Global Positioning System (GPS) Standard Positioning Service (SPS) Performance Analysis Report

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Submitted by

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Executive Summary

The GPS Product Team has tasked the Navigation Branch at the William J. Hughes Technical Center to document the Global Positioning System (GPS) Standard Positioning Service (SPS) performance in quarterly GPS Performance Analysis (PAN) Reports. The report contains the analysis performed on data collected at twenty-eight Wide Area Augmentation System (WAAS) Reference Stations. This analysis verifies the GPS SPS performance as compared to the performance parameters stated in the SPS Specification (September 2008).

This report, Report #80, includes data collected from 1 October through 31 December 2012. The next quarterly report will be issued April 30, 2013.

Analysis of this data includes the following standards and categories: PDOP Availability, NANU Summary and Evaluation, Service Availability, Position and Range Accuracy and Solar Storm Effects on GPS SPS performance.

PDOP availability is based on Position Dilution of Precision (PDOP). Utilizing the weekly almanac posted on the US Coast Guard navigation web site, the coverage for every 5^o grid point between 180W to 180E and 80S and 80N was calculated for every minute over a 24-hour period for each of the weeks covered in the reporting period. For this reporting period, the global availability based on PDOP less than six for CONUS was 100%.

NANU summary and evaluation was achieved by reviewing the “Notice: Advisory to Navstar Users” (NANU) reports issued between 1 October and 31 December 2012. Using this data, we compute a set of statistics that give a relative idea of constellation health for both the current and combined history of past quarters. A total of ten outages were reported in the NANU’s this quarter. Eight outages were scheduled while two were unscheduled.

The quarterly service availability standard was verified using 24-hour position accuracy values computed from data collected at one-second intervals. All of the sites achieved a 100% availability, which exceeds the SPS “average location” value of 99% and the “worst-case location” value of 90%.

Calculating the 24-hour 95% horizontal and vertical position error values verified the accuracy standards. The User Range Error standard was verified for each satellite from 24-hour accuracy values computed using data collected at the following six sites: Boston, Honolulu, Los Angeles, Miami, San Juan and Juneau. This data was also collected in one-second samples. All sites achieved 100% reliability, meeting the SPS specification. The maximum range error recorded was 28.372 meters on Satellite PRN 15. The SPS specification states that the range error should never exceed 30 meters for less than 99.79% of the day for a worst-case point and 99.94% globally. The maximum RMS range error value of 3.443 was recorded on satellite PRN 22. The SPS specification states that RMS URE cannot exceed 6 meters in any 24-hour interval.

Geomagnetic storms had little to no effect on GPS performance this quarter. All sites met all GPS Standard Positioning Service (SPS) specifications on those days with the most significant solar activity.

The IGS is a voluntary federation of many worldwide agencies that pool resources and permanent GNSS station data to generate precise GNSS products. During the evaluation period, the maximum 95% horizontal and vertical SPS errors were 8.20 meters at Santiago, Chile and 7.41 meters at Petropavlovsk-Kamchatka, Russian Federation respectively.

From the analysis performed on data collected between 1 October and 31 December 2012, the GPS performance met all SPS requirements that were evaluated. No GPS issues were noted this quarter.

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1 Introduction

1.1 Objective of GPS SPS Performance Analysis Report

In 1993, the FAA began monitoring and analyzing Global Positioning System (GPS) Standard Positioning Service (SPS) performance data. At present, the FAA has approved GPS and WAAS for IFR operations and is developing Local Area Augmentation (LAAS), which is an additional GPS augmentation system. In order to ensure the safe and effective use of GPS and its augmentation systems within the NAS, it is critical that characteristics of GPS performance as well as specific causes for service outages be monitored and understood. To accomplish this objective, GPS SPS performance data is documented in a quarterly GPS Analysis report. This report contains data collected at the following twenty-eight WAAS reference station locations:

- Bethel, AK
- Billings, MT
- Fairbanks, AK
- Cold Bay, AK
- Kotzebue, AK
- Juneau, AK
- Albuquerque, NM
- Anchorage, AK
- Boston, MA
- Washington, D.C.
- Honolulu, HI
- Houston, TX
- Kansas city, KS
- Los Angeles, CA
- Salt Lake City, UT
- Miami, FL
- Minneapolis, MI
- Oakland, CA
- Cleveland, OH
- Seattle, WA
- San Juan, PR
- Atlanta, GA
- Barrow, AK
- Merida, Mexico
- Gander, Canada
- Tapachula, Mexico
- San Jose Del Cabo, Mexico
- Iqaluit, Canada

The analysis of the data is divided into the four performance categories stated in the Standard Positioning Service Performance Specification (September 2008). These categories are:

- PDOP Availability Standard
- Service Availability Standard
- Service Reliability Standard
- Positioning, Ranging and Timing Accuracy Standard

The results were then compared to the performance parameters stated in the SPS.

1.2 Report Overview

Section 2 of this report summarizes the results obtained from the coverage calculation program developed by the GPS test team. The SPS coverage area program uses the GPS satellite almanacs to compute each satellite position as a function of time for a selected day of the week. This program establishes a 5-degree grid between 180 degrees east and 180 degrees west, and from 80 degrees north and 80 degrees south. The program then computes the PDOP at each grid point (1485 total grid points) every minute for the entire day and stores the results. After the PDOP's have been saved the 99.99% index of 1-minute PDOP at each grid point is determined and plotted as contour lines (Figure 2-1). The program also saves the number of satellites used in PDOP calculation at each grid point for analysis.

Section 3 summarizes the GPS constellation performance by providing the "Notice: Advisory to Navstar Users" (NANU) messages to calculate the total time of forecasted and actual satellite outages. This section also evaluates the Service Availability Standard using 24-hour 95% horizontal and vertical position accuracy values.

Section 4 summarizes service reliability performance. It will be reported at the end of the first year of this analysis because the SPS standard is based on a measurement interval of one year. Data for the quarter is provided for completeness.

Section 5 provides the position accuracies based on data collected on a daily basis at one-second intervals. This section also provides the statistics on the range error, range error rate and range acceleration error for each satellite. The overall average, maximum, minimum and standard deviations of the range rates and accelerations are tabulated for each satellite.

In Section 6, the data collected during solar storms is analyzed to determine the effects, if any, of GPS SPS performance.

Section 7 provides an analysis of GPS-SPS accuracy performance from a selection of high rate IGS stations around the world.

Section 8 provides a summary of GPS Test NOTAMs.

Section 9 provides four appendices to summarize the data found in this report and provide further information.

Appendix A provides a summary of all the results as compared to the SPS specification.

Appendix B provides the geomagnetic data used for Section 6.

Appendix C provides a PAN Problem Report.

Appendix D provides a glossary of terms used in this PAN report. This glossary was obtained directly from the GPS SPS specification document (September 2008).

1.3 Summary of Performance Requirements and Metrics

Table 1-1 over the next four pages lists the performance parameters from the SPS and identifies those parameters verified in this report.

Table 1-1 SPS SIS Performance Requirements Standards

Per-Satellite Coverage	**Conditions and Constraints**	**Evaluated in This Report**
Terrestrial Service Volume: 100% Coverage Space Service Volume: No Coverage Performance Specified	• For any health or marginal SPS SIS	**Future Report**
Constellation Coverage	**Conditions and Constraints**	
Terrestrial Service Volume: 100% Coverage Space Service Volume: No Coverage Performance Specified	• For any healthy or marginal SPS SIS	**Future Report**
User Range Error Accuracy	**Conditions and Constraints**	
Single Frequency C/A-Code • ≤ 7.8m 9%% Global Average URE during normal operations over All AODs • ≤ 6.0m 95% Global Average URE during operations at Zero AOD • ≤ 12.8m 95% Global Average URE during normal operations at Any AOD	• For any healthy SPS SIS • Neglecting single-frequency ionospheric delay model errors • Including group delay time correction (T_{GD}) errors at L1 • Including inter-signal bias (P(Y)-code to C/A-code) errors at L1	✓
Single Frequency C/A-Code • ≤ 30m 99.94% Global Average URE during normal operations • ≤ 30m 99.79% Worst Case single point average during normal operations.	• For any healthy SPS SIS. • Neglecting single-frequency ionospheric delay model errors • Including group delay time correction (T_{GD}) errors at L1 • Including inter-signal bias (P(Y)-code to C/A-code) errors at L1 • Standard based on measurement interval of one year; average of daily values within service volume • Standard based on 3 service failures per year, lasting no more than 6 hours each	✓
User Range Rate Error Accuracy	**Conditions and Constraints**	
Single-Frequency C/A-Code: • ≤ 6 mm/sec 95% Global Average URRE over any 3-second interval during normal operations at Any AOD	• For any healthy SPS SIS • Neglecting all perceived pseudorange rate errors attributable to pseudorange step changes caused by NAV message data cutovers • Neglecting single-frequency ionospheric delay model errors	✓

User Range Acceleration Error Accuracy	Conditions and Constraints	Evaluated in This Report
Single-Frequency C/A-Code: • ≤ 2 mm/sec^2 95% Global average URAE over any 3-second interval during normal operations at Any AOD	• For any healthy SPS SIS • Neglecting all perceived pseudorange rate errors attributable to pseudorange step changes caused by NAV message data cutovers • Neglecting single-frequency ionospheric delay model errors	✓
Coordinated Universal Time Offset Error Accuracy		
• ≤ 40 nanoseconds 95% Global average UTCOE during normal operations at Any AOD.	• For any healthy SPS SIS	✓
Instantaneous URE Integrity	**Conditions and Constraints**	
Single-Frequency C/A-Code: • ≤ 1x10^{-5} Probability over any hour of the SPS SIS Instantaneous URE exceeding the NTE tolerance without a timely alert during normal operations.	• For any healthy SPS SIS • SPS SIS URE NTE tolerance defined to be ±4.42 times the upper bound on the URA value corresponding to the URA index "N" currently broadcast by the satellite. • Given that the maximum SPS SIS instantaneous URE did not exceed the NTE tolerance at the start of the hour • Worst case for delayed alert is 6 hours. • Neglecting singe-frequency ionospheric delay model errors	**Future Report**
Instantaneous UTCOE Integrity	**Conditions and Constraints**	
Single-Frequency C/A-Code: • ≤ 1x10^{-5} Probability over any hour of the SPS SIS Instantaneous UTCOE exceeding the NTE tolerance without a timely alert during normal operations.	• For any healthy SPS SIS • SPS SIS URE NTE tolerance defined	**Future Report**
Unscheduled Failure Interruption Continuity	**Conditions and Constraints**	
Unscheduled Failure Interruptions: • ≥ 0.9998 Probability over any hour of not losing the SPS SIS availability from a slot due to unscheduled interruption	• Calculated as an average over all slots in the 24-slot constellation, normalized annually • Given that the SPS SIS is available from the slot at the start of the hour	**Future Report**

Status and Problem Reporting	Conditions and Constraints	Evaluated in This Report
Scheduled event affecting service • Appropriate NANU issued to the Coast Guard and the FAA at least 48 hours prior to the event	• For any SPS SIS	✓
Unscheduled outage or problem affecting service • Appropriate NANU issued to the Coast Guard and the FAA as soon as possible after the event	• For any SPS SIS	✓
Per-Slot Availability	**Conditions and Constraints**	
• ≥ 0.957 Probability that a slot in the baseline 24-slot configuration will be occupied by a satellite broadcasting a healthy SPS SIS • ≥ 0.957 Probability that a slot in the expanded configuration will be occupied by a pair of satellites each broadcasting a health SPS SIS	• Calculated as an average over all slots in the 24-slot constellation, normalized annually • Applies to satellites broadcasting a healthy SPS SIS that also satisfy the other performance standards in the SPS performance standard.	✓
Constellation Availability	**Conditions and Constraints**	
• ≥ 0.98 Probability that at least 21 slots out of the 24 will be occupied either by a satellite broadcasting a healthy SPS SIS in the baseline 24-slot configuration or by a pair of satellites each broadcasting a healthy SPS SIS in the expanded slot configuration • ≥ 0.99999 Probability that at least 20 slots out of the 24 will be occupied either by a satellite broadcasting a healthy SPS SIS in the baseline 24-slot configuration or by a pair of satellites each broadcasting a healthy SPS SIS in the expanded slot configuration	• Calculated as an average over all slots in the 24-slot constellation, normalized annually. • Applies to satellites broadcasting a healthy SPS SIS that also satisfies the other performance standards in the SPS performance standard.	✓
Operational Satellite Count	**Conditions and Constraints**	
• ≥ 0.95 Probability that the constellation will have at least 24 operational satellites regardless of whether those operational satellites are located in slots or not	• Applies to the total number of operational satellites in the constellation (averaged over any day); where any satellite which appears in the transmitted navigation message almanac is defined to be an operation satellite regardless of whether that satellite is currently broadcasting a healthy SPS SIS or not and regardless of whether the broadcast SPS SIS also satisfies the other performance standards in the SPS performance standard or not.	✓

PDOP Availability	Conditions and Constraints	Evaluated in This Report
• ≥ 98% global PDOP of 6 or less • ≥ 88% worst site PDOP of 6 or less	• Defined for a position/time solution meeting the representative user conditions and operating within the service volume over any 24-hour interval	✓
Service Availability	**Conditions and Constraints**	
• ≥ 99% Horizontal Service Availability, average location • ≥ 99% Vertical Service Availability, average location	• 17m Horizontal (SIS only) 95% threshold • 37m Vertical (SIS only) 95% threshold • Defined for a position/time solution meeting the representative user conditions and operating within the service volume over any 24-hour interval.	✓
• ≥ 90% Horizontal Service Availability, worst-case location • ≥ 90% Vertical Service Availability, worst-case location	• 17m Horizontal (SIS only) 95% threshold • 37m Vertical (SIS only) 95% threshold • Defined for a position/time solution meeting the representative user conditions and operating within the service volume over any 24-hour interval.	✓
Position/Time Accuracy	**Conditions and Constraints**	
Global Average Position Domain Accuracy • ≤ 9m 95% Horizontal Error • ≤ 15m 95% Vertical Error	• Defined for a position/time solution meeting the representative user conditions • Standard based on a measurement interval of 24 hours averaged over all points in the service volume.	✓
Worst Site Position Domain Accuracy • ≤ 17m 95% Horizontal Error • ≤ 37m 95% Vertical Error	• Defined for a position/time solution meeting the representative user conditions • Standard based on a measurement interval of 24 hours averaged over all points in the service volume.	✓
Time Transfer Domain Accuracy • ≤ 40 nanoseconds time transfer error 95% of time (SIS only)	• Defined for a time transfer solution meeting the representative user conditions • Standard based on a measurement interval of 24 hours averaged over all points in the service volume.	✓

2 PDOP Availability Standard

PDOP Availability: The percentage of time over any 24-hour interval that the PDOP value is less than or equal to its threshold for any point within the service volume.

Dilution of Precision (DOP): The magnifying effect on GPS position error induced by mapping GPS range errors into position within the specified coordinate system through the geometry of the position solution. The DOP varies as a function of satellite positions relative to user position. The DOP may be represented in any user local coordinate desired. Examples are HDOP for local horizontal, VDOP for local vertical, PDOP for all three coordinates, and TDOP for time.

PDOP Availability Standard	Conditions and Constraints
≥ 98% global PDOP of 6 or less ≥ 88% worst site PDOP of 6 or less	• Defined for a position/time solution meeting the representative user conditions and operating within the service volume over any 24-hour interval

Almanacs for GPS weeks used for this coverage portion of the report were obtained from the Coast Guard web site (www.navcen.uscg.mil). Using these almanacs, an SPS coverage area program developed by the GPS test team was used to calculate the PDOP at every 5^{o} point between longitudes of 180W to 180E and 80S and 80N at one-minute intervals. This gives a total of 1440 samples for each of the 2376 grid points in the coverage area. Table 2-1 provides the global averages and worst-case availability over a 24-hour period for each week. Table 2-1 also gives the global 99.9% PDOP value for each of the thirteen GPS Weeks. The PDOP was 2.799 or better 99.9% of the time for each of the 24-hour intervals.

Figure 2-1 is a contour plot of PDOP values over the entire globe. Inside each contour area, the PDOP value is greater than or equal to the contour value shown in the legend for that color line. That areas' value is also less than the next higher contour value, unless another contour line lies within the current area. A single "DOP hole" where the PDOP value is greater than 6 was evaluated for satellite visibility for one 24-hour interval from the week shaded in Table 2-1. The histogram in figure 2-2 shows the satellite visibility at the DOP hole position for the 24 hour interval in question.

The GPS coverage performance evaluated met the specifications stated in the SPS.

