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

Submitted To

Federal Aviation Administration

GPS Product Team

1284 Maryland Avenue SW

Washington, DC 20024

Report #72

January 31, 2011

Reporting Period: 1 October – 31 December 2010

Submitted by

William J. Hughes Technical Center

NSTB/WAAS T&E Team

Atlantic City International Airport, NJ 08405

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 #72, includes data collected from 1 October through 31 December 2010. The next quarterly report will be issued April 30, 2011.

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 the CONUS was 99.986% or better.

NANU summary and evaluation was achieved by reviewing the “Notice: Advisory to Navstar Users” (NANU) reports issued between 1 October and 31 December 2010. 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 nine outages were reported in the NANU’s this quarter. Eight outages were scheduled while one was an unscheduled outage.

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 20.998 meters on Satellite PRN 27. 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 2.441 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 5.03 meters at Maspalomas, Spain and 5.33 meters at Bishkek, Kyrgyzstan respectively.

From the analysis performed on data collected between 1 October and 31 December 2010, the GPS performance met all SPS requirements that were evaluated. There were no significant problems to report for the duration of the quarter.

Table of Contents

List of Figures

List of Tables

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 (October 2001). 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 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 (October 2001).

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 occup0ied 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 a n 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 a t 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 3.126 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%)
2 – 8 Oct	3.126	99.990	98.611
9 – 15 Oct	3.048	99.990	98.542
16 – 22 Oct	2.954	99.990	98.542
23 – 29 Oct	2.852	99.990	98.472
30 Oct – 5 Nov	3.000	99.986	98.542
6 – 12 Nov	2.738	99.995	98.889
13 – 19 Nov	2.707	100	99.653
20 – 26 Nov	2.682	100	100
27 Nov – 3 Dec	2.696	100	100
4 – 10 Dec	2.708	100	100
11 – 17 Dec	2.725	100	100
18 – 24 Dec	2.743	100	100
25 – 31 Dec	2.761	100	100

Figure 2-1 World GPS Maximum PDOP

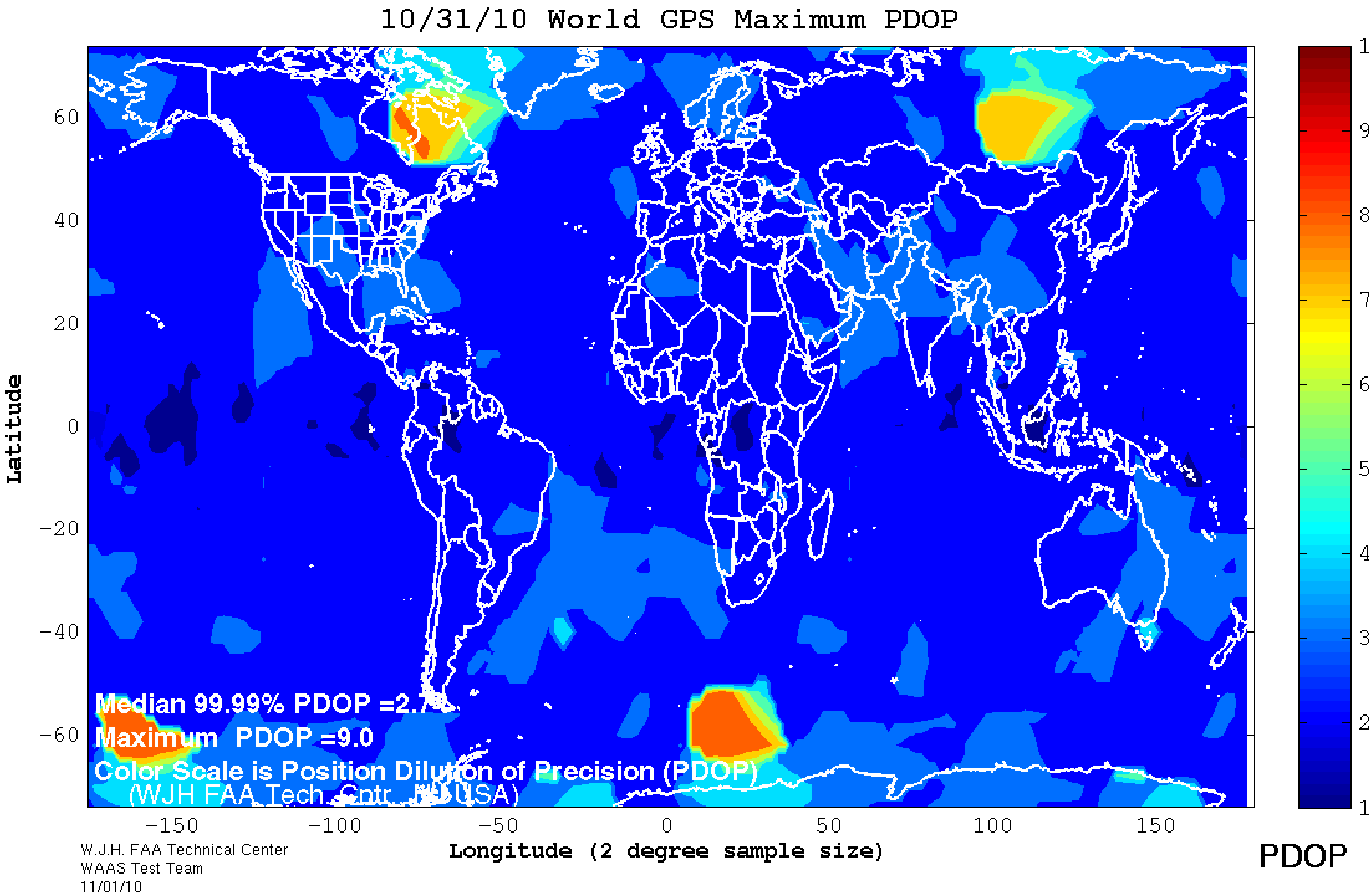
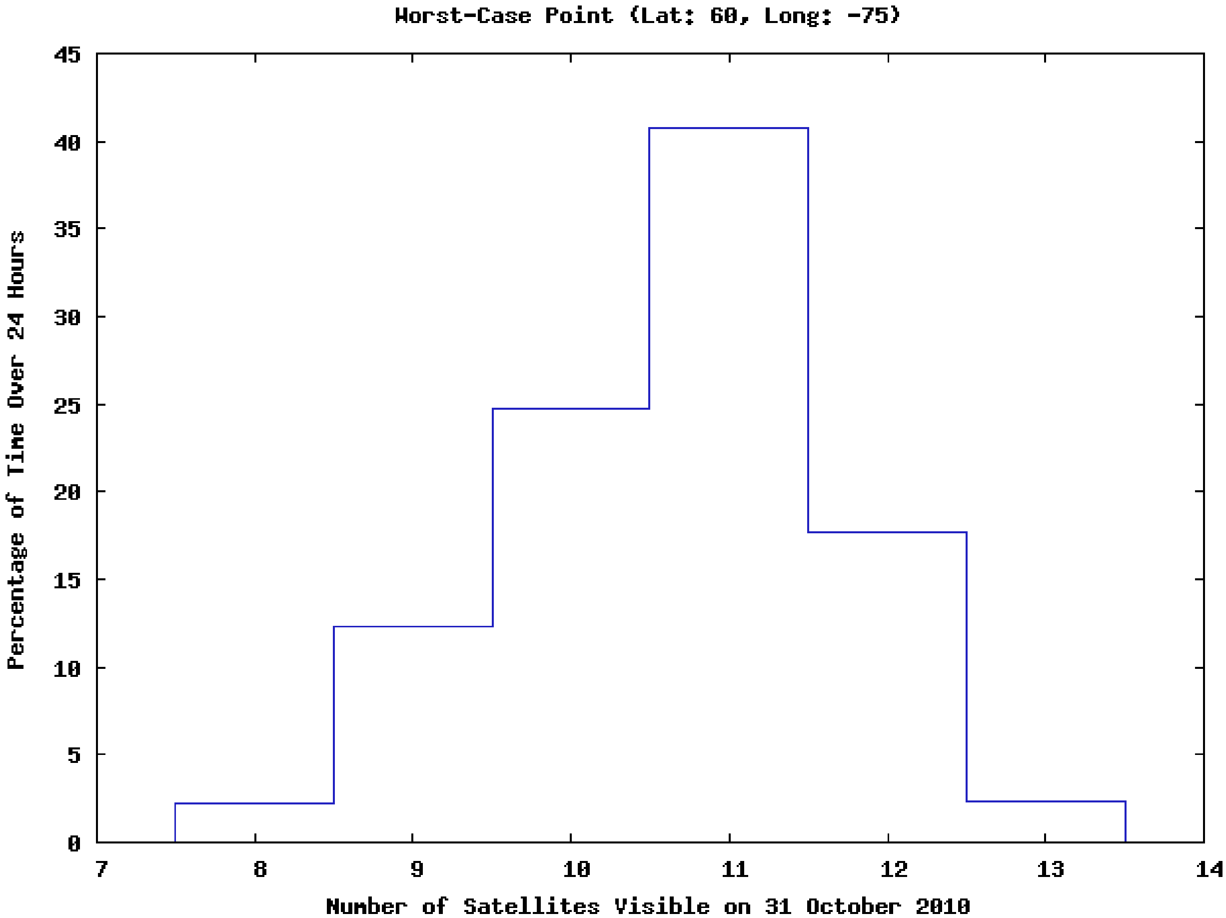


