of traffic control devices and to help them maneuver through cross traffic. Eventually, CICAS may also inform other drivers (i.e., potential victims) about impending violations as well as identify pedestrians and cyclists within an intersection.

CICAS consists of:

- Vehicle-based technologies and systems—sensors, processors, and driver interfaces within each vehicle;
- Infrastructure-based technologies and systems—roadside sensors and processors to detect vehicles and identify hazards and signal systems, messaging signs, and/or other interfaces to communicate various warnings to drivers;
- Communications systems—dedicated short-range communications (DSRC) to communicate warnings and data between the infrastructure and equipped vehicles.

CICAS will require precise knowledge of the relative locations and speeds of vehicles in relation to each other, to the infrastructure, and within the perspective of the phase of the signal for vehicles as they approach the intersection. Due to the early stage of development of this system, it cannot be determined what combinations of technologies will be required. Current documentation of CICAS applications identifies the location accuracy requirements for CICAS-V applications as one-half lane width, which is 1-1.5 meters. Other CICAS applications may require location accuracies of 0.3 meters (defined as WhereInLane). Detailed accuracy and integrity requirements for CICAS have not been documented as of the time of writing of this report.

[Applicable references in Appendix A: 9, 10, 46. Applicable references from responses to the Federal Register Notice, Table E-1, entries 0068, 0099.]

This page intentionally left blank.

Appendix J – Land Transportation Radionavigation Requirements

The tables below are copied from Appendix D of the report *Radionavigation Systems: A Capabilities Investment Strategy*, prepared by the Radionavigation Systems Task Force and published in January 2004 by Overlook Systems Technologies, Inc.

Table D-3. Land Requirements[1] (Highway)

Operations Area		Accuracy (95%)	Availability	Integrity: Probability of Broadcasting Hazardously Misleading Info	Integrity: Alert Limit	Time to Alarm	Coverage	Current or Planned Primary System (s)
Highway	Navigation and Route Guidance	1 - 20 m	>95%	Not Applicable	2-20 m	>=5 sec	Nationwide/ Surface Coverage	NDGPS
	Automated Vehicle Monitoring	10 cm to 30 m	>95%	Not Applicable	20 cm to 30m	5 sec to 5 m	Nationwide/ Surface Coverage	NDGPS
	Automated Vehicle Identification	1m	99.7%	Not Applicable	3 m	>=5 sec	Nationwide/ Surface Coverage	NDGPS
	Public Safety	10cm to 30m	95 - 99.7%	Not Applicable	20 cm to 30 m	2-15 sec	Nationwide/ Surface Coverage	NDGPS
	Resource Management	5 mm to 30 m (H and V)	99.7%	Not Applicable	20 cm to 1 m	2-15 sec	Nationwide/ Surface Coverage	NDGPS[2]
	Accident Survey	.1 to 4 m	99.7%	Not Applicable	20 cm to 4 m	30 sec	Nationwide/ Surface Coverage	NDGPS[2]
	Emergency Response	30cm to 10 m	99.7%	Not Applicable	50cm to 10 m	near zero	Nationwide/ Surface Coverage	NDGPS[2]
	Collision Avoidance	0.1 m	99.9%	Not Applicable	.2m	5 sec	Nationwide/ Surface Coverage	NDGPS[2]
	Intelligent Vehicle Initiative	0.1m	99.9%	Not Applicable	.2m	5 sec	Nationwide/ Surface Coverage	NDGPS[2]

(H) - Horizontal
(V) - Vertical

There are no quantifiable requirements for continuity

[1]Reflects potential future needs and have not yet been validated.
[2]Requires High Accuracy NDGPS (HANDGPS)

Table D-4. Land Requirements (Railroad and Transit)

Operations Area		Accuracy (95%)	Availability	Integrity: Probability of Broadcasting Hazardously Misleading Info	Integrity: Alert Limit	Integrity: Time to Alarm	Coverage	Current or Planned Primary System (s)
Rail	Automated Vehicle Warning	1.0 m	99.9%	Not Applicable	10 m	5 sec	Nationwide	NDGPS
	Train Control	1.0 m	99.9%	Not Applicable	10 m	5 sec	Nationwide	NDGPS
	Track Maintenance	1.0 m	99.7%	Not Applicable	10 m	5 sec	Nationwide	NDGPS
Transit	Vehicle Command & Control	30 - 50 m	99.7%	Not Applicable	Not Available	Not Available	Nationwide	NDGPS
	Automated Voice Bus Stop Annunciation	5 m	99.7%	Not Applicable	Not Available	Not Available	Nationwide	NDGPS
	Emergency Response	75 - 100 m	99.7%	Not Applicable	Not Available	Not Available	Nationwide	NDGPS
	Data Collection	5 m	99.7%	Not Applicable	Not Available	Not Available	Nationwide	NDGPS

There are no quantifiable requirements for continuity