Table 2-1 PDOP Availability Statistics

Date Range of Week	Global 99.9% PDOP Value	Global Average (Spec: ≥ 98%)	Worst-Case Point (Spec: ≥ 88%)
1 – 6 October	2.748	100%	100%
7 – 13 October	2.799	100%	100%
14 – 20 October	2.737	100%	100%
21 – 27 October	2.642	100%	100%
28 Oct – 3 November	2.797	100%	100%
4 – 10 November	2.652	100%	100%
11 – 17 November	2.671	100%	100%
18 – 24 November	2.662	100%	100%
25 Nov – 1 December	2.661	100%	100%
2 – 8 December	2.728	100%	100%
9 – 15 December	2.718	100%	100%
16 – 22 December	2.704	100%	100%
23 – 29 December	2.691	100%	100%

Figure 2-1 World GPS Maximum PDOP

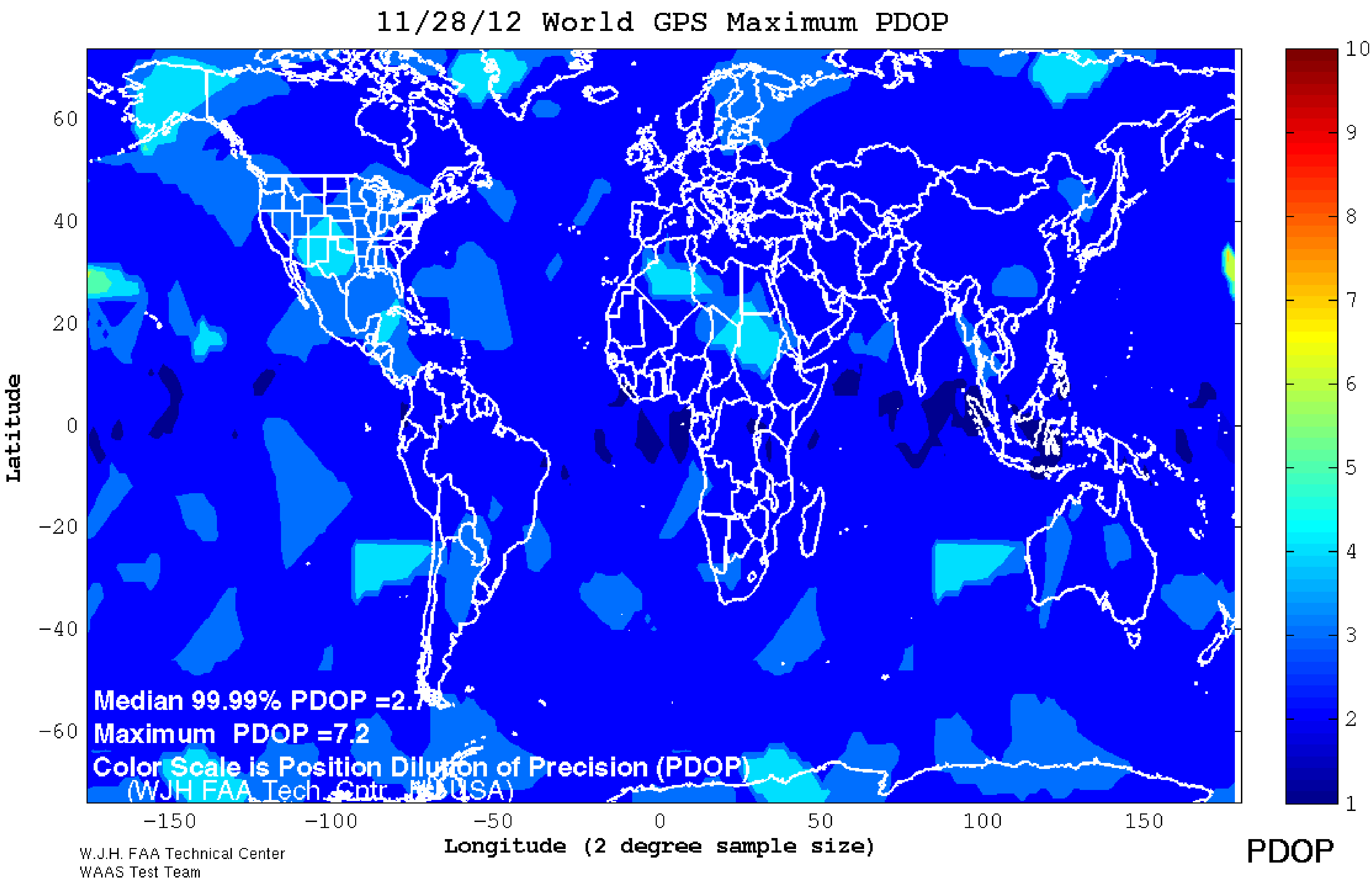
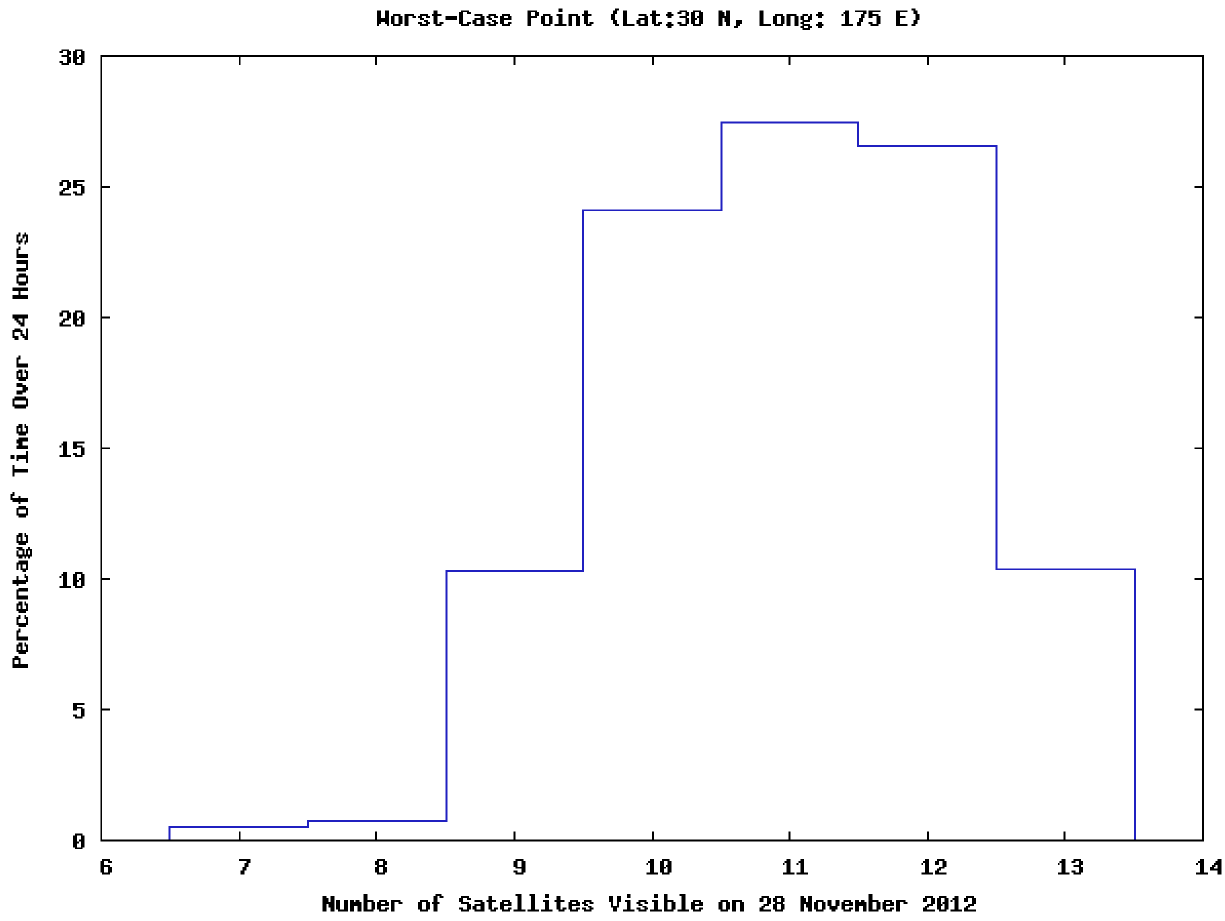


Figure 2-2 Satellite Visibility Profile for Worst-Case Point



3 NANU Summary and Evaluation

NANU: Notice Advisory to NAVSTAR Users – A periodic bulletin alerting users to changes in the satellite system performance.

Status and Problem Reporting	Conditions and Constraints
Scheduled event affecting service • Appropriate NANU issued to the Coast Guard and the FAA at least 48 hours prior to the event	• For any SPS SIS
Unscheduled outage or problem affecting service • Appropriate NANU issued to the Coast Guard and the FAA as soon as possible after the event	• For any SPS SIS

3.1 Satellite Outages from NANU Reports

Satellite availability performance was analyzed based on published "Notice: Advisory to Navstar Users" messages (NANU's). During this reporting period, 1 October through 31 December 2012, there were a total of ten reported outages. Eight of these outages were maintenance activities and were reported in advance while two were unscheduled. A complete listing of outage NANU's for the reporting period is provided in Table 3-1. A complete listing of the forecasted outage NANU's for the reporting period can be found in Table 3-2. Canceled outage NANU's (if any) are provided in Table 3-3. The minimum duration a scheduled outage was forecasted ahead of time was 36.3 hours. Although this did not meet the 48-hour requirement, the outage did not result in a loss of continuity. The maximum response time for a NANU issued for an unscheduled outage was 7 minutes.

Table 3-1 NANUs Affecting Satellite Availability

NANU#	PRN	TYPE	Start Date	Start Time	End Date	End Time	Total Unscheduled	Total Scheduled	Total
2012066	1	FCSTSUMM	26-Oct-12	2:29	26-Oct-12	7:17		4.8	4.8
2012069	23	FCSTSUMM	13-Nov-12	2:19	13-Nov-12	8:13		5.9	5.9
2012071	9	FCSTSUMM	15-Nov-12	13:53	15-Nov-12	20:55		7.03	7.03
2012074	32	FCSTSUMM	21-Nov-12	1:06	21-Nov-12	6:28		5.37	5.37
2012075	2	FCSTSUMM	28-Nov-12	14:27	28-Nov-12	19:37		5.17	5.17
2012078	32	UNUSABLE	4-Dec-12	17:46	4-Dec-12	18:30	0.73		0.73
2012079	16	FCSTSUMM	6-Dec-12	21:35	7-Dec-12	3:06		5.52	5.52
2012081	30	FCSTSUMM	12-Dec-12	17:31	13-Dec-12	1:25		7.9	7.9
2012084	30	UNUSABLE	17-Dec-12	21:44	18-Dec-12	2:03	4.32		4.32
2012086	3	FCSTSUMM	20-Dec-12	12:57	20-Dec-12	19:13		6.27	6.27
Totals of Unscheduled, Scheduled & Total Downtime							5.05	47.96	53.01

GENERAL NANUs

NANU 2012064 stated that the L-band signal would resume transmitting from PRN27 (SVN 49) on October 12, 2012. The satellite would not be included in the almanac.

Table 3-2 NANUs Forecasted to Affect Satellite Availability

NANU #	PRN	Type	Start Date	Start Time	End Date	End Time	Total	Comments
2012065	1	FCSTDV	26-Oct	2:00	26-Oct	14:00	12	2012066
2012067	23	FCSTDV	13-Nov	2:00	13-Nov	14:00	12	2012069
2012068	9	FCSTDV	15-Nov	13:30	16-Nov	13:30	24	2012071
2012072	32	FCSTDV	21-Nov	0:30	21-Nov	12:30	12	2012074
2012073	2	FCSTDV	28-Nov	14:00	29-Nov	2:00	12	2012075
2012076	16	FCSTDV	6-Dec	21:00	7-Dec	9:00	12	2012079
2012077	32	UNUSUFN	4-Dec	17:46				2012078
2012080	30	FCSTDV	12-Dec	17:15	13-Dec	5:15	12	2012081
2012082	3	FCSTDV	19-Dec	12:50	20-Dec	0:50	0	2012085
2012083	30	UNUSUFN	17-Dec	21:44				2012084
2012085	3	FCSTRESCD	20-Dec	12:45	21-Dec	0:45	12	2012086
Total Forecasted Downtime							108	

Table 3-3 Cancelled NANUs

NANU#	PRN	Type	Start Date	Start Time	Comments
None					

Satellite Reliability, Maintainability, and Availability (RMA) data is being collected based on published "Notice: Advisory to Navstar Users" messages (NANU's). This data has been summarized in Table 3-4. The "Total Satellite Observed MTTR" was calculated by taking the average downtime of all satellite outage occurrences. Scheduled downtime was forecasted in advance via NANU's. All other downtime reported via NANU was considered unscheduled. The "Percent Operational" was calculated based on the ratio of total actual operating hours to total available operating hours for every satellite.

Table 3-4 GPS Satellite Maintenance Statistics

Satellite Reliability/Maintainability/Availability (RMA) Parameter	1-Jul-12 31-Dec-12	1-Jan-00 31-Dec-12
Total Forecast Downtime (hrs):	108	9648.82
Total Actual Downtime (hrs):	53.01	37945.56
Total Actual Scheduled Downtime (hrs):	47.96	5707.44
Total Actual Unscheduled Downtime (hrs):	5.05	32238.12
Total Satellite Observed MTTR (hrs):	5.3	51.63
Scheduled Satellite Observed MTTR (hrs):	6	9.87
Unscheduled Satellite Observed MTTR (hrs):	2.52	205.34
# Total Satellite Outages:	10	735
# Scheduled Satellite Outages:	8	578
# Unscheduled Satellite Outages:	2	157
Percent Operational -- Scheduled Downtime:	99.93	99.84
Percent Operational -- All Downtime:	99.92	98.93

3.2 Service Availability Standard

Service Availability: The percentage of time over any 24-hour interval that the predicted 95% position error is less than the threshold at any given point within the service volume.

• **Horizontal Service Availability:** The percentage of time over any 24-hour interval that the predicted 95% horizontal error is less than its threshold for any point within the service volume.

• **Vertical Service Availability:** The percentage of time over any 24-hour interval that the predicted 95% vertical error is less than its threshold for any point within the service volume.

Service Availability Standard	Conditions and Constraints
• ≥ 99% Horizontal Service Availability, average location • ≥ 99% Vertical Service Availability, average location	• 17m Horizontal (SIS only) 95% threshold • 37m Vertical (SIS only) 95% threshold • Defined for a position/time solution meeting the representative user conditions and operating within the service volume over any 24-hour interval.
• ≥ 90% Horizontal Service Availability, worst-case location • ≥ 90% Vertical Service Availability, worst-case location	• 17m Horizontal (SIS only) 95% threshold • 37m Vertical (SIS only) 95% threshold • Defined for a position/time solution meeting the representative user conditions and operating within the service volume over any 24-hour interval.

To verify availability, the data collected from receivers at the twenty-eight WAAS sites was reduced to calculate 24-hour accuracy information and reported in Table 3-5. The data was collected at one-second intervals between 1 October and 31 December 2012.

Table 3-5 Accuracies Exceeding Threshold Statistics

Site	Total Number of Seconds of SPS Monitoring	Instances of 24-hour Threshold Failures	Quarters Service Availability %
Albuquerque	7614126	0	100%
Anchorage	7614127	0	100%
Atlanta	7614128	0	100%
Barrow	7610764	0	100%
Bethel	7612033	0	100%
Billings	7612353	0	100%
Boston	7613892	0	100%
Cleveland	7614130	0	100%
Cold Bay	7611526	0	100%
Fairbanks	7612369	0	100%
Gander	7612730	0	100%
Honolulu	7614123	0	100%
Houston	7614128	0	100%
Iqaluit	7606497	0	100%
Juneau	7609669	0	100%
Kansas City	7614129	0	100%
Kotzebue	7612577	0	100%
Los Angeles	7612476	0	100%
Merida	7614129	0	100%
Miami	7612467	0	100%
Minneapolis	7614129	0	100%
Oakland	7614130	0	100%
Salt Lake City	7614129	0	100%
San Jose Del Cabo	7588792	0	100%
San Juan	3588160	0	100%
Seattle	7196416	0	100%
Tapachula	7589111	0	100%
Washington, DC	7614125	0	100%
Global Average over Reporting Period = 100% (SPS Spec. > 95.87%)			

4 Service Reliability Standard

Service Reliability: The percentage of time over a specific time interval that the instantaneous SIS SPS URE is maintained within a specified reliability threshold at any given point within the service volume, for all healthy GPS satellites.

User Range Error Accuracy	Conditions and Constraints
Single Frequency C/A-Code • ≤ 30m 99.94% Global Average URE during normal operations • ≤ 30m 99.79% Worst Case single point average during normal operations.	• For any healthy SPS SIS. • Neglecting single-frequency ionospheric delay model errors • Including group delay time correction (T_{GD}) errors at L1 • Including inter-signal bias (P(Y)-code to C/A-code) errors at L1 • Standard based on measurement interval of one year; average of daily values within service volume • Standard based on 3 service failures per year, lasting no more than 6 hours each

Table 4-1 shows a comparison to the service reliability standard for range data collected at a set of six receivers across North America. Although the specification calls for yearly evaluations, we will be evaluating this SPS requirement at quarterly intervals. Additional range analysis results can be found in table 5-2. The maximum User Range Error recorded this quarter was 28.372 meters on satellite PRN 15.

Table 4-1 User Range Error Accuracy

Date Range of Data Collection	Site	Number of Samples This Quarter	Number of Samples where SPS URE > 30m NTE	Percentage
1 Apr – 30 Jun 2012	**Boston**	63,738,823	0	100%
1 Apr – 30 Jun 2012	**Honolulu**	66,667,199	0	100%
1 Apr – 30 Jun 2012	**Los Angeles**	66,189,069	0	100%
1 Apr – 30 Jun 2012	**Miami**	63,934,408	0	100%
1 Apr – 30 Jun 2012	**Merida**	65,824,922	0	100%
1 Apr – 30 Jun 2012	**Juneau**	66,675,621	0	100%
1 Apr – 30 Jun 2012	**Global**	393,030,042	0	100%

5 Accuracy Standard

Positioning Accuracy: The statistical difference, at a 95% probability, between position measurements and a surveyed benchmark for any point within the service volume over any 24-hour interval.

• **Horizontal Positioning Accuracy**: The statistical difference, at a 95% probability, between horizontal position measurements and a surveyed benchmark for any point within the service volume over any 24-hour interval.

• **Vertical Positioning Accuracy**: The statistical difference, at a 95% probability, between vertical position measurements and a surveyed benchmark for any point within the service volume over any 24-hour interval.