Figure 2-2 Satellite Visibility Profile for Worst-Case Point



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 2010, there were a total of nine reported outages. Eight of these outages were maintenance activities and were reported in advance while one was an unscheduled outage. 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 62.30 hours, which exceeded the 48-hour requirement. The maximum response time for a NANU issued for an unscheduled outage was 0.233 hours.

Table 3-1 NANUs Affecting Satellite Availability

NANU#	PRN	TYPE	Start Date	Start Time	End Date	End Time	Total Unscheduled	Total Scheduled	Total
2010130	30	FCSTSUMM	2010-Oct-01	0:00	2010-Oct-01	4:55		4.91	4.91
2010132	11	FCSTSUMM	2010-Oct-14	13:37	2010-Oct-14	18:36		4.98	4.98
2010134	22	UNUSABLE	2010-Oct-31	3:51	2010-Nov-01	16:58	37.12		37.12
2010141	27	FCSTSUMM	2010-Nov-16	14:38	2010-Nov-16	22:37		7.98	7.98
2010142	31	FCSTSUMM	2010-Nov-19	6:52	2010-Nov-19	13:10		6.30	6.30
2010149	32	FCSTSUMM	2010-Dec-10	1:26	2010-Dec-10	7:17		5.85	5.85
2010151	32	FCSTSUMM	2010-Dec-14	1:58	2010-Dec-14	6:49		4.85	4.85
2010154	4	FCSTSUMM	2010-Dec-17	7:42	2010-Dec-17	13:21		5.65	5.65
2010157	24	FCSTSUMM	2010-Dec-28	22:12	2010-Dec-29	4:24		6.20	6.20
Totals of Unscheduled, Scheduled & Total Downtime							37.12	46.72	83.84

GENERAL NANUs

2010144 Announced installation of new ground software on 1-Dec-2010

Table 3-2 NANUs Forecasted to Affect Satellite Availability

NANU #	PRN	Type	Start Date	Start Time	End Date	End Time	Total	Comments
2010125	30	FCSTDV	30-Sep	21:30	1-Oct	21:30	24	2010130
2010131	11	FCSTDV	14-Oct	13:15	15-Oct	1:15	12	2010132
2010133	22	UNUSUFN	31-Oct	3:51				2010134
2010135	27	FCSTMX	16-Nov	14:30	17-Nov	2:30	0	2010137
2010136	31	FCSTMX	19-Nov	6:15	19-Nov	18:15	0	2010138
2010139	27	FCSTDV	16-Nov	14:30	17-Nov	2:30	12	2010141
2010140	31	FCSTDV	19-Nov	6:15	19-Nov	18:15	12	2010142
2010143	4	FCSTMX	2-Dec	14:00	3-Dec	2:00	0	2010145
2010145	4	FCSTRESCD	22-Dec	13:00	23-Dec	1:00	0	2010155
2010146	4	FCSTDV	17-Dec	7:15	17-Dec	19:15	12	2010154
2010147	32	FCSTDV	10-Dec	1:15	10-Dec	13:15	12	2010150
2010148	32	FCSTDV	14-Dec	1:45	14-Dec	13:45	12	2010151
2010152	24	FCSTDV	28-Dec	22:00	29-Dec	22:00	24	2010157
						Total Forecasted Downtime	120.00	