Position/Time Accuracy	Conditions and Constraints
Global Average Position Domain Accuracy • ≤ 9m 95% Horizontal Error • ≤ 15m 95% Vertical Error	• Defined for a position/time solution meeting the representative user conditions • Standard based on a measurement interval of 24 hours averaged over all points in the service volume.
Worst Site Position Domain Accuracy • ≤ 17m 95% Horizontal Error • ≤ 37m 95% Vertical Error	• Defined for a position/time solution meeting the representative user conditions • Standard based on a measurement interval of 24 hours averaged over all points in the service volume.
Time Transfer Domain Accuracy • ≤ 40 nanoseconds time transfer error 95% of time (SIS only)	• Defined for a time transfer solution meeting the representative user conditions • Standard based on a measurement interval of 24 hours averaged over all points in the service volume.

User Range Accuracy	Conditions and Constraints
Single Frequency C/A-Code • ≤ 7.8m 9%% Global Average URE during normal operations over All AODs • ≤ 6.0m 95% Global Average URE during operations at Zero AOD • ≤ 12.8m 95% Global Average URE during normal operations at Any AOD	• For any healthy SPS SIS • Neglecting single-frequency ionospheric delay model errors • Including group delay time correction (T_{GD}) errors at L1 • Including inter-signal bias (P(Y)-code to C/A-code) errors at L1
Single-Frequency C/A-Code: • ≤ 6 mm/sec 95% Global Average URRE over any 3-second interval during normal operations at Any AOD	• For any healthy SPS SIS • Neglecting all perceived pseudorange rate errors attributable to pseudorange step changes caused by NAV message data cutovers • Neglecting single-frequency ionospheric delay model errors
Single-Frequency C/A-Code: • ≤ 2 mm/sec^2 95% Global average URAE over any 3-second interval during normal operations at Any AOD	• For any healthy SPS SIS • Neglecting all perceived pseudorange rate errors attributable to pseudorange step changes caused by NAV message data cutovers • Neglecting single-frequency ionospheric delay model errors
Coordinated Universal Time Offset Error Accuracy	**Conditions and Constraints**
• ≤ 40 nanoseconds 95% Global average UTCOE during normal operations at Any AOD.	• For any healthy SPS SIS

5.1 Position Accuracy

The data used for this section was collected for every second from 1 October through 31 December 2012 at the selected WAAS locations. Table 5-1 provides the 95% and 99.99% horizontal and vertical error accuracies for the quarter. Every twenty-four hour analysis period this quarter passed both the worst-case and global position accuracy requirements set forth by the SPS specification.

Table 5-1 Horizontal & Vertical Accuracy Statistics for the Quarter

Site	95% Vertical (Meters)	95% Horizontal (Meters)	99.99% Vertical (Meters)	99.99% Horizontal (Meters)
Albuquerque	5.214	2.093	11.499	5.568
Anchorage	6.476	2.109	12.324	4.085
Atlanta	5.238	2.398	11.022	4.890
Barrow	6.696	2.244	13.477	4.546
Bethel	6.655	2.049	11.848	3.852
Billings	4.671	2.131	9.236	4.443
Boston	4.188	2.400	8.004	5.186
Cleveland	4.517	2.346	8.787	4.732
Cold Bay	6.549	2.046	10.647	5.212
Fairbanks	6.501	2.137	12.680	3.909
Gander	3.999	2.389	7.722	5.894
Honolulu	6.511	8.261	16.331	13.026
Houston	5.657	2.334	10.880	5.516
Iqaluit	4.760	2.572	8.847	5.775
Juneau	5.898	2.095	11.307	4.359
Kansas City	4.846	2.323	10.235	4.170
Kotzebue	6.727	2.112	14.077	4.167
Los Angeles	5.950	2.017	11.107	5.331
Merida	6.093	3.319	20.601	13.301
Miami	5.653	2.505	14.034	6.403
Minneapolis	4.658	2.247	9.983	4.596
Oakland	6.025	2.091	11.295	5.778
Salt Lake City	5.039	2.123	9.794	5.194
San Jose Del Cabo	6.479	3.384	16.032	12.343
San Juan	6.235	4.884	22.226	21.510
Seattle	5.338	2.066	9.669	4.585
Tapachula	9.105	7.696	25.491	16.822
Washington, DC	4.657	2.521	9.231	5.273

Figures 5-1 and 5-2 are the combined histograms of the vertical and horizontal errors for all twenty-eight WAAS sites from 1 October to 31 December 2012.

Figure 5-1 Global Vertical Error Histogram

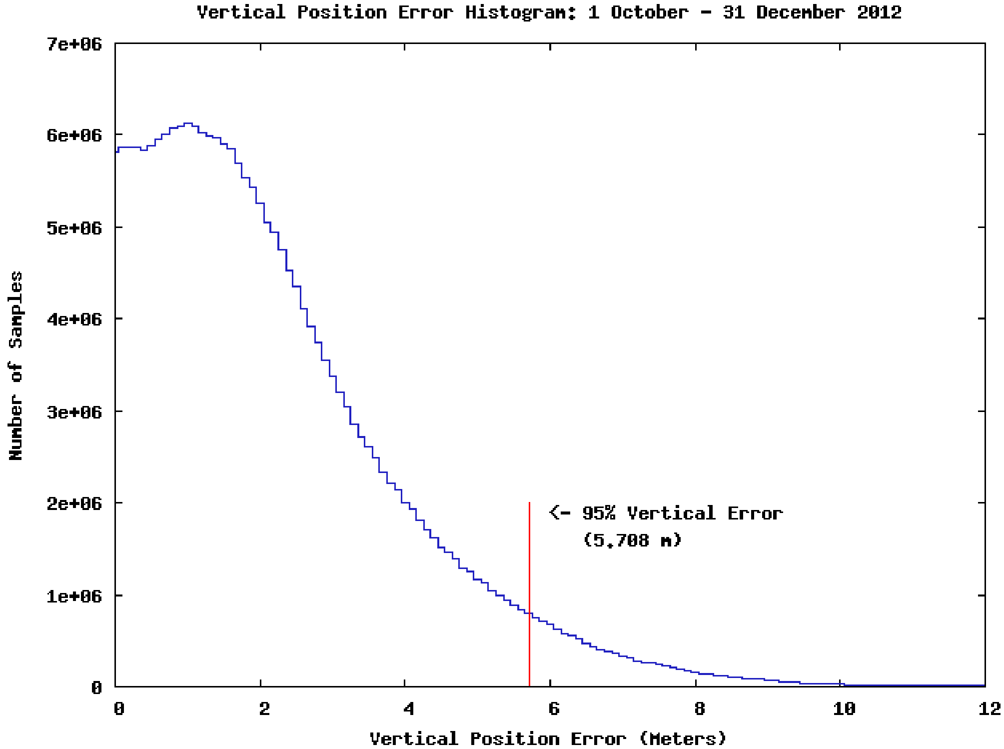
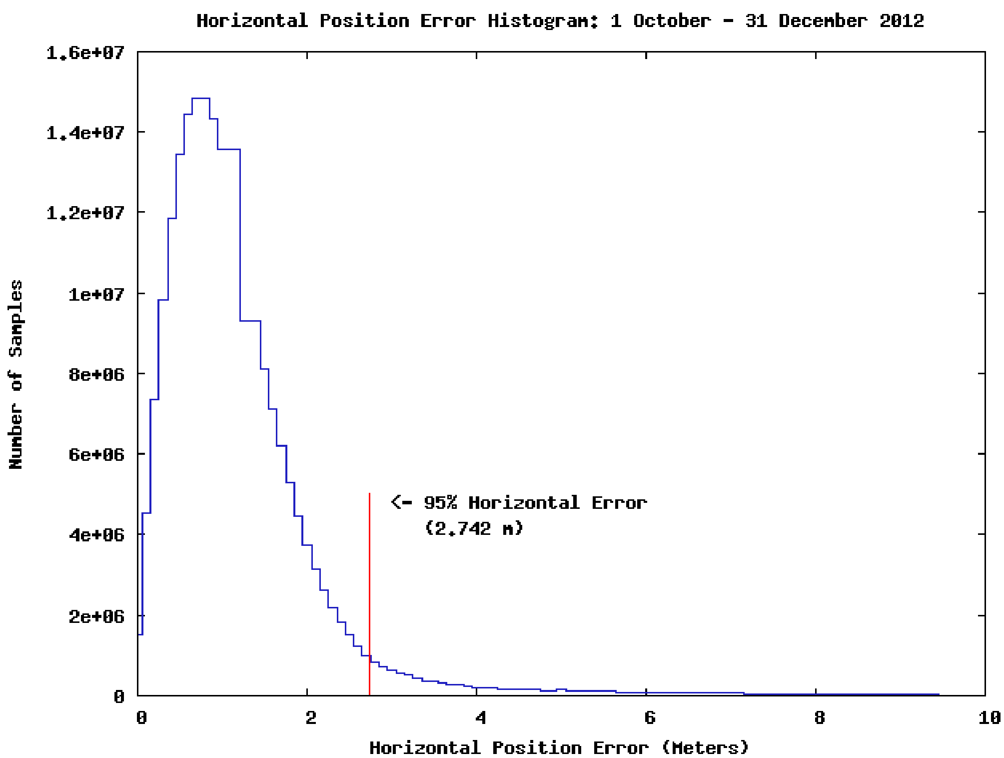


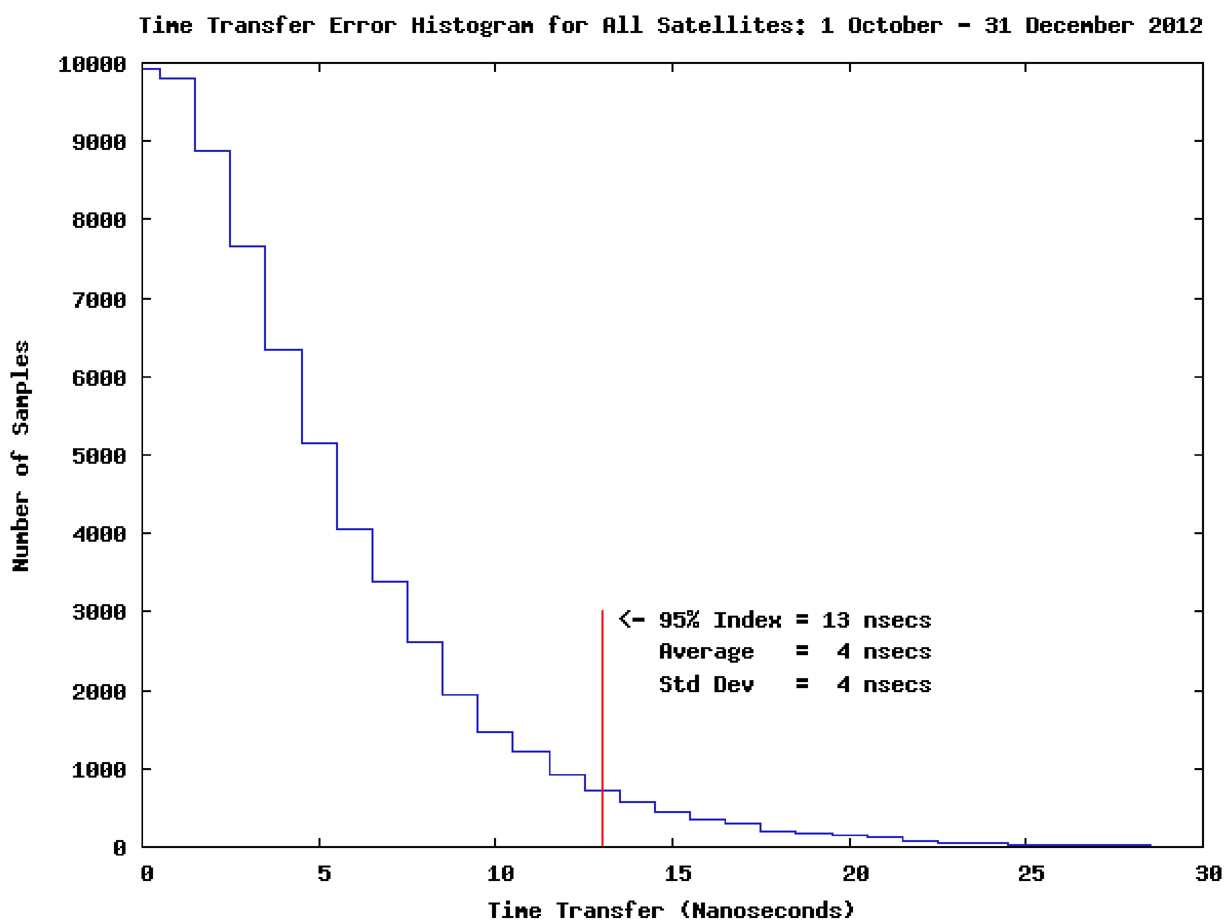
Figure 5-2 Global Horizontal Error Histogram



5.2 Time Transfer Accuracy

The GPS time error data between 1 October and 31 December 2012 was down loaded from USNO Internet site. The USNO data file contains the time difference between the USNO master clock and GPS system time for each GPS satellites during the time period. Over 10,000 samples of GPS time error are contained in the USNO data file. In order to evaluate the GPS time transfer error, the data file was used to create a histogram (Fig 5-3) to represent the distribution of GPS time error. The histogram was created by taking the absolute value of time difference between the USNO master clock and GPS system time, then creating data bins with one nanosecond precision. The number of samples in each bin was then plotted to form the histogram in Fig 5-3. The mean, standard deviation, and 95% index are within the requirements of GPS SPS time error.

Figure 5-3 Time Transfer Error



5.3 Range Domain Accuracy

Tables 5-3 through 5-5 provide the statistical data for the range error, range rate error and the range acceleration error for each satellite. This data was collected between 1 October and 31 December 2012. A weighted average filter was used for the calculation of the range rate error and the range acceleration error. All Range Domain SPS specifications were met.

Table 5-2 Range Error Statistics

(Meters)

PRN	RMS Range Error ($\leq$ 6 m)	Range Error Mean	1σ	95% Range Error	Max Range Error (SPS Spec. $\leq$ 30 m)	Samples
1	2.180	0.544	1.690	3.842	16.673	13200367
2	1.815	0.504	1.359	3.290	19.288	13798874
3	2.396	0.824	1.787	4.223	23.821	11699827
4	1.766	0.072	1.434	3.323	22.257	13090599
5	1.698	0.206	1.336	3.141	18.925	13108027
6	2.276	0.687	1.819	4.262	22.433	13036483
7	1.600	0.501	1.328	3.124	21.870	12137943
8	1.924	0.553	1.488	3.556	20.393	12479681
9	2.334	1.055	1.775	4.156	19.255	13620044
10	2.460	1.377	1.513	4.220	21.052	11747140
11	2.315	0.688	1.788	4.090	20.068	12253387
12	1.761	0.523	1.407	3.315	22.445	13703516
13	1.573	0.513	1.306	2.977	17.372	12522290
14	2.839	1.453	1.932	4.975	17.399	13844024
15	1.796	1.076	1.231	3.083	28.372	12321200
16	1.941	0.735	1.494	3.433	21.128	12772618
17	1.883	0.016	1.582	3.724	18.078	13889884
18	2.899	1.695	1.731	4.834	16.911	13045636
19	2.468	1.195	1.758	4.422	18.221	11862285
20	2.143	0.862	1.656	3.831	19.340	13680445
21	2.915	1.358	1.843	4.976	15.722	12311053
22	3.443	2.101	1.785	5.471	19.386	12326258
23	1.980	1.022	1.442	3.568	16.436	12055257
24	1.816	0.318	1.606	3.258	17.587	7478339
25	1.892	0.781	1.482	3.703	22.078	13853286
26	1.812	0.869	1.388	3.238	17.531	13082857
27	2.349	0.162	2.107	4.595	17.229	790577
28	1.926	0.949	1.316	3.515	18.572	12933604
29	1.986	0.363	1.504	3.614	21.543	12642243
30	2.520	1.304	1.822	4.552	23.887	11908503
31	2.142	0.528	1.699	4.023	26.069	13262179
32	2.519	1.274	1.663	4.339	18.213	12571616

Table 5-3 Range Rate Error Statistics

(Millimeters/ Second)

PRN	Range Rate Error RMS	95% Range Rate Error	Max Range Rate Error	Samples
1	1.552	2.913	184.880	13200367
2	1.594	2.939	170.550	13798874
3	2.031	3.272	169.390	11699827
4	1.600	2.907	150.650	13090599
5	1.610	3.032	184.390	13108027
6	1.737	3.098	144.870	13036483
7	1.506	2.829	113.780	12137943
8	1.917	3.269	141.370	12479681
9	1.925	3.118	171.880	13620044
10	2.011	3.139	170.550	11747140
11	1.744	3.108	144.600	12253387
12	1.678	3.172	201.580	13703516
13	1.637	3.138	143.870	12522290
14	1.637	3.168	102.570	13844024
15	1.558	2.977	114.660	12321200
16	1.639	3.175	138.720	12772618
17	1.710	3.167	129.250	13889884
18	1.643	3.163	162.870	13045636
19	1.617	3.119	127.650	11862285
20	1.740	3.283	166.790	13680445
21	1.673	3.217	132.900	12311053
22	1.675	3.137	155.530	12326258
23	1.573	3.032	168.570	12055257
24	1.694	2.984	130.120	7478339
25	1.517	2.906	151.250	13853286
26	1.488	2.785	127.970	13082857
27	3.648	3.901	152.730	790577
28	1.796	2.854	227.980	12933604
29	1.604	3.033	99.830	12642243
30	3.148	3.009	329.530	11908503
31	1.708	3.178	162.740	13262179
32	1.647	3.067	221.190	12571616

Table 5-4 Range Acceleration Error Statistics

(Micrometers/Second^2)

PRN	Range Acceleration Error RMS (μm/s^2)	95% Range Acceleration Error (μm/s^2)	Max Range Acceleration Error (μm/s^2)	Samples
1	10.836	21.516	1860	13200367
2	11.518	21.945	1700	13798874
3	14.454	23.093	1680	11699827
4	11.765	21.906	1520	13090599
5	11.329	22.209	1840	13108027
6	12.098	22.104	1460	13036483
7	10.789	22.005	1140	12137943
8	13.851	22.233	1410	12479681
9	14.293	22.264	1730	13620044
10	15.015	22.567	1690	11747140
11	12.156	22.374	1450	12253387
12	11.702	22.362	2010	13703516
13	11.073	22.562	1450	12522290
14	10.814	22.053	1020	13844024
15	10.756	22.196	1120	12321200
16	11.202	22.730	1380	12772618
17	11.981	22.035	1290	13889884
18	10.878	22.295	1610	13045636
19	10.678	22.512	1260	11862285
20	11.456	22.287	1660	13680445
21	11.029	22.347	1340	12311053
22	11.273	21.926	1550	12326258
23	10.582	22.059	1680	12055257
24	12.408	21.874	1310	7478339
25	10.930	21.378	1510	13853286
26	10.883	21.770	1270	13082857
27	30.784	25.042	1520	790577
28	13.744	21.882	2280	12933604
29	11.279	21.726	1000	12642243
30	26.479	22.525	3280	11908503
31	11.280	22.304	1610	13262179
32	11.036	21.178	2220	12571616

Figures 5-4, 5-5 and 5-6 are graphical representations of the distributions of the maximum range error, range rate error and range acceleration error for all satellites. The highest maximum range error occurred on satellite 15 with an error of 28.372 meters. Satellite 21 had the lowest maximum range error of 15.722 meters.

Figure 5-4 Distribution of Daily Max Range Errors

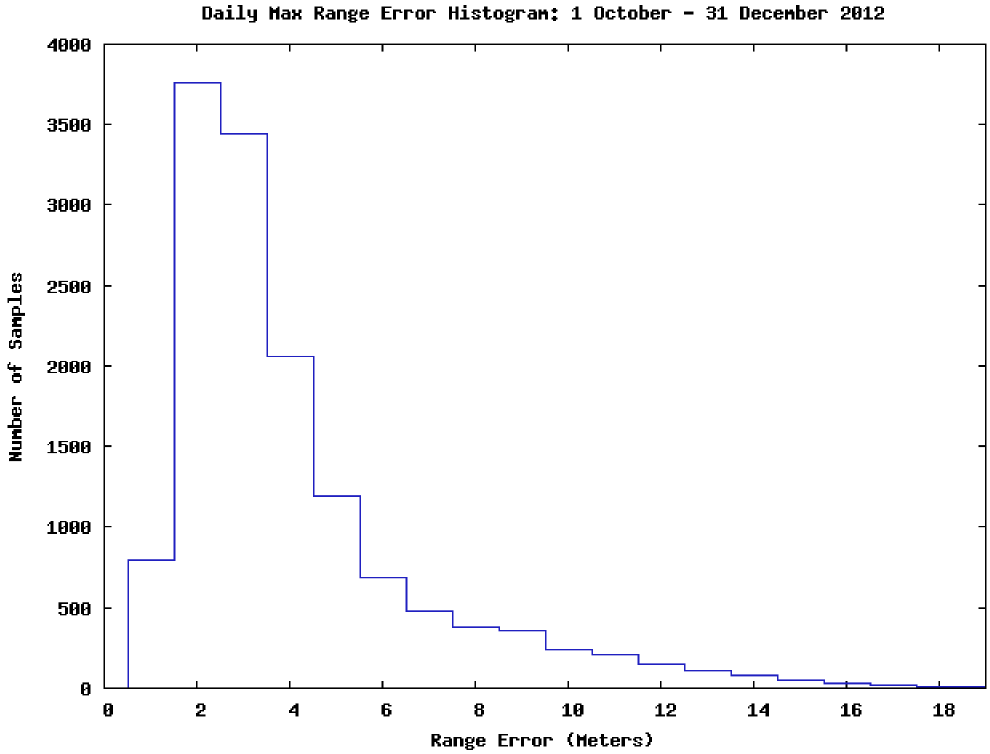


Figure 5-5 Distribution of Daily Max Range Rate Errors

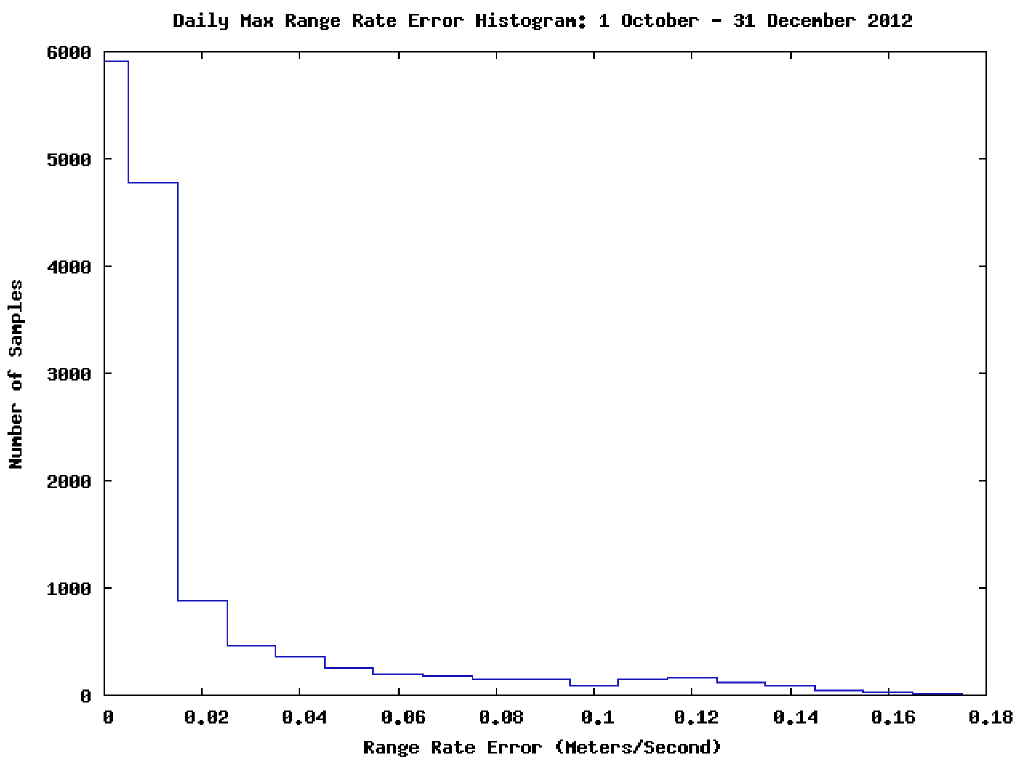


Figure 5-6 Distribution of Daily max Range Acceleration Errors

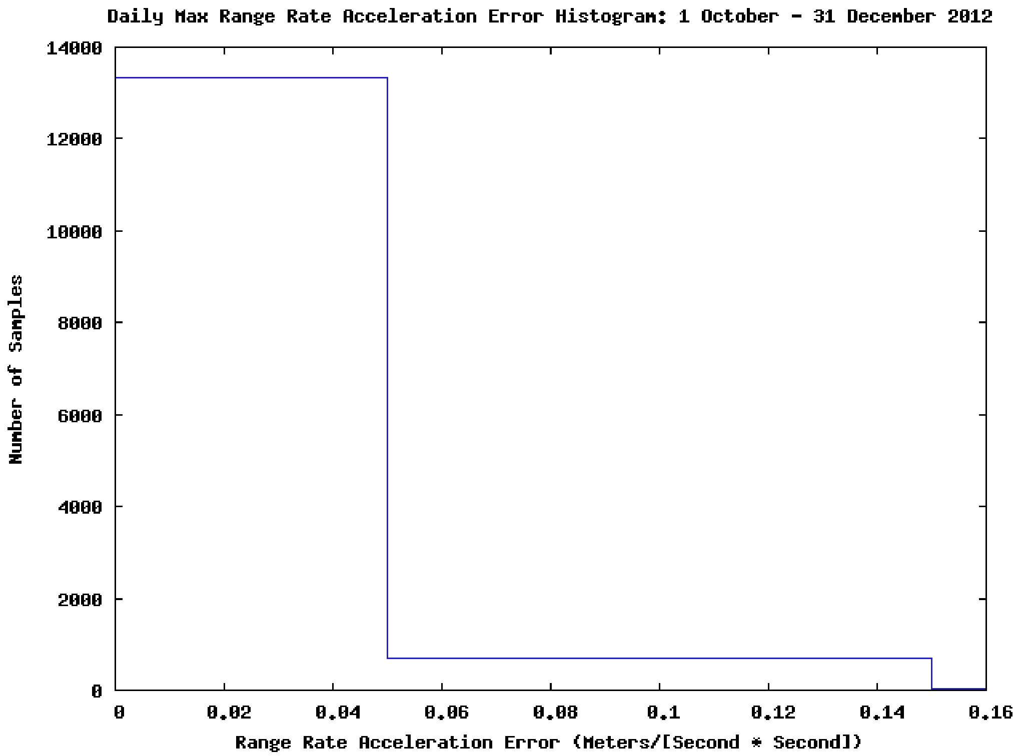


Figure 5-7 Range Error Histogram

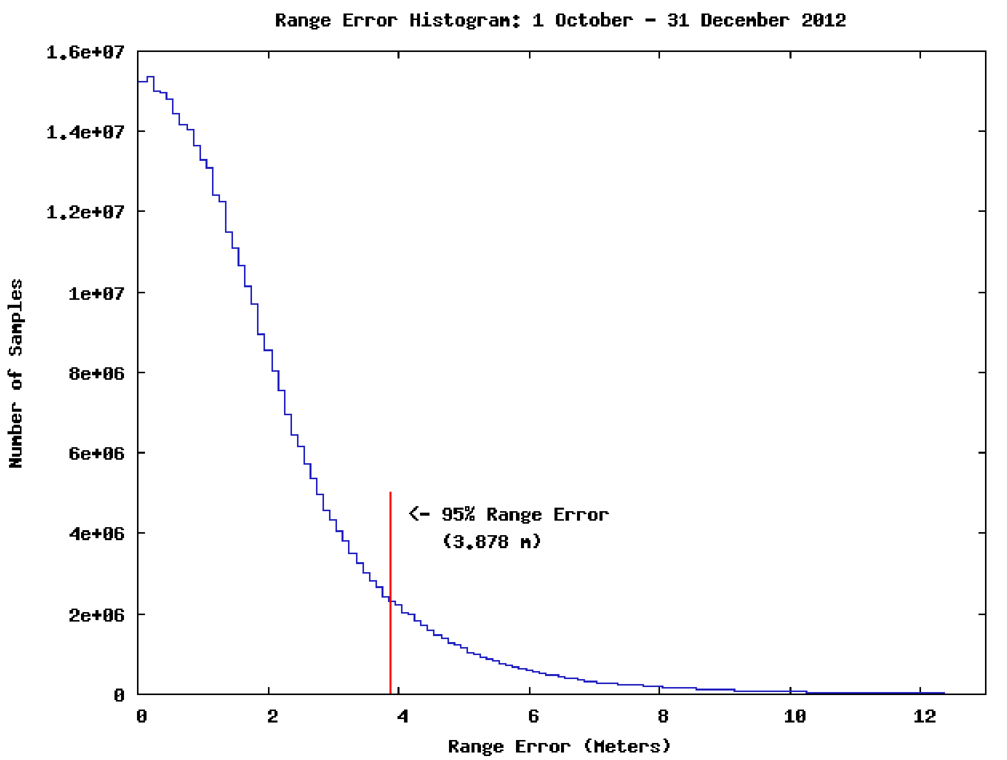


Figure 5-8 Maximum Range Error Per Satellite

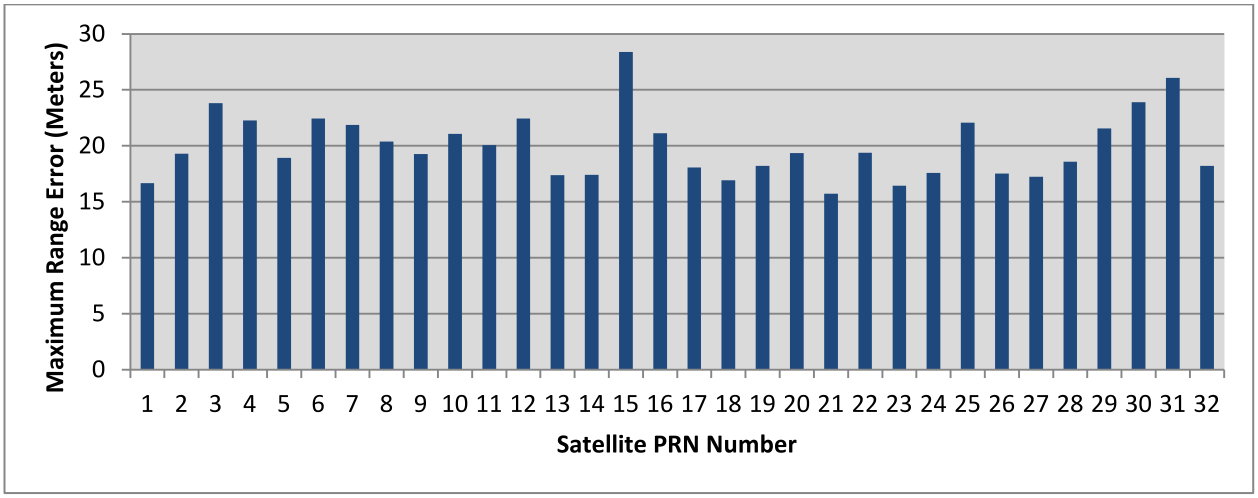


Figure 5-9 Maximum Range Rate Error Per Satellite

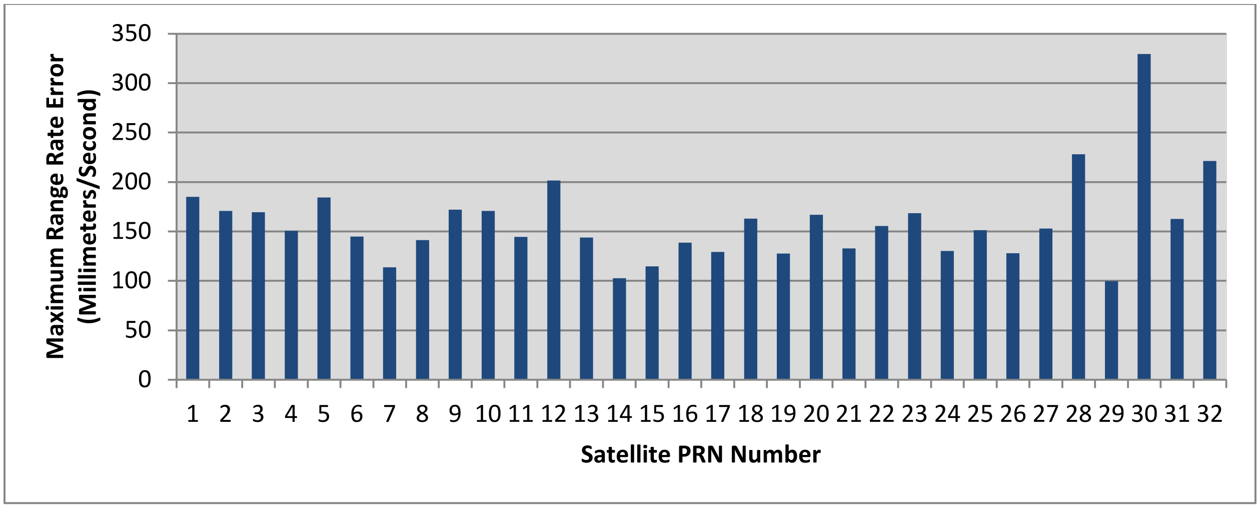
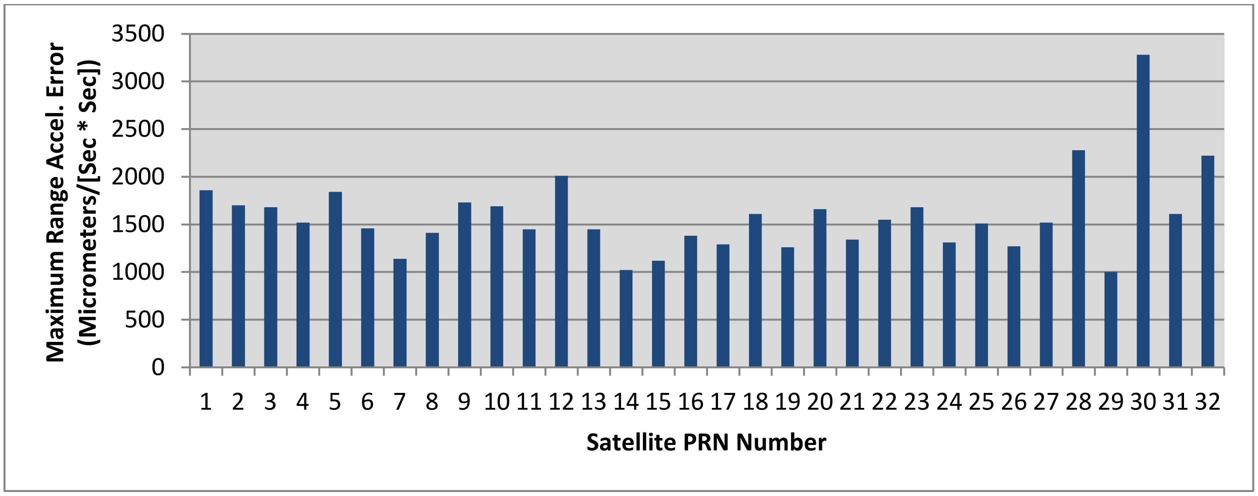


Figure 5-10 Maximum Range Acceleration Error Per Satellite



6 Solar Storms

Solar storm activity is being monitored in order to assess the possible impact on GPS SPS performance. Solar activity is reported by the Space Weather Prediction Center (SWPC) , a division of the National Oceanic and Atmospheric Administration (NOAA). When storm activity is indicated, ionospheric delays of the GPS signal, satellite outages, position accuracy and availability will be analyzed.