Table 3-3 Cancelled NANUs

NANU#	PRN	Type	Start Date	Start Time	Comments
2010137	27	FCSTCANC	16-Nov	14:30:00	2010135
2010138	31	FCSTCANC	19-Nov	6:15:00	2010136
2010155	4	FCSTCANC	22-Dec	13:00:00	2010145

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. Schedule 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-Oct-10 31-Dec-10	1-Jan-00 31-Dec-10
Total Forecast Downtime (hrs):	120.00	8449.72
Total Actual Downtime (hrs):	83.84	36684.70
Total Actual Scheduled Downtime (hrs):	46.72	4601.77
Total Actual Unscheduled Downtime (hrs):	37.12	32082.93
Total Satellite Observed MTTR (hrs):	9.32	54.92
Scheduled Satellite Observed MTTR (hrs):	5.84	8.90
Unscheduled Satellite Observed MTTR (hrs):	37.12	212.47
# Total Satellite Outages:	9	668
# Scheduled Satellite Outages:	8	517
# Unscheduled Satellite Outages:	1	151
Percent Operational -- Scheduled Downtime:	99.93	99.85
Percent Operational -- All Downtime:	99.88	98.77

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 2010.

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	7944536	0	100%
Anchorage	7944663	0	100%
Atlanta	7945774	0	100%
Barrow	7940141	0	100%
Bethel	7636134	0	100%
Billings	7945126	0	100%
Boston	7477171	0	100%
Cleveland	7944609	0	100%
Cold Bay	7936193	0	100%
Fairbanks	7940847	0	100%
Gander	7932438	0	100%
Honolulu	7941536	0	100%
Houston	7945733	0	100%
Iqaluit	7937706	0	100%
Juneau	7930515	0	100%
Kansas City	7945581	0	100%
Kotzebue	7909843	0	100%
Los Angeles	7945773	0	100%
Merida	7925850	0	100%
Miami	7945742	0	100%
Minneapolis	7945774	0	100%
Oakland	7438584	0	100%
Salt Lake City	7945813	0	100%
San Jose Del Cabo	7910691	0	100%
San Juan	7932920	0	100%
Seattle	7942874	0	100%
Tapachula	2536201	0	100%
Washington, DC	7944000	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 20.998 meters on satellite PRN 27.

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 2010	**Boston**	63,559,041	0	100%
1 Apr – 30 Jun 2010	**Honolulu**	70,024,279	0	100%
1 Apr – 30 Jun 2010	**Los Angeles**	68,865,455	0	100%
1 Apr – 30 Jun 2010	**Miami**	67,956,553	0	100%
1 Apr – 30 Jun 2010	**San Juan**	69,405,503	0	100%
1 Apr – 30 Jun 2010	**Juneau**	69,936,380	0	100%
1 Apr – 30 Jun 2010	**Global**	409,747,211	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 2010 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% Horizontal (Meters)	95% Vertical (Meters)	99.99% Horizontal (Meters)	99.99% Vertical (Meters)
Albuquerque	1.941	3.837	4.458	7.553
Anchorage	1.858	4.442	3.484	8.497
Atlanta	2.249	4.031	4.728	7.733
Barrow	1.711	4.764	3.246	8.801
Bethel	1.894	4.510	3.456	7.949
Billings	2.151	3.780	3.509	6.911
Boston	2.430	3.711	4.662	6.936
Cleveland	2.312	3.721	4.398	7.231
Cold Bay	2.145	4.530	4.004	7.457
Fairbanks	1.786	4.552	3.555	8.987
Gander	2.441	3.252	4.677	6.281
Honolulu	4.449	4.429	8.234	10.805
Houston	1.953	4.115	4.842	7.391
Iqaluit	1.989	3.559	5.576	19.554
Juneau	1.935	4.263	3.676	8.155
Kansas City	2.170	3.929	3.995	7.292
Kotzebue	1.793	4.546	3.982	8.870
Los Angeles	1.953	4.403	4.814	9.058
Merida	2.254	4.076	4.834	7.697
Miami	2.287	4.192	4.876	8.406
Minneapolis	2.219	3.728	3.465	6.782
Oakland	1.981	4.440	3.769	9.126
Salt Lake City	2.078	3.924	3.419	7.661
San Jose Del Cabo	2.107	4.574	5.162	9.396
San Juan	2.644	4.203	6.794	9.092
Seattle	2.230	4.149	4.119	7.468
Tapachula	2.690	4.236	6.011	10.601
Washington, DC	2.410	3.852	5.092	7.379

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 2010.

Figure 5-1 Global Vertical Error Histogram

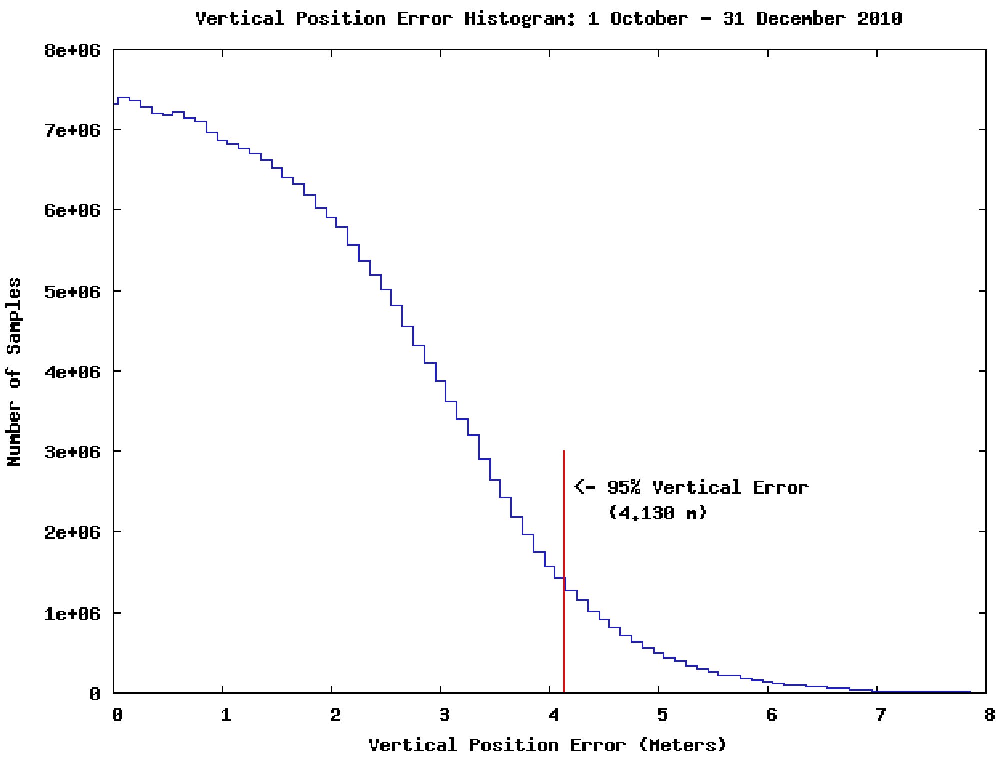
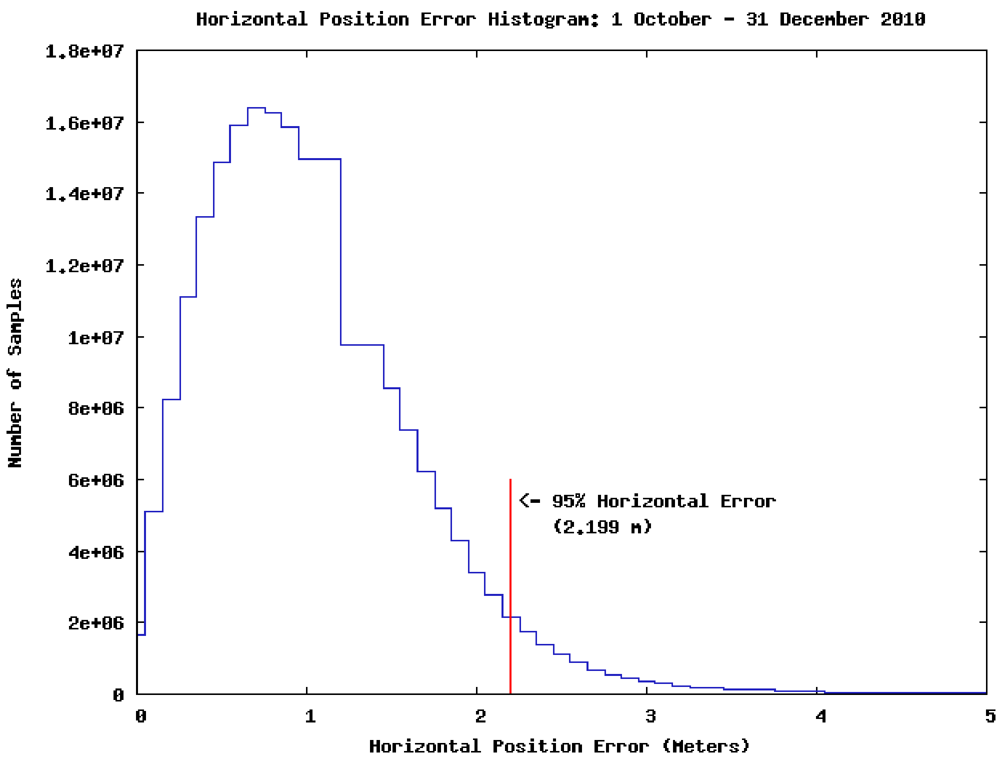


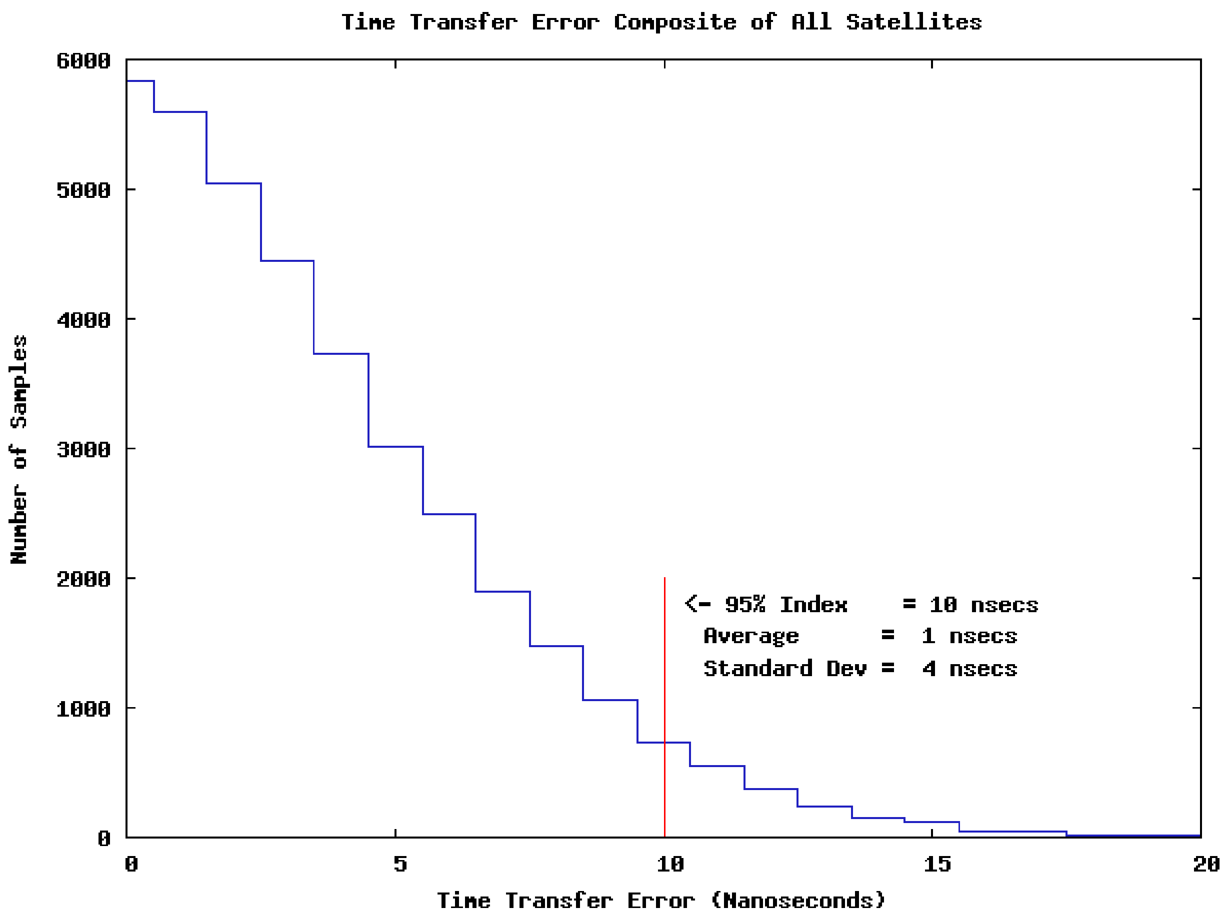
Figure 5-2 Global Horizontal Error Histogram