The following article was taken from the SEC web site http://swpc.noaa.gov. It briefly explains some of the ideas behind the association of the aurora with geomagnetic activity and a bit about how the 'K-index' or 'K-factor' works.

> *The aurora is caused by the interaction of high-energy particles (usually electrons) with neutral atoms in the earth's upper atmosphere. These high-energy particles can 'excite' (by collisions) valence electrons that are bound to the neutral atom. The 'excited' electron can then 'de-excite' and return back to its initial, lower energy state, but in the process it releases a photon (a light particle). The combined effect of many photons being released from many atoms results in the aurora display that you see.*
>
> *The details of how high energy particles are generated during geomagnetic storms constitute an entire discipline of space science in its own right. The basic idea, however, is that the Earth's magnetic field (let us say the 'geomagnetic field') is responding to an outwardly propagating disturbance from the Sun. As the geomagnetic field adjusts to this disturbance, various components of the Earth's field change form, releasing magnetic energy and thereby accelerating charged particles to high energies. These particles, being charged, are forced to stream along the geomagnetic field lines. Some end up in the upper part of the earth's neutral atmosphere and the auroral mechanism begins.*
>
> *An instrument called a magnetometer may also measure the disturbance of the geomagnetic field. At NOAA's operations center magnetometer data is received from dozens of observatories in one-minute intervals. The data is received at or near to 'real-time' and allows NOAA to keep track of the current state of the geomagnetic conditions. In order to reduce the amount of data NOAA converts the magnetometer data into three-hourly indices, which give a quantitative, but less detailed measure of the level of geomagnetic activity. The K-index scale has a range from 0 to 9 and is directly related to the maximum amount of fluctuation (relative to a quiet day) in the geomagnetic field over a three-hour interval.*
>
> *The K-index is therefore updated every three hours. The K-index is also necessarily tied to a specific geomagnetic observatory. For locations where there are no observatories, one can only estimate what the local K-index would be by looking at data from the nearest observatory, but this would be subject to some errors from time to time because geomagnetic activity is not always spatially homogenous.*
>
> *Another item of interest is that the location of the aurora usually changes geomagnetic latitude as the intensity of the geomagnetic storm changes. The location of the aurora often takes on an 'oval-like' shape and is appropriately called the auroral oval.*

Figures 6-1 through 6-3 show the K-index for three time periods with significant solar activity. Although there were other days with increased solar activity, these time periods were selected as examples. (See Appendix B for the actual geomagnetic data for this reporting period.)

Figure 6-1 K-Index for 30 September-2 October 2012

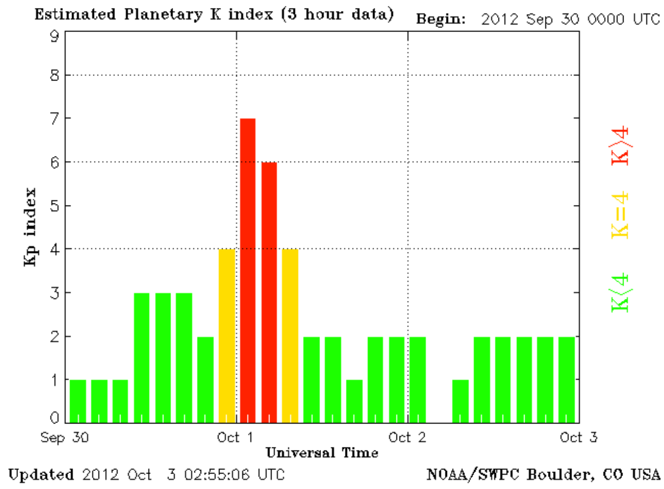


Figure 6-2 K-Index for 8-10 October 2012

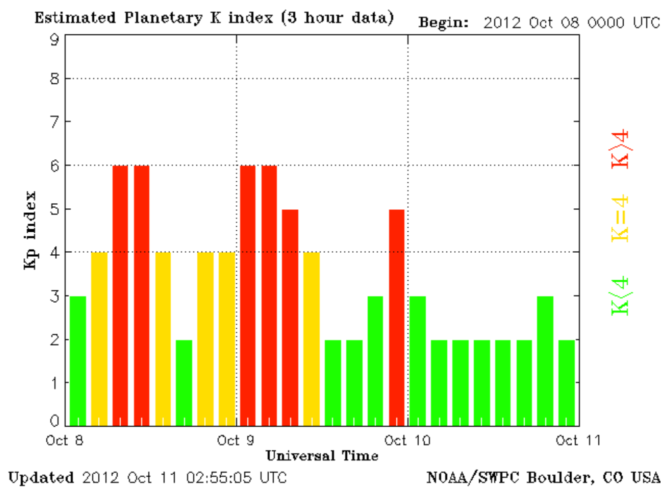


Figure 6-3 K-Index for 12-14 October 2012

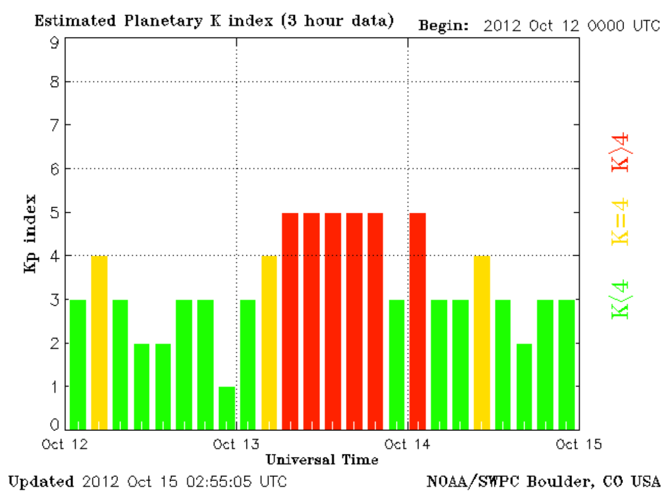


Table 6-1 shows the position accuracy information for the day corresponding to Figure 6-1. The GPS SPS performance met all requirements during all storms that occurred during this quarter.

Table 6-1 Horizontal & Vertical Accuracy Statistics for October 1, 2012

Site	95% Horizontal (Meters)	95% Vertical (Meters)	Maximum Horizontal (Meters)	Maximum Vertical (Meters)
Albuquerque	3.578	4.943	4.373	6.132
Anchorage	2.826	4.370	4.538	5.274
Atlanta	3.880	6.021	5.231	7.779
Barrow	2.516	5.195	3.862	7.052
Bethel	3.174	4.282	4.072	5.435
Billings	2.534	3.351	3.231	4.246
Boston	2.32	6.140	2.698	8.072
Cleveland	2.436	6.287	3.037	7.358
Cold Bay	3.300	4.218	5.012	4.837
Fairbanks	2.388	7.517	3.461	13.032
Gander	2.646	4.294	3.915	4.791
Honolulu	7.460	8.267	9.335	13.440
Houston	5.053	5.884	5.738	7.970
Iqaluit	2.808	3.395	4.228	5.310
Juneau	3.106	4.953	4.773	9.760
Kansas City	3.504	5.123	3.813	7.008
Kotzebue	2.856	6.517	3.453	11.577
Los Angeles	2.607	4.148	3.173	5.645
Merida	4.661	6.836	6.483	10.628
Miami	5.744	6.450	6.577	9.003
Minneapolis	2.132	4.593	2.878	5.833
Oakland	2.724	4.910	3.600	6.477
Salt Lake City	3.627	4.283	3.851	7.118
San Jose Del Cabo	5.091	8.192	10.465	14.396
San Juan	Site	Down	No Data	Available
Seattle	2.722	3.543	3.356	4.426
Tapachula	7.898	12.734	12.121	17.44
Washington, DC	2.477	6.647	3.861	7.947

7 IGS Data

GPS SPS accuracy performance was evaluated at a selection of high rate IGS stations[1]. The IGS is a voluntary federation of many worldwide agencies that pool resources and permanent GNSS station data to generate precise GNSS products.

High data rate (1 Hz) sites with good availability that were outside of the WAAS service area, and provided a good geographic distribution have been selected. To facilitate differentiating between GPS accuracy issues and receiver tracking problems, an automatic data screening function excluded errors greater than 500 meters and or times when VDOP or HDOP were greater than 10. See Figure 7-4 to 7-5 for example plots. The remaining receiver tracking issues are still included in the processing and are forced into the 50.1 meter histogram bin and are believed to influence the outliers in the 99.99% statistics.

High quality broadcast navigation data and Klobachar model data is created by voting across all available IGS high rate RINEX navigation data.

Table 7.1 and Figure 7-1 show the IGS site information and locations. Table 7.2 shows the GPS SPS Accuracy Performance observed at a selection of High Rate IGS sites. Figure 7-2 shows the 95% horizontal accuracy trends at these sites. Figure 7-3 shows the 95% vertical accuracy trends at these sites. A value of zero indicates no data. SANT being an outlier in Figure 7-2 is believed to be due to limitations of the Klobuchar model.

Figure 7-4 shows an example of a suspected receiver tracking issue (IISC outlier on Day 350). Figure 7-5 shows an example of SANT increased ionosphere errors due to the limitations of the Klobuchar model (trend in first part of the plot Figure 7-5) and tracking issues caused by scintillation associated with the magnetic equatorial anomalies (outlier glitches).

(1) J.M. Dow, R.E. Neilan, G. Gendt, "The International GPS Service (IGS): Celebrating the 10th Anniversary and Looking to the Next Decade," Adv. Space Res. 36 vol. 36, no. 3, pp. 320-326, 2005. Doi: 10.1016/j.asr.2005.05.125

Table 7-1 Selected IGS Site Information

ID	City	Country
BOGT	Bogota	Columbia
GUAM	Dededo	Guam
IISC	Bangalore	India
KIRU	Kiruna	Sweden
KOUR	Kourou	French Guyana
MADR	Robledo	Spain
MAL2	Malindi	Kenya
MAS1	Maspalomas	Spain
MATE	Matera	Italy
MOBN	Obninsk	Russian Federation
NNOR	New Norcia	Australia
NRIL	Norilsk	Russian Federation
PETS	Petropavlovsk-Kamchatka	Russian Federation
POL2	Bishkek	Kyrghyzstan
SANT	Santiago	Chile
SUTM	Sutherland	South Africa
TIDB	Tidbinbilla	Australia
UNSA	Salta	Argentina
USUD	Usuda	Japan

Figure 7-1 Selected IGS Site Locations

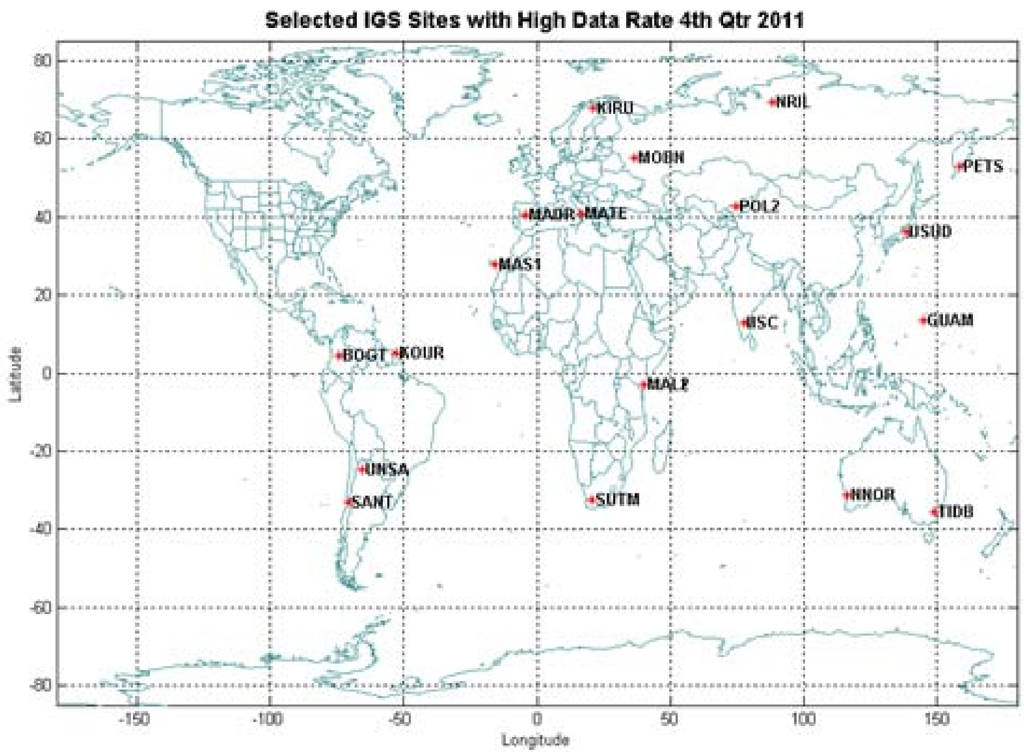


Table 7-2 GPS SPS Performance at Selected High Rate IGS Sites

Site	95% Horizontal Error (m)	95% Vertical Error (m)	99.99% Horizontal Error (m)	99.99% Vertical Error (m)	Percent Data Available
BOGT	6.84	7.38	14.37	46.26	26.84%
GLPS	4.02	4.91	8.33	16.42	27.14%
GUAM	3.25	6.29	8.70	18.73	99.02%
IISC	4.32	6.95	26.90	23.25	96.65%
KIRU	2.46	6.77	6.13	13.01	99.89%
MAL2	5.12	5.45	11.20	14.63	93.86%
MATE	2.61	5.39	10.34	13.50	95.74%
MOBN	2.58	6.67	6.43	12.27	99.87%
NRIL	2.23	6.67	5.49	15.08	98.76%
PETS	2.46	7.41	6.51	12.83	99.99%
POL2	2.36	7.11	13.78	32.44	85.13%
SANT	8.20	6.05	16.79	18.50	95.38%
SUTM	2.62	4.55	6.00	10.02	94.42%
TIDB	2.50	4.78	12.19	19.24	91.31%
UNSA	3.87	7.22	20.70	49.05	26.20%
USUD	3.21	7.11	11.00	16.00	100.00%