5.2 Time Transfer Accuracy

The GPS time error data between 1 October and 31 December 2010 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 2010. 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 (≤ 6 m)	Range Error Mean	1σ	95% Range Error	Max Range Error (SPS Spec. ≤ 30 m)	Samples
2	1.475	0.658	1.132	2.676	10.443	14288384
3	1.951	0.680	1.442	3.395	13.258	12337123
4	1.481	0.444	1.126	2.731	13.217	13825172
5	1.347	-0.012	1.177	2.574	9.013	14046661
6	1.720	0.404	1.401	3.039	11.960	12803409
7	1.311	0.214	1.051	2.435	13.955	12222642
8	1.827	0.678	1.308	3.279	15.984	12908853
9	1.816	0.441	1.459	3.305	12.897	13047739
10	2.165	1.513	1.276	3.703	10.952	12568120
11	1.722	0.768	1.245	2.961	7.908	12283418
12	1.447	0.268	1.245	2.687	12.589	14363103
13	1.257	0.380	1.065	2.327	10.301	13823765
14	1.891	1.304	1.224	3.479	11.249	14124907
15	1.243	0.365	1.040	2.331	10.726	13022571
16	1.753	1.009	1.275	3.145	11.220	13114876
17	1.550	0.220	1.295	2.832	13.507	14173435
18	2.091	1.293	1.401	3.620	11.940	13018805
19	1.994	1.319	1.276	3.367	8.530	12577911
20	1.768	1.105	1.249	3.131	12.021	14128481
21	2.002	1.077	1.318	3.423	11.067	12293058
22	2.441	1.770	1.341	4.087	12.249	12164297
23	1.588	1.031	1.101	2.810	14.525	12786410
24	1.995	1.074	1.393	3.451	14.673	13326362
25	1.552	0.537	1.326	3.130	13.218	13454680
26	1.529	0.567	1.202	2.784	15.727	12632569
27	1.925	0.469	1.600	3.599	20.998	13556792
28	1.892	0.984	1.234	3.316	15.098	12637912
29	1.421	0.085	1.144	2.648	11.157	13843319
30	1.711	0.333	1.365	3.150	11.887	12453246
31	1.482	0.606	1.206	2.931	14.559	14022059
32	2.025	1.491	1.245	3.660	14.171	13897132

Table 5-3 Range Rate Error Statistics

(Millimeters/ Second)

PRN	Range Rate Error RMS	95% Range Rate Error	Max Range Rate Error	Samples
2	1.478	2.704	154.05	14288384
3	1.803	2.893	183.00	12337123
4	1.532	2.599	171.54	13825172
5	1.491	2.726	172.15	14046661
6	1.539	2.578	140.84	12803409
7	1.381	2.569	145.44	12222642
8	1.875	2.970	161.47	12908853
9	1.973	2.919	208.41	13047739
10	2.024	2.932	188.55	12568120
11	1.455	2.627	172.53	12283418
12	1.553	2.874	180.69	14363103
13	1.464	2.668	158.76	13823765
14	1.391	2.659	141.20	14124907
15	1.432	2.718	156.21	13022571
16	1.441	2.757	144.00	13114876
17	1.499	2.693	142.72	14173435
18	1.439	2.748	155.04	13018805
19	1.365	2.593	113.34	12577911
20	1.453	2.708	162.10	14128481
21	1.501	2.814	180.39	12293058
22	1.604	2.752	141.56	12164297
23	1.366	2.574	148.42	12786410
24	1.818	2.799	139.18	13326362
25	1.402	2.571	159.67	13454680
26	1.515	2.627	151.70	12632569
27	2.404	2.920	168.94	13556792
28	1.547	2.635	143.73	12637912
29	1.524	2.689	142.99	13843319
30	1.766	2.874	160.03	12453246
31	1.525	2.656	147.79	14022059
32	1.429	2.526	157.94	13897132

Table 5-4 Range Acceleration Error Statistics

(Micrometers/Second^2)