Figure 7-2 GPS SPS 95% Horizontal Accuracy Trends at Selected IGS Sites

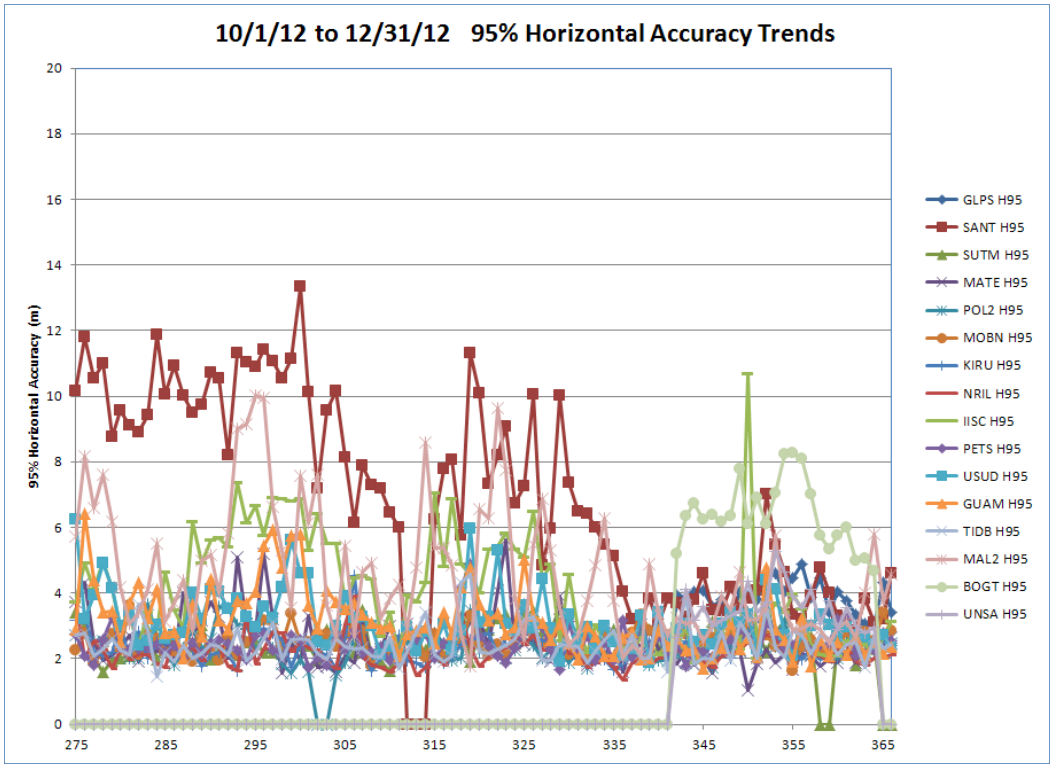


Figure 7-3 GPS SPS 95% Vertical Accuracy Trends at Selected IGS Sites

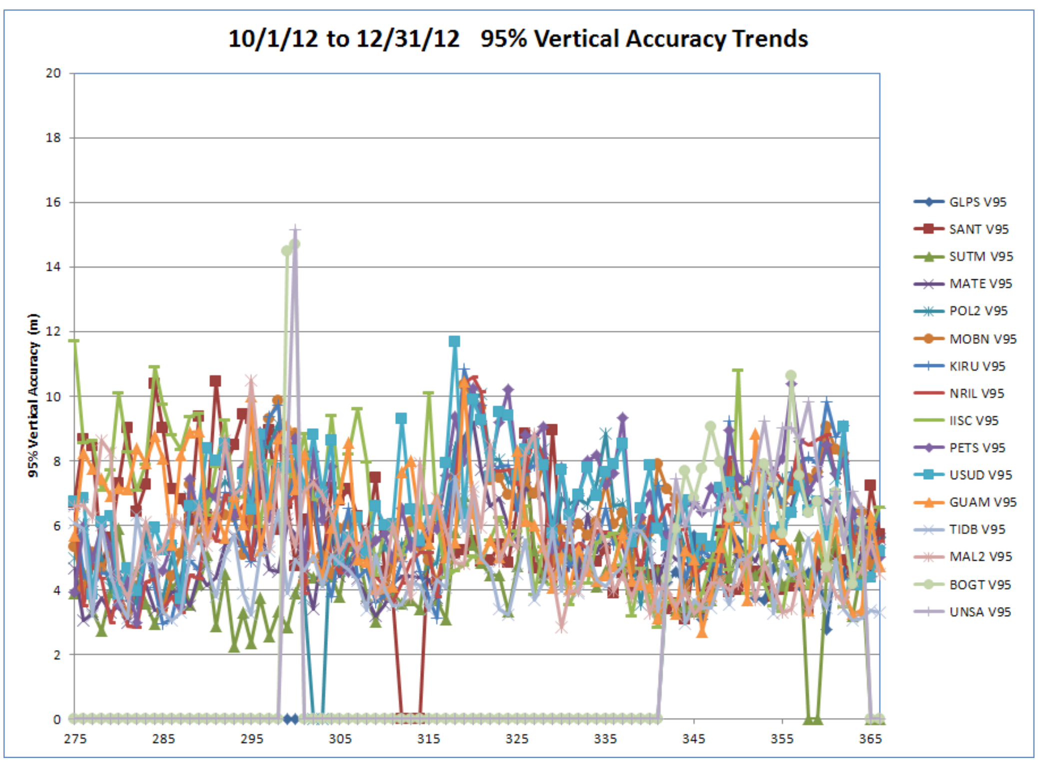


Figure 7-4 Example Receiver Tracking Problem

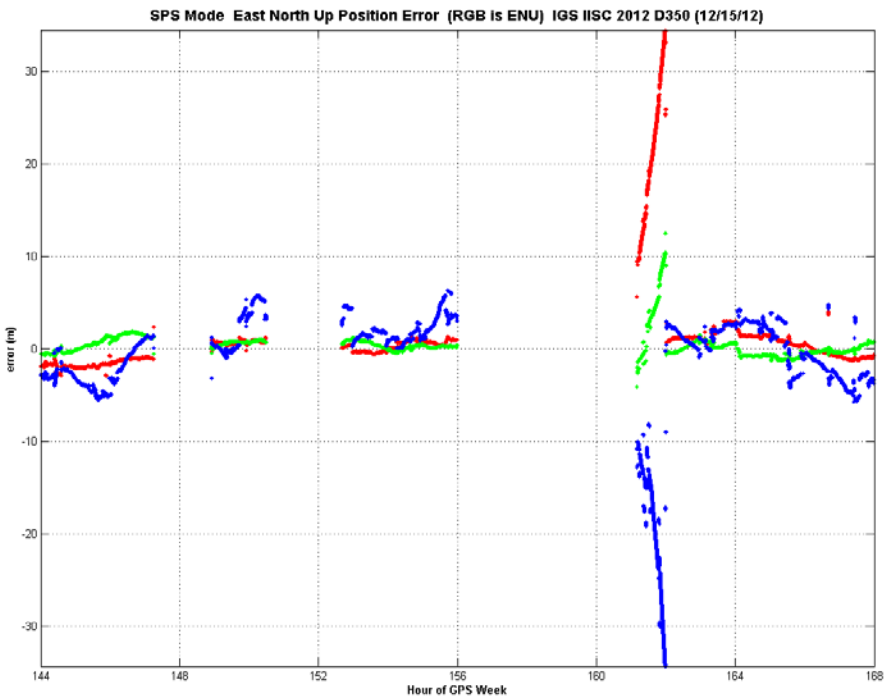
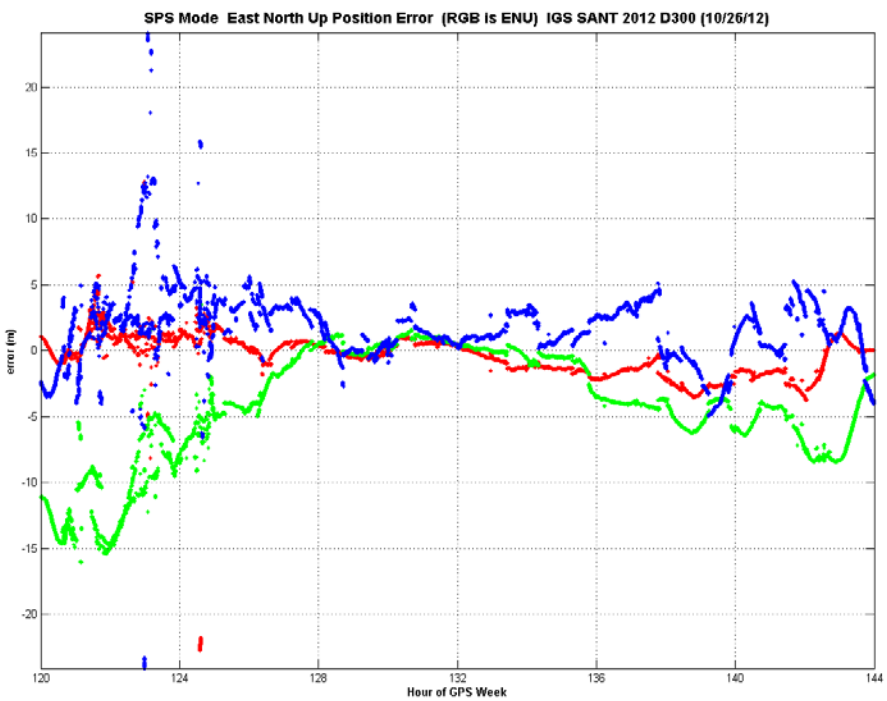


Figure 7-5 Example Receiver Tracking Problem



8 GPS Test NOTAMs Summary

GPS test NOTAM: Global Positioning System test Notices to Airmen - GPS test NOTAMs are issued in the event that GPS is predicted to be unreliable and/or unavailable at a defined location for specific times, as indicated in the NOTAM, due to scheduled testing events.

Status and Problem Reporting	Conditions and Constraints
Scheduled event affecting service • Appropriate GPS Test NOTAM issued to the FAA at least 5 hours prior to the event	• For any SPS SIS

8.1 GPS Test NOTAMs Issued

GPS test NOTAMs were tracked and trended from GPS test NOTAMs posted on the FAA PilotWeb website (https://pilotweb.nas.faa.gov/PilotWeb/). During this reporting period, October 1 through December 31 2012, there were a total of 27 GPS test NOTAMs. The total number of days affected in this reporting period is 33. Tables 8.1 and 8.2 below list the statistics of areas affected and durations. Note that the durations are on a per GPS test NOTAM basis.

Table 8-1 GPS test NOTAM Durations

Cumulative duration	147 hours
Minimum duration	0.5 hours
Average duration	4.3 hours
Maximum duration	17 hours

Table 8-2 GPS Test NOTAM Affected Areas (Square Miles) by Altitude

	40,000 feet	25,000 feet	10,000 feet	4,000 feet	50 feet
Minimum	936	936	936	936	936
Average	524,053	389,937	227,921	218,175	169,267
Maximum	907,335	730,402	483,774	492,324	379,444

8.2 Tracking and Trending of GPS Test NOTAMs

The GPS Test NOTAMs that are tracked and trended for this reporting period were done with a specialized software analysis tool that is designed to not only trend but also archive GPS Test NOTAMs. It is designed to trend archived GPS Test NOTAMs for any specified time frame. In addition to the data provided in this report, this tool provides all affected RNAV routes and procedures for each NOTAM in a web interface format. It can be accessed at the following link: **http://waas.faa.gov/ess/gps_test_outage/index.html**

The four plots below illustrate a visual depiction of the affected areas at their corresponding altitudes along with the impacted RNAV routes (indicated in red). Note that some GPS Test NOTAMs occupy the same area and position but differ in effective dates and/or durations.

Figure 8-1 GPS Test NOTAMs @ FL400

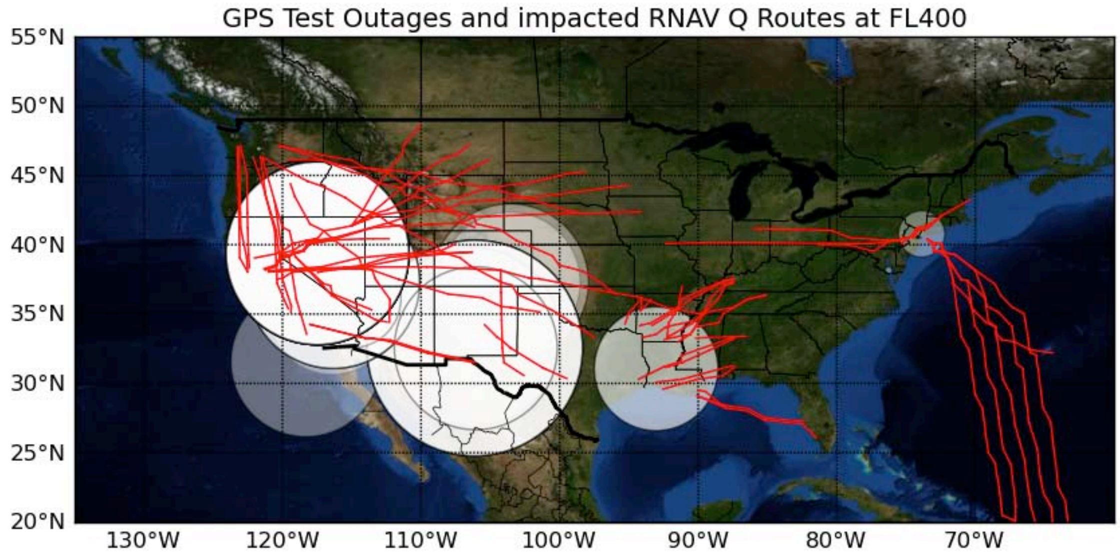


Figure 8-2 GPS NOTAMs @ FL250

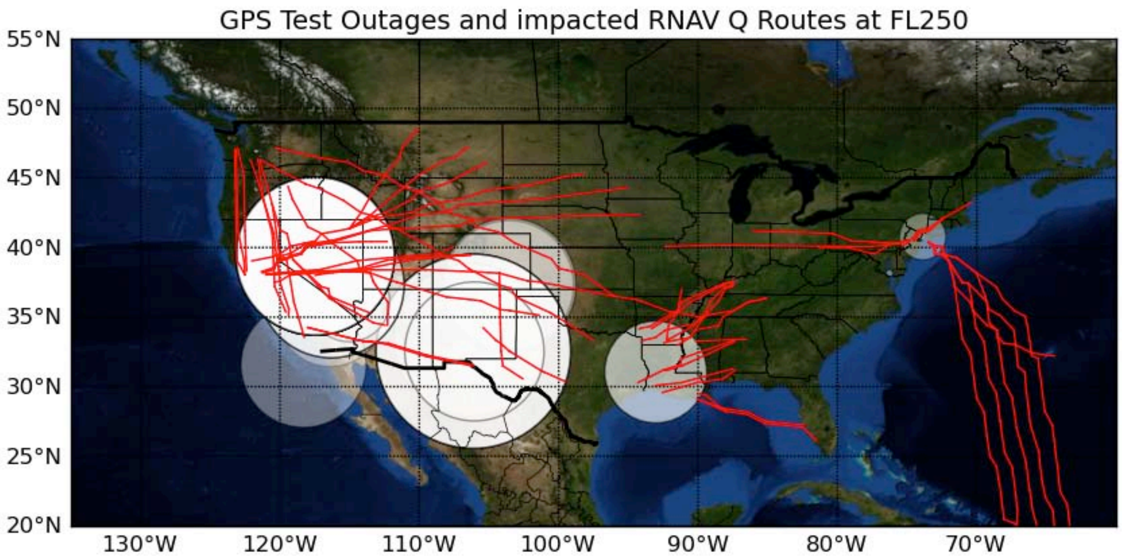


Figure 8-3 GPS NOTAMs @ 10k Feet

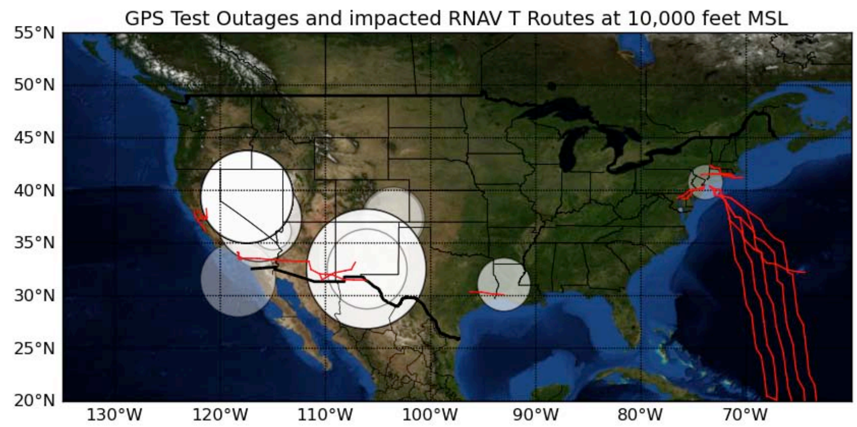


Figure 8-4 GPS NOTAMs @ 4k Feet

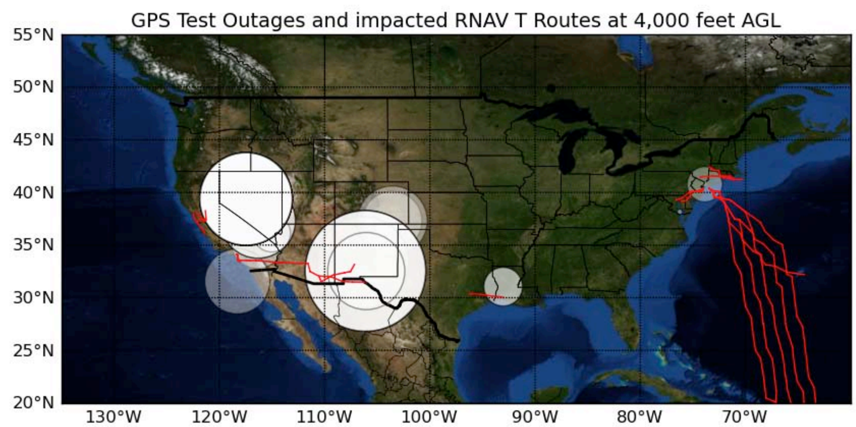
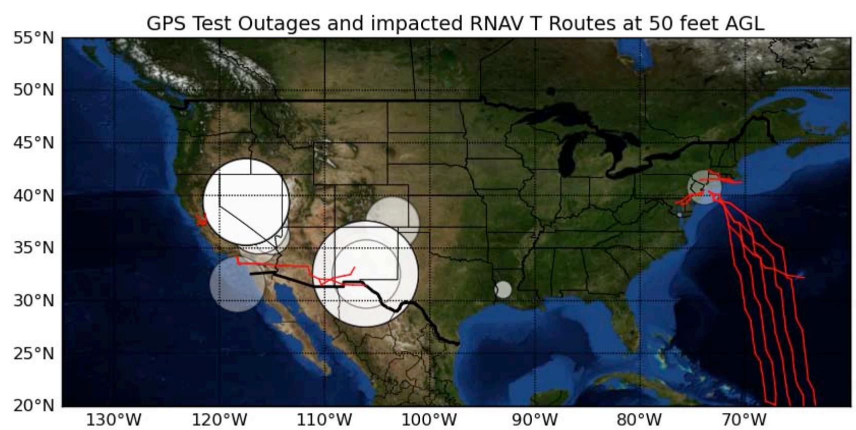


Figure 8-5 GPS NOTAMs @ 50 Feet



8.3 GPS Availability

The impacts to GPS availability are listed below for the corresponding locations and times. The percentage impact to GPS availability indicates that GPS is impacted for *X* % of the total time that the GPS Test NOTAM is active within the indicated area, centered at the indicated latitude/longitude. The radius column indicates the distance from the latitude/longitude for which the impacted GPS availability extends. Note that the radius listed is for an altitude of 40,000 feet. The impact to GPS availability at lower altitudes is the same. Each row of the following table represents one GPS Test NOTAM. The remaining tables each represent one GPS Test NOTAM.