PRN	Range Acceleration Error RMS ($\mu m/s^2$)	95% Range Acceleration Error ($\mu m/s^2$)	Max Range Acceleration Error ($\mu m/s^2$)	Samples
2	11.246	21.105	1540	14288384
3	13.723	22.737	1830	12337123
4	12.198	20.237	1720	13825172
5	11.104	21.288	1710	14046661
6	12.107	20.573	1400	12803409
7	10.440	20.614	1460	12222642
8	14.220	24.192	1630	12908853
9	15.277	22.206	1910	13047739
10	16.225	23.211	1880	12568120
11	11.122	20.628	1730	12283418
12	11.217	21.767	1820	14363103
13	11.086	21.325	1590	13823765
14	10.223	20.633	1370	14124907
15	10.399	20.983	1570	13022571
16	10.357	21.245	1430	13114876
17	11.357	20.534	1430	14173435
18	10.273	21.286	1550	13018805
19	10.434	20.572	1140	12577911
20	10.783	20.556	1620	14128481
21	10.729	22.624	1790	12293058
22	12.092	21.062	1450	12164297
23	10.531	20.303	1480	12786410
24	14.217	21.031	1400	13326362
25	10.985	18.463	1590	13454680
26	11.505	20.468	1520	12632569
27	19.725	21.515	1700	13556792
28	12.090	20.574	1430	12637912
29	11.650	20.603	1410	13843319
30	13.266	21.44	1590	12453246
31	11.670	20.678	1490	14022059
32	10.974	19.772	1590	13897132

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 27 with an error of 20.998 meters. Satellite 11 had the lowest maximum range error of 7.908 meters.

Figure 5-4 Distribution of Daily Max Range Errors

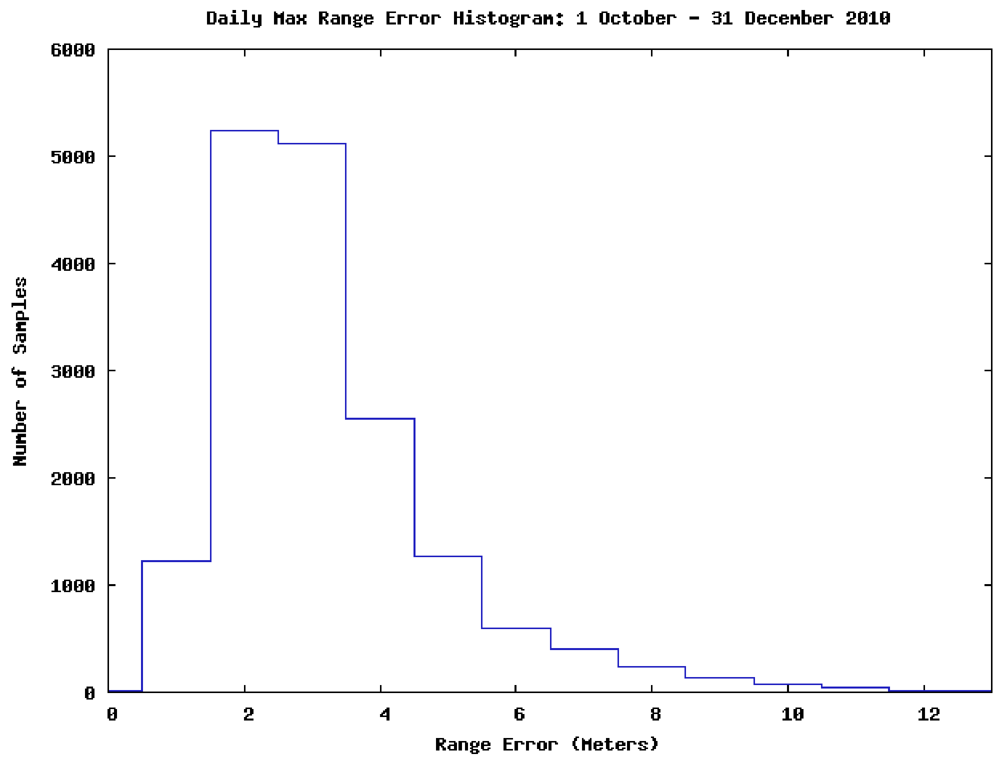


Figure 5-5 Distribution of Daily Max Range Rate Errors

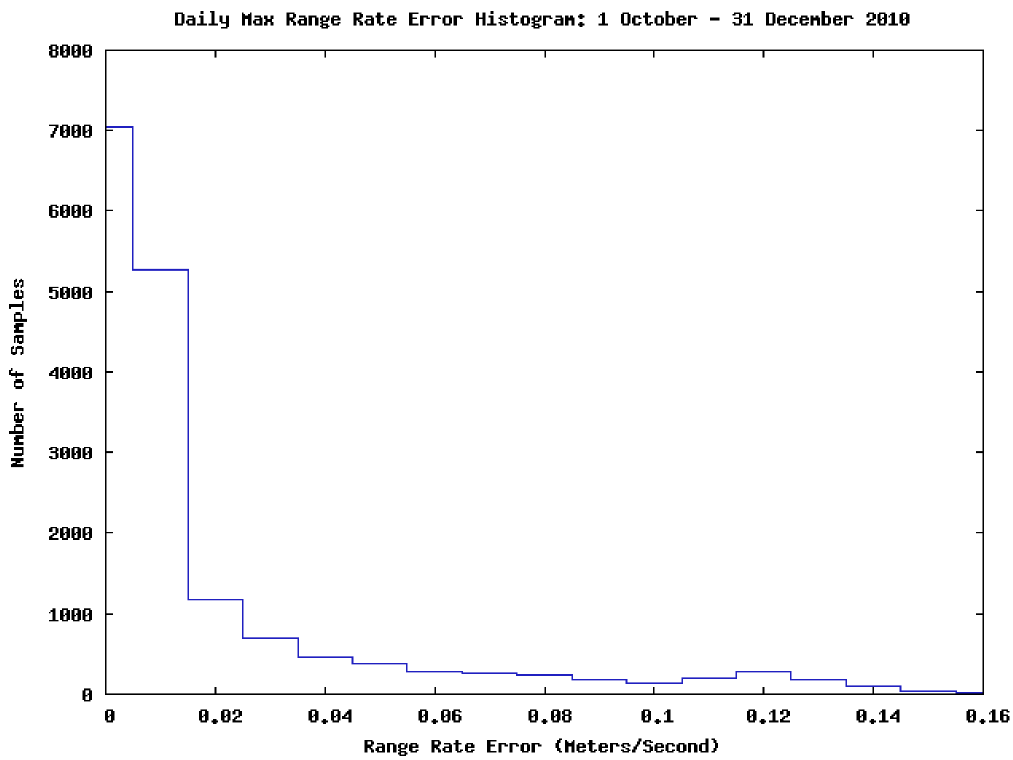


Figure 5-6 Distribution of Daily max Range Acceleration Errors

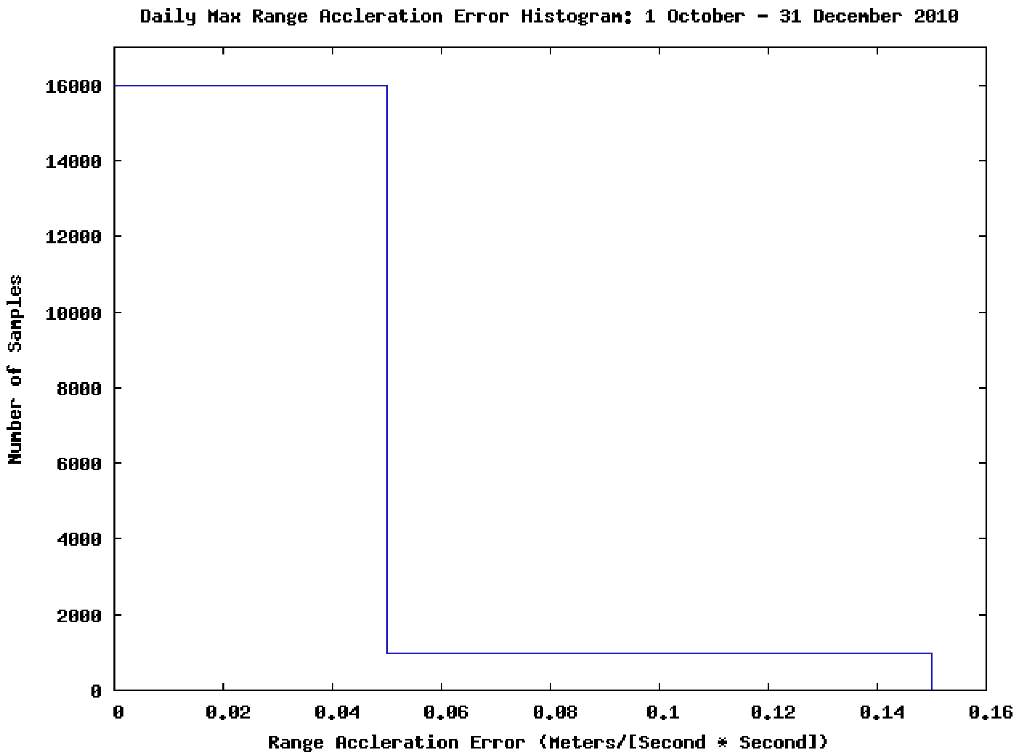


Figure 5-7 Range Error Histogram

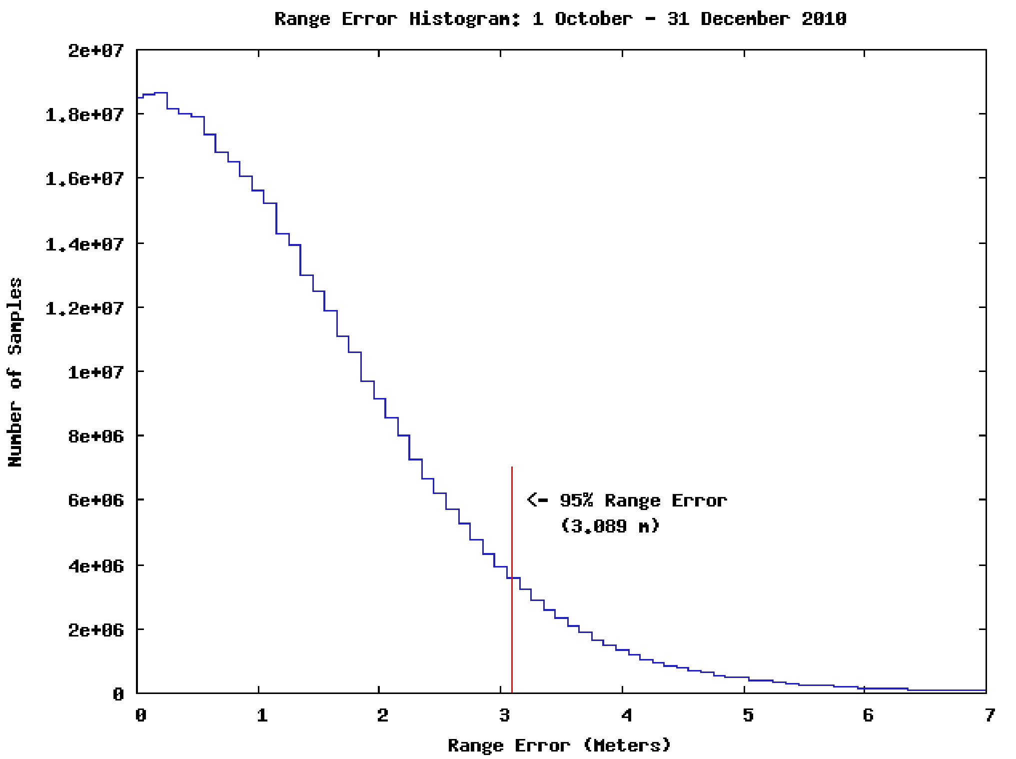


Figure 5-8 Maximum Range Error Per Satellite

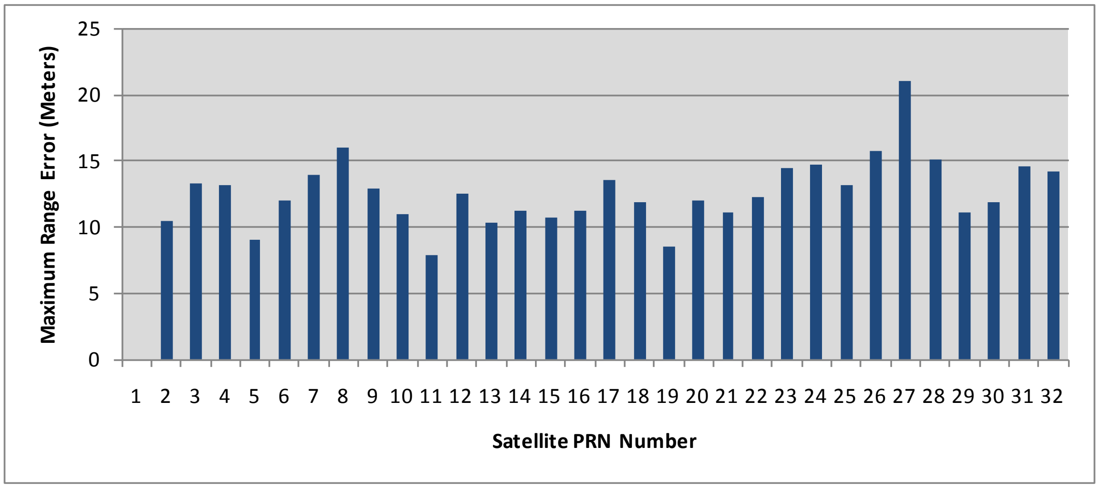