Table 8-3 NOTAM Impact to GPS Availability

DATE	TIME	Location(lat/lon)	Percent impact to GPS availability over CONUS by altitude (feet)				
			≤50	50 to 4K	4K to 10K	10K to 25K	25K to 40K
October 8 – 9	17:00 – 22:00	37.2954N/103.5741W	2.47	3.30	3.19	8.87	10.4
October 9	17:00 – 22:00	37.3003N/103.5621W	2.78	4.43	3.71	9.49	12.7
October 14 – 22	00:00 – 17:00	31.0535N/93.0350W	0.20	1.13	2.16	4.85	6.81
October 16 – 20	02:00 – 12:00	33.3747N/106.3400	3.81	6.60	6.60	9.90	13.4
October 23	00:00 – 05:00	31.0535N/93.0350W	0.20	1.13	2.16	4.85	6.81
November 1 – 9	07:00 – 12:00	35.2635N/116.3856W	1.34	2.37	2.68	5.26	7.22
November 1	00:00 – 02:00	40.7772N/73.8752W	1.13	1.13	1.13	1.13	1.13
November 3 – 4	13:00 – 15:00	31.5700N/118.3000W	0.82	1.03	1.44	2.47	3.50
November 3 – 5	19:00 – 23:00	32.5447N/106.1206W	8.04	10.1	10.0	14.2	17.1
November 4	03:00 – 07:00	32.5447N/106.1206W	8.04	10.1	10.0	14.2	17.1
November 5 – 6	02:00 – 07:00	32.5447N/106.1206W	8.04	10.1	10.0	14.2	17.1

November 8 – 9	02:00 – 11:00	32.5447N/106.1206W	8.04	10.1	10.0	14.2	17.1
November 9	19:00 – 23:00	32.5447N/106.1206W	8.04	10.1	10.0	14.2	17.1
December 1	01:30 – 06:00	37.3036N/116.3257W	3.30	5.15	6.70	10.5	13.9
December 8	03:00 – 09:00	37.3036N/116.3257W	3.30	5.15	6.70	10.5	13.9
December 8	00:00 – 03:00	36.1307N/115.0308W	1.13	1.13	1.13	3.30	5.26
December 9	16:00 – 19:00	36.1307N/115.0308W	1.13	1.13	1.13	3.30	5.26
December 10	00:00 – 04:00	37.3036N/116.3257W	3.30	5.15	6.70	10.5	13.9
December 10 – 14	13:00 – 22:00	38.1541N/76.2612W	<0.10	<0.10	<0.10	<0.10	<0.10
December 11 – 15	02:00 – 12:00	32.5330N/106.0456W	3.61	4.74	5.05	7.84	10.3
December 14	01:30 – 03:30	39.3835N/117.4702W	7.01	8.04	7.94	12.7	15.9
December 17	21:30 – 23:00	39.3835N/117.4702W	7.01	8.04	7.94	12.7	15.9
December 20	00:01 – 04:00	39.3835N/117.4702W	7.01	8.04	7.94	12.7	15.9

DATE	**TIME**	**Location(lat/lon)**	**Percent impact to GPS availability over CONUS by altitude (feet)**				
			≤50	**50 to 4K**	**4K to 10K**	**10K to 25K**	**25K to 40K**
December 12	22:30 – 23:59	39.3835N/117.4702W	7.01	8.04	7.94	12.7	15.9
December 12	19:00 – 21:00	39.3835N/117.4702W	c	8.04	7.94	12.7	15.9

DATE	TIME	Location(lat/lon)	Percent impact to GPS availability over CONUS by altitude (feet)				
			≤50	50 to 4K	4K to 10K	10K to 25K	25K to 40K
December 12	22:30 – 23:59	39.3835N/117.4702W	7.01	8.04	7.94	12.7	15.9
December 12	19:00 – 21:00	39.3835N/117.4702W	c	8.04	7.94	12.7	15.9

DATE	TIME	Location(lat/lon)	Percent impact to GPS availability over CONUS by altitude (feet)				
			≤50	50 to 4K	4K to 10K	10K to 25K	25K to 40K
December 13	22:30 – 23:59	39.3835N/117.4702W	7.01	8.04	7.94	12.7	15.9
December 13	20:00 – 21:00	39.3835N/117.4702W	7.01	8.04	7.94	12.7	15.9
December 13	02:30 – 04:00	39.3835N/117.4702W	7.01	8.04	7.94	12.7	15.9
December 13 – 14	00:01 – 00:30	39.3835N/117.4702W	7.01	8.04	7.94	12.7	15.9

DATE	TIME	Location(lat/lon)	Percent impact to GPS availability over CONUS by altitude (feet)				
			≤50	50 to 4K	4K to 10K	10K to 25K	25K to 40K
December 18	17:00 – 18:30	39.3835N/117.4702W	7.01	8.04	7.94	12.7	15.9
December 18 – 19	02:00 – 05:00	39.3835N/117.4702W	7.01	8.04	7.94	12.7	15.9
December 18	21:30 – 23:00	39.3835N/117.4702W	7.01	8.04	7.94	12.7	15.9

DATE	TIME	Location(lat/lon)	Percent impact to GPS availability over CONUS by altitude (feet)				
			≤50	50 to 4K	4K to 10K	10K to 25K	25K to 40K
December 19	02:00 – 05:00	39.3835N/117.4702W	7.01	8.04	7.94	12.7	15.9
December 19	18:00 – 23:59	39.3835N/117.4702W	7.01	8.04	7.94	12.7	15.9

9 Appendices

9.1 Appendix A: Performance Summary

Table 9-1 Performance Summary

User Range Error Accuracy	**Conditions and Constraints**	**Measured Performance**
Single Frequency C/A-Code • ≤ 7.8m 95% Global Average URE during normal operations over All AODs • ≤ 6.0m 95% Global Average URE during operations at Zero AOD • ≤ 12.8m 95% Global Average URE during normal operations at Any AOD	• For any healthy SPS SIS • Neglecting single-frequency ionospheric delay model errors • Including group delay time correction (T_{GD}) errors at L1 • Including inter-signal bias (P(Y)-code to C/A-code) errors at L1	≤ 3.878 m N/A N/A
Single Frequency C/A-Code • ≤ 30m 99.94% Global Average URE during normal operations • ≤ 30m 99.79% Worst Case single point average during normal operations.	• For any healthy SPS SIS. • Neglecting single-frequency ionospheric delay model errors • Including group delay time correction (T_{GD}) errors at L1 • Including inter-signal bias (P(Y)-code to C/A-code) errors at L1 • Standard based on measurement interval of one year; average of daily values within service volume • Standard based on 3 service failures per year, lasting no more than 6 hours each	100% Global 100% WCP
User Range Rate Error Accuracy	**Conditions and Constraints**	
Single-Frequency C/A-Code: • ≤ 6 mm/sec 95% Global Average URRE over any 3-second interval during normal operations at Any AOD	• For any healthy SPS SIS • Neglecting all perceived pseudorange rate errors attributable to pseudorange step changes caused by NAV message data cutovers • Neglecting single-frequency ionospheric delay model errors	≤ 3.097 mm/sec
User Range Acceleration Error Accuracy	**Conditions and Constraints**	
Single-Frequency C/A-Code: • ≤ 2 mm/sec^2 95% Global average URAE over any 3-second interval during normal operations at Any AOD	• For any healthy SPS SIS • Neglecting all perceived pseudorange rate errors attributable to pseudorange step changes caused by NAV message data cutovers • Neglecting single-frequency ionospheric delay model errors	≤ 0.022 mm/s^2

Status and Problem Reporting	**Conditions and Constraints**	**Measured Performance**
Scheduled event affecting service • Appropriate NANU issued to the Coast Guard and the FAA at least 48 hours prior to the event	• For any SPS SIS	≥ 36.3 hours Prior to event
Unscheduled outage or problem affecting service • Appropriate NANU issued to the Coast Guard and the FAA as soon as possible after the event	• For any SPS SIS	< 7 minutes
Operational Satellite Count	**Conditions and Constraints**	
• ≥ 0.95 Probability that the constellation will have at least 24 operational satellites regardless of whether those operational satellites are located in slots or not	• Applies to the total number of operational satellites in the constellation (averaged over any day); where any satellite which appears in the transmitted navigation message almanac is defined to be an operation satellite regardless of whether that satellite is currently broadcasting a healthy SPS SIS or not and regardless of whether the broadcast SPS SIS also satisfies the other performance standards in the SPS performance standard or not.	100%
PDOP Availability	**Conditions and Constraints**	
• ≥ 98% global PDOP of 6 or less • ≥ 88% worst site PDOP of 6 or less	• Defined for a position/time solution meeting the representative user conditions and operating within the service volume over any 24-hour interval	100 % 100 %
Service Availability	**Conditions and Constraints**	
• ≥ 99% Horizontal Service Availability, average location • ≥ 99% Vertical Service Availability, average location	• 17m Horizontal (SIS only) 95% threshold • 37m Vertical (SIS only) 95% threshold • Defined for a position/time solution meeting the representative user conditions and operating within the service volume over any 24-hour interval.	100% Horizontal 100% Vertical
• ≥ 90% Horizontal Service Availability, worst-case location • ≥ 90% Vertical Service Availability, worst-case location	• 17m Horizontal (SIS only) 95% threshold • 37m Vertical (SIS only) 95% threshold • Defined for a position/time solution meeting the representative user conditions and operating within the service volume over any 24-hour interval.	100% Horizontal 100% Vertical
Position/Time Accuracy	**Conditions and Constraints**	
Global Average Position Domain Accuracy • ≤ 9m 95% Horizontal Error • ≤ 15m 95% Vertical Error	• Defined for a position/time solution meeting the representative user conditions • Standard based on a measurement interval of 24 hours averaged over all points in the service volume.	≤ 2.742 m Horizontal ≤ 5.708 m Vertical
Worst Site Position Domain Accuracy • ≤ 17m 95% Horizontal Error • ≤ 37m 95% Vertical Error	• Defined for a position/time solution meeting the representative user conditions • Standard based on a measurement interval of 24 hours averaged over all points in the service volume.	≤ 8.261 m Horiz. ≤ 9.105 m Vert.
Time Transfer Domain Accuracy • ≤ 40 nanoseconds time transfer error 95% of time (SIS only)	• Defined for a time transfer solution meeting the representative user conditions • Standard based on a measurement interval of 24 hours averaged over all points in the service volume.	≤ 13 nanoseconds

Per-Slot Availability	Conditions and Constraints	
• ≥ 0.957 Probability that a slot in the baseline 24-slot configuration will be occupied by a satellite broadcasting a healthy SPS SIS • ≥ 0.957 Probability that a slot in the expanded configuration will be occupied by a pair of satellites each broadcasting a healthy SPS SIS	• Calculated as an average over all slots in the 24-slot constellation, normalized annually • Applies to satellites broadcasting a healthy SPS SIS that also satisfy the other performance standards in the SPS performance standard.	100% 100%
Constellation Availability	**Conditions and Constraints**	
• ≥ 0.98 Probability that at least 21 slots out of the 24 will be occupied either by a satellite broadcasting a healthy SPS SIS in the baseline 24-slot configuration or by a pair of satellites each broadcasting a healthy SPS SIS in the expanded slot configuration • ≥ 0.99999 Probability that at least 20 slots out of the 24 will be occupied either by a satellite broadcasting a healthy SPS SIS in the baseline 24-slot configuration or by a pair of satellites each broadcasting a healthy SPS SIS in the expanded slot configuration	• Calculated as an average over all slots in the 24-slot constellation, normalized annually. • Applies to satellites broadcasting a healthy SPS SIS that also satisfies the other performance standards in the SPS performance standard.	100% 100%

9.2 Appendix B: Geomagnetic Data

Prepared by the U.S. Dept. of Commerce, NOAA, Space Weather Prediction Center

Current Quarter Daily Geomagnetic Data

	Middle Latitude - Fredericksburg -		High Latitude ---- College ----		Estimated --- Planetary ---	
Date	A	K-indices	A	K-indices	A	K-indices
2012 10 01	21	5 5 4 2 3 2 2 2	23	5 5 5 4 2 1 1 0	31	7 6 4 2 2 1 2 2
2012 10 02	5	2 0 0 1 3 2 1 2	11	1 0 0 5 4 1 1 2	5	2 0 1 2 2 2 2 2
2012 10 03	5	2 2 1 1 2 2 1 0	2	2 0 1 2 0 0 0 0	5	3 2 2 1 1 1 1 0
2012 10 04	3	1 0 1 1 1 2 1 0	2	0 0 1 3 0 0 0 0	3	0 0 1 1 1 1 0 0
2012 10 05	3	0 0 0 1 2 2 1 2	3	0 0 0 2 1 2 1 1	4	0 0 0 1 1 2 1 2
2012 10 06	5	2 1 1 2 2 2 1 1	14	1 1 1 4 5 3 1 2	6	2 1 1 2 2 2 1 2
2012 10 07	4	0 2 1 2 1 1 1 2	6	1 1 2 4 0 0 1 1	5	1 2 1 2 1 1 1 2
2012 10 08	21	2 3 5 5 3 2 3 3	66	2 4 8 7 5 3 4 4	35	3 4 6 6 4 2 4 4
2012 10 09	32	6 5 5 4 2 2 3 4	54	4 5 7 7 4 2 3 4	42	6 6 5 4 2 2 3 5
2012 10 10	6	2 1 2 2 2 1 2 1	22	4 2 3 5 5 3 2 2	10	3 2 2 2 2 2 3 2
2012 10 11	5	2-1-1-1 2 2 1 1	7	2 1 1 3 3 2 1 1	6	2 1 1 2 2 2 1 2
2012 10 12	12	3 4 3 1 2 2 3 1	18	3 3 3 4 5 3 2 1	12	3 4 3 2 2 3 3 1
2012 10 13	28	3 4 5 5 4 4 3 3	70	2 5 6 7 7 6 5 3	38	3 4 5 5 5 5 5 3
2012 10 14	20	5 3 3 4 3 2 3 3	33	4 4 5 6 5 2 3 3	19	5 3 3 4 3 2 3 3
2012 10 15	7	3 2 2 2 2 1 2 1	12	3 2 3 4 3 1 2 1	8	3 2 2 2 2 1 2 1
2012 10 16	5	1 1 2 1 2 2 1 1	14	2 1 4 4 4 3 1 1	5	1 1 2 1 2 1 1 1
2012 10 17	6	2 1 3 1 2 1 1 2	7	1 3 3 1 2 1 0 2	7	2 2 2 1 2 1 0 2
2012 10 18	4	2 1 0 1 2 2 1 1	3	1 1 0 3 0 1 1 0	5	2 1 0 1 1 2 1 1
2012 10 19	3	2 0 0 1 2 1 1 0	1	1 1 0 0 0 0 0 0	4	2 1 0 1 1 1 1 0
2012 10 20	3	0 0 0 1 2 1 2 1	0	0 0 0 0 0 0 0 0	3	0 0 0 1 1 1 1 0
2012 10 21	2	0 0 0 1 2 1 1 0	0	0 0 0 0 0 0 0 0	3	0 0 1 1 1 1 1 0
2012 10 22	2	1 0 0 0 1 1 2 1	0	0 0 0 0 0 0 0 1	3	1 0 0 1 0 1 1 0
2012 10 23	9	2 3 2 1 3 2 2 2	13	1 2 2 5 3 2 2 2	7	2 2 2 2 2 2 2 2
2012 10 24	3	1 2 1 1 1 1 0 0	5	1 1 2 3 2 1 0 0	4	1 2 1 1 1 1 0 0
2012 10 25	3	1 1 1 1 2 1 0 1	2	0 0 1 3 0 0 0 0	4	1 1 1 1 1 1 1 1
2012 10 26	4	0 0 2 1 2 2 1 1	2	0 0 2 1 0 2 0 0	4	0 0 2 1 1 2 1 1
2012 10 27	3	1 1 1 1 1 0 1 1	3	1 0 2 2 0 1 0 0	4	1 1 1 1 1 1 0 1
2012 10 28	3	0 0 2 1 2 1 1 0	5	0 0 2 3 3 1 0 0	3	0 0 2 1 1 1 1 0
2012 10 29	2	0 0 2 0 2 1 0 0	1	0 0 2 1 0 0 0 0	3	0 1 1 1 0 0 0 1
2012 10 30	1	1 0 0 0 1 1 0 0	1	0 0 1 0 1 0 0 0	2	1 0 0 0 1 0 0 0
2012 10 31	5	0 0 0 1 2 3 2 2	2	0 0 0 0 1 2 1 1	5	0 0 0 0 1 3 2 2
2012 11 01	17	3 3 3 4 3 4 3 2	48	2 2 3 6 6 7 4 4	17	3 2 3 4 3 4 3 3
2012 11 02	5	2 2 1 2 1 1 1 1	3	2 2 0 0 0 1 0 1	5	2 2 1 1 1 1 1 1
2012 11 03	2	0 0 0 0 2 1 1 0	1	0 0 0 0 1 2 0 0	3	0 0 0 0 1 1 1 0
2012 11 04	1	0 0 0 0 2 1 0 0	2	0 1 1 1 2 0 0 0	2	0 1 1 0 1 0 0 0
2012 11 05	2	0 0 1 1 2 1 1 0	2	0 0 1 1 1 2 0 0	2	0 0 1 0 1 1 1 0
2012 11 06	4	0 0 1 1 2 2 1 2	7	0 0 1 3 3 3 1 1	4	0 0 1 1 1 2 1 1
2012 11 07	10	2 3 1 2 3 2 3 2	10	0 1 1 1 4 3 3 3	10	2 3 1 1 2 3 4 2
2012 11 08	2	0 0 0 1 2 1 1 1	2	1 0 0 2 1 0 0 0	3	1 0 0 1 1 1 0 1
2012 11 09	1	0 0 0 0 1 1 1 0	0	0 0 0 0 1 0 0 0	2	0 0 0 0 1 1 0 0
2012 11 10	1	0 0 0 0 1 0 1 1	0	0 0 0 0 0 0 0 0	2	0 0 0 0 1 0 1 2
2012 11 11	2	1 1 0 1 2 0 0 1	2	0 0 0 1 2 1 0 0	3	1 1 0 1 1 1 0 1
2012 11 12	4	1 0 0 0 1 1 2 3	1	0 0 0 0 0 0 1 2	5	1 0 0 0 0 2 2 3
2012 11 13	10	3 3 2 2 2 3 2 2	13	3 2 2 2 4 4 2 2	15	4 3 2 3 3 4 3 3
2012 11 14	21	5 5 4 3 3 2 1 2	44	3 5 7 5 6 3 1 1	33	6 6 5 4 4 2 1 1
2012 11 15	3	1 1 0 1 1 1 1 1	1	0 0 0 2 0 0 0 0	3	1 1 0 1 0 0 1 1
2012 11 16	5	1 2 1 1 2 1 2 1	3	0 0 1 2 2 1 1 1	5	1 2 1 1 1 2 2 1
2012 11 17	7	1 3 1 2 2 1 2 2	5	1 1 1 1 3 2 2 0	7	1 2 1 2 2 2 3 1
2012 11 18	4	1 2 1 2 1 1 1 1	5	1 2 1 3 2 1 0 0	5	1 2 2 2 1 1 0 1
2012 11 19	3	1 0 2 1 2 1 1 0	8	2 0 3 3 3 3 0 0	4	1 0 2 1 2 2 0 1
2012 11 20	10	2 2 2 3 2 2 3 3	28	1 2 4 5 5 5 4 3	11	2 2 2 2 2 2 4 3

2012 11 21	7	3 2 3 2 1 1 1 1	14	2 2 5 4 2 1 1 2	7	3 2 2 2 1 1 1 1
2012 11 22	1	1 0 0 0 0 1 0 1	1	1 1 0 0 1 0 0 0	2	1 1 0 0 1 0 0 1
2012 11 23	6	0 1 1 1 1 1 1 4	5	0 0 1 3 2 0 0 3	7	0 1 1 1 0 0 1 4
2012 11 24	11	3 3 3 2 3 2 2 2	26	3 4 6 5 4 2 1 1	13	4 3 3 2 3 2 2 1
2012 11 25	4	1 2 2 0 2 1 1 1	6	0 1 1 0 4 3 1 0	4	1 1 1 0 1 1 1 1
2012 11 26	6	3 2 1 1 1 2 1 1	3	2 1 1 2 0 0 1 0	5	3 2 1 1 0 1 1 1
2012 11 27	3	1 1 1 1 1 1 1 0	2	0 0 1 1 2 0 0 0	4	1 1 1 1 1 1 1 1
2012 11 28	2	0 1 0 0 1 1 1 1	0	0 0 0 0 0 0 0 1	2	1 1 0 0 0 0 1 1
2012 11 29	2	0 1 0 1 1 1 1 0	1	0 0 0 2 0 0 0 1	3	0 1 1 1 0 1 1 1
2012 11 30	1	0 0 0 1 1 1 0 0	2	0 0 1 2 1 0 0 0	2	0 0 0 1 0 1 0 0
2012 12 01	3	1 1 0 0 1 2 2 1	1	0 0 0 0 0 1 1 0	4	1 1 0 0 0 1 2 2
2012 12 02	8	2 3 3 3 2 0 1 0	13	1 2 5 3 4 1 0 0	7	2 2 3 2 2 1 0 1
2012 12 03	3	0 1 1 1 1 1 1 2	4	0 0 2 3 2 1 0 0	4	1 1 1 1 1 1 1 2
2012 12 04	5	1 2 2 1 1-1 2-1	2	0 2 2 0 0 0 0 0	3	1 2 2 1 0 0 1 0
2012 12 05	4	2 1 0 3 2 0 0 1	0	0 0 0 0 0 0 0 0	2	1 0 0 1 0 0 1 1
2012 12 06	2	1 2 0 0 1 0 1 0	0	0 0 0 0 1 0 0 0	1	0 0 0 0 0 0 1 0
2012 12 07	1	1 1 0 0 0 0 1 0	0	0 0 0 0 0 0 0 0	1	0 0 0 0 0 0 0 0
2012 12 08	1	1 1 0 0 1 0 0 0	0	0 0 0 0 0 0 0 0	1	0 1 0 0 0 0 0 0
2012 12 09	3	0 2 0 0 1 0 1 2	2	0 0 0 0 2 1 1 1	4	0 1 0 0 0 1 1 2
2012 12 10	3	2 1 1 0 1 0 1 1	4	1 0 1 3 2 0 0 0	3	2 1 0 1 1 0 1 0
2012 12 11	2	2 1 0 0 0 1 1 1	0	0 0 1 0 0 0 0 0	2	1 1 0 0 0 0 1 1
2012 12 12	3	1 0 1 1 1 1 1 1	1	0 0 0 0 2 1 0 0	2	0 0 1 0 1 1 0 0
2012 12 13	2	1 1 0 0 1 1 0 1	0	0 0 0 0 0 0 0 0	3	1 1 0 0 0 1 0 0
2012 12 14	4	1 2 1 1 1 0 1 2	0	0 0 0 0 0 0 0 1	3	1 1 1 0 0 0 1 2
2012 12 15	7	1 3 1 2 2 1 2 2	11	0 1 2 3 5 2 1 1	7	2 2 1 2 2 2 2 2
2012 12 16	5	1 0 2 2 2 2 1 1	11	1 0 3 4 4 2 1 1	5	2 0 2 2 2 2 1 1
2012 12 17	9	2 3 2 3 3 2 1 1	21	1 3 4 4 6 3 1 0	10	2 2 3 3 4 2 1 0
2012 12 18	5	1 2 2 2 1 2 1 1	10	0 1 2 4 3 4 0 1	6	1 2 2 2 2 2 1 1
2012 12 19	4	1 2 1 1 2 2 1 0	3	0 2 1 2 2 0 1 0	4	1 2 1 1 1 0 1 1
2012 12 20	7	1 2 2 1 2 3 2 1	18	0 0 2 5 5 4 2 1	6	0 2 2 2 2 3 2 1
2012 12 21	3	2 0 1 1 1 1 1 0	3	0 1 1 3 1 1 0 0	4	2 1 1 1 1 1 0 0
2012 12 22	1	0 0 0 0 1 1 0 0	1	0 0 0 2 0 0 0 0	1	0 0 0 1 0 0 0 0
2012 12 23	2	0 1 0 0 1 1 1 0	1	0 0 0 1 1 1 0 0	2	0 0 0 0 0 1 0 0
2012 12 24	2	0 0 0 0 1 2 1 1	1	0 0 0 0 0 2 1 0	3	0 0 0 0 1 2 1 1
2012 12 25	2	0 0 0 1 1 0 1 1	0	0 0 0 1 0 0 0 0	3	1 1 0 1 1 0 0 1
2012 12 26	2	0 1 1 1 1 1 0 0	1	0 0 0 0 2 0 0 0	3	0 2 1 1 1 0 0 0
2012 12 27	0	0 0 0 0 0 1 0 0	0	0 0 0 0 0 0 0 0	1	0 0 0 0 0 0 0 0
2012 12 28	2	0 0 0 0 1 1 1 1	0	0 0 0 0 1 0 0 0	2	0 0 0 0 0 0 1 0
2012 12 29	3	0 1 1 1 1 1 1 1	1	0 0 1 1 0 0 0 0	3	0 1 1 1 0 0 0 1
2012 12 30	4	0 0 1 1 2 2 2 1	4	0 0 0 3 2 1 1 0	4	1 0 0 1 2 2 2 0
2012 12 31	1	0 0 0 0 0 1 1 0	0	0 0 0 0 0 0 0 0	2	0 0 0 0 0 0 1 1

9.3 Appendix C: Performance Analysis (PAN) Problem Report

In 1993, the FAA began monitoring and analyzing Global Positioning System (GPS) Standard Positioning Service (SPS) performance data. At present, the FAA has approved GPS for IFR and is developing WAAS and LAAS, both of which are GPS augmentation systems. In order to ensure the safe and effective use of GPS and its augmentation systems within the NAS, it is critical that characteristics of GPS performance as well as specific causes for service outages be monitored and understood. To accomplish this objective, GPS SPS performance data is documented in a quarterly GPS Performance Analysis (PAN) report. The PAN report contains data collected at various National Satellite Test Bed (NSTB) and Wide Area Augmentation System (WAAS) reference station locations. This PAN Problem Report will be issued only when the performance data fails to meet the GPS Standard Positioning Service (SPS) Signal Specification.

Problem Description:

The minimum duration a scheduled satellite outage was forecasted ahead of time by a NANU was 36.3 hours. Although this did not meet the 48-hour requirement, the outage did not result in a loss of continuity. This value was calculated from a rescheduled event. The original forecast NANU met the requirement, but the rescheduling did not. Please see NANUs 2012082, 2012085 and 2012086.

9.4 Appendix D: Glossary

The terms and definitions discussed below are taken from the Standard Positioning Service Performance Specification (October 2001). An understanding of these terms and definitions is a necessary prerequisite to full understanding of the Signal Specification.

General Terms and Definitions

Almanac Longitude of the Ascending Node (.o): Equatorial angle from the Prime Meridian (Greenwich) at the weekly epoch to the ascending node at the ephemeris reference epoch.

Coarse/Acquisition (C/A) Code: A PRN code sequence used to modulate the GPS L1 carrier.

Corrected Longitude of Ascending Node (Ωk) and Geographic Longitude of the Ascending Node (GLAN): Equatorial angle from the Prime Meridian (Greenwich) to the ascending node, both at arbitrary time T_k.

Dilution of Precision (DOP): The magnifying effect on GPS position error induced by mapping GPS ranging errors into position within the specified coordinate system through the geometry of the position solution. The DOP varies as a function of satellite positions relative to user position. The DOP may be represented in any user local coordinate desired. Examples are HDOP for local horizontal, VDOP for local vertical, PDOP for all three coordinates, and TDOP for time.

Equatorial Angle: An angle along the equator in the direction of Earth rotation.

Geometric Range: The difference between the estimated locations of a GPS satellite and an SPS receiver.

Ground track Equatorial Crossing (GEC, λ, 2 SOPS GLAN): Equatorial angle from the Prime Meridian (Greenwich) to the location a ground track intersects the equator when crossing from the Southern to the Northern hemisphere. GEC is equal to Ωk when the argument of latitude (Φ) is zero.

Instantaneous User Range Error (URE): The difference between the pseudo range measured at a given location and the expected pseudo range, as derived from the navigation message and the true user position, neglecting the bias in receiver clock relative to GPS time. A signal-in-space (SIS) URE includes residual orbit, satellite clock, and group delay errors. A system URE (sometimes known as a User Equivalent Range Error, or UERE) contains all line-of-sight error sources, to include SIS, single-frequency ionosphere model error, troposphere model error, multipath and receiver noise.

Longitude of Ascending Node (LAN): A general term for the location of the ascending node – the point that an orbit intersects the equator when crossing from the Southern to the Northern hemisphere.

Longitude of the Ground track Equatorial Crossing (GEC, λ, 2 SOPS GLAN): Equatorial angle from the Prime Meridian (Greenwich) to the location a ground track intersects the equator when crossing from the Southern to the Northern hemisphere. GEC is equal to Ωk when the argument of latitude (Φ) is zero.

Mean Down Time (MDT): A measure of time required to restore function after any downing event.

Mean Time Between Downing Events (MTBDE): A measure of time between any downing events.

Mean Time Between Failures (MTBF): A measure of time between unscheduled downing events.

Mean Time to Restore (MTTR): A measure of time required to restore function after an unscheduled downing event.

Navigation Message: Data contained in each satellite's ranging signal and consisting of the ranging signal time-of-transmission, the transmitting satellite's orbital elements, an almanac containing abbreviated orbital element information to support satellite selection, ranging measurement correction information, and status flags. The message structure is described in Section 2.1.2 of the SPS Performance Standard.

Operational Satellite: A GPS satellite which is capable of, but is not necessarily transmitting a usable ranging signal.

PDOP Availability: Defined to be the percentage of time over any 24-hour interval that the PDOP value is less than or equal to its threshold for any point within the service volume.

Positioning Accuracy: Defined to be the statistical difference, at a 95% probability, between position measurements and a surveyed benchmark for any point within the service volume over any 24-hour interval.

- **Horizontal Positioning Accuracy:** Defined to be the statistical difference, at a 95% probability, between horizontal position measurements and a surveyed benchmark for any point within the service volume over any 24-hour interval.

- **Vertical Positioning Accuracy:** Defined to be the statistical difference, at a 95% probability, between vertical position measurements and a surveyed benchmark for any point within the service volume over any 24-hour interval.

Position Solution: An estimate of a user's location derived from ranging signal measurements and navigation data from GPS.

Position Solution Geometry: The set of direction cosines that define the instantaneous relationship of each satellite's ranging signal vector to each of the position solution coordinate axes.

Pseudo Random Noise (PRN): A binary sequence that appears to be random over a specified time interval unless the shift register configuration and initial conditions for generating the sequence are known. Each satellite generates a unique PRN sequence that is effectively uncorrelated (orthogonal) to any other satellite's code over the integration time constant of a receiver's code tracking loop.

Representative SPS Receiver: The minimum signal reception and processing assumptions employed by the U.S. Government to characterize SPS performance in accordance with performance standards defined in Section 3 of the SPS Performance Standard. Representative SPS receiver capability assumptions are identified in Section 2.2 of the SPS Performance Standard.

Right Ascension of Ascending Node (RAAN): Equatorial angle from the celestial principal direction to the ascending node.

Root Mean Square (RMS) SIS URE: A statistic that represents instantaneous SIS URE performance in an RMS sense over some sample interval. The statistic can be for an individual satellite or for the entire constellation. The sample interval for URE assessment used in the SPS Performance Standard is 24 hours.

Selective Availability: Protection technique formerly employed to deny full system accuracy to unauthorized users. SA was discontinued effective midnight May 1, 2000.

Service Availability: Defined to be the percentage of time over any 24-hour interval that the predicted 95% positioning error is less than its threshold for any given point within the service volume.

- **Horizontal Service Availability:** Defined to be the percentage of time over any 24-hour interval that the predicted 95% horizontal error is less than its threshold for any point within the service volume.

- **Vertical Service Availability:** Defined to be the percentage of time over any 24-hour interval that the predicted 95% vertical error is less than its threshold for any point within the service volume.

Service Degradation: A condition over a time interval during which one or more SPS performance standards are not supported.

Service Failure: A condition over a time interval during which a healthy GPS satellite's ranging signal exceeds the Not-to-Exceed (NTE) SPS SIS URE tolerance.

Service Reliability: The percentage of time over a specified time interval that the instantaneous SIS SPS URE is maintained within a specified reliability threshold at any given point within the service volume, for all healthy GPS satellites.

Service Volume: The spatial volume supported by SPS performance standards. Specifically, the SPS Performance Standard supports the terrestrial service volume. The terrestrial service volume covers from the surface of the Earth up to an altitude of 3,000 kilometers.

SPS Performance Envelope: The range of nominal variation in specified aspects of SPS performance.

SPS Performance Standard: A quantifiable minimum level for a specified aspect of GPS SPS performance. SPS performance standards are defined in Section 3.0.

SPS Ranging Signal: An electromagnetic signal originating from an operational satellite. The SPS ranging signal consists of a Pseudo Random Noise (PRN) C/A code, a timing reference and sufficient data to support the position solution generation process. A description of the GPS SPS signal is provided in Section 2. The formal definition of the SPS ranging signal is provided in ICDGPS-200C.

SPS Ranging Signal Measurement: The difference between the ranging signal time of reception (as determined by the receiver's clock) and the time of transmission derived from the navigation signal (as defined by the satellite's clock) multiplied by the speed of light. Also known as the *pseudo range*.

SPS SIS User Range Error (URE) Statistic:

- A satellite SPS SIS URE statistic is defined to be the Root Mean Square (RMS) difference between SPS ranging signal measurements (neglecting user clock bias and errors due to propagation environment and receiver), and "true" ranges between the satellite and an SPS user at any point within the service volume over a specified time interval.

- A constellation SPS SIS URE statistic is defined to be the average of all satellite SPS SIS URE statistics over a specified time interval.

Time Transfer Accuracy Relative to UTC (USNO): The difference at a 95% probability between user UTC time estimates and UTC (USNO) at any point within the service volume over any 24-hour interval.

Transient Behavior: Short-term behavior not consistent with steady-state expectations.

Usable SPS Ranging Signal: An SPS ranging signal that can be received, processed, and used in a position solution by a receiver with representative SPS receiver capabilities.

User Navigation Error (UNE): Given a sufficiently stationary and ergodic satellite constellation ranging error behavior over a minimum sample interval, multiplication of the DOP and a constellation ranging error standard deviation value will yield an approximation of the RMS position error. This RMS approximation is known as the UNE (UHNE for horizontal, UVNE for vertical, and so on). The user is cautioned that any divergence away from the stationary and ergodic assumptions will cause the UNE to diverge from a RMS value based on actual measurements.

User Range Accuracy (URA): A conservative representation of each satellite's expected (1σ) SIS URE performance (excluding residual group delay) based on historical data. A URA value is provided that is representative over the curve fit interval of the navigation data from which the URA is read. The URA is a coarse representation of the URE statistic in that it is quantized to levels represented in ICDGPS200C.