Figure 5-9 Maximum Range Rate Error Per Satellite

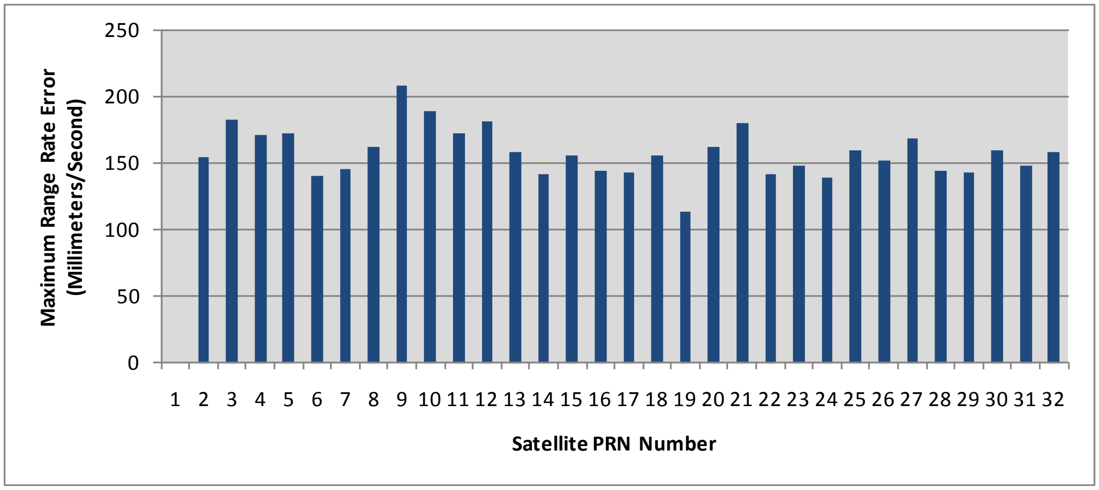
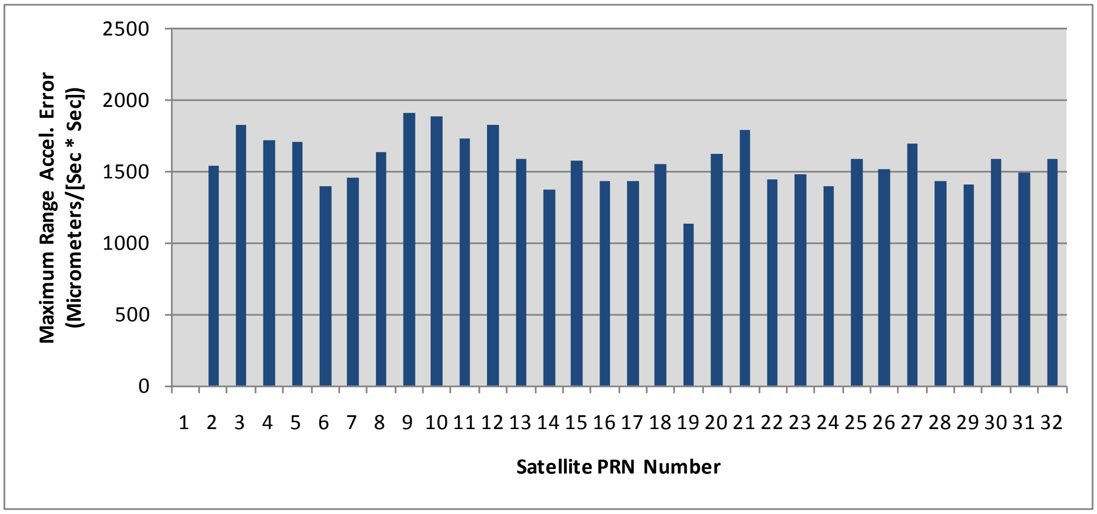


Figure 5-10 Maximum Range Acceleration Error Per Satellite



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 Environment Center (SEC) , 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://sec.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 26-28 November 2010

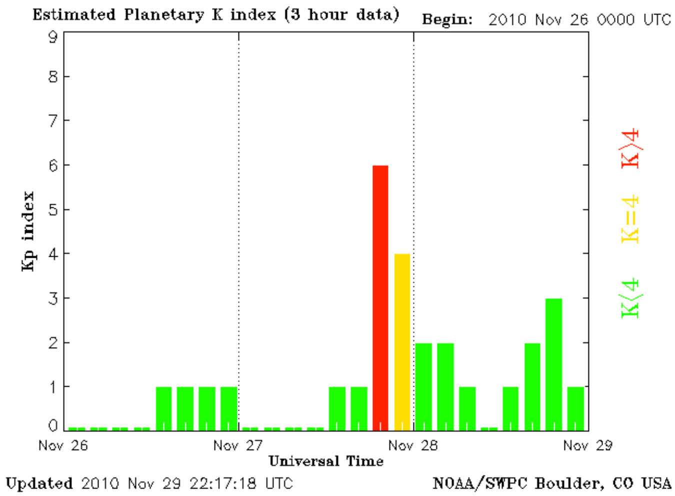


Figure 6-2 K-Index for 22-24 October 2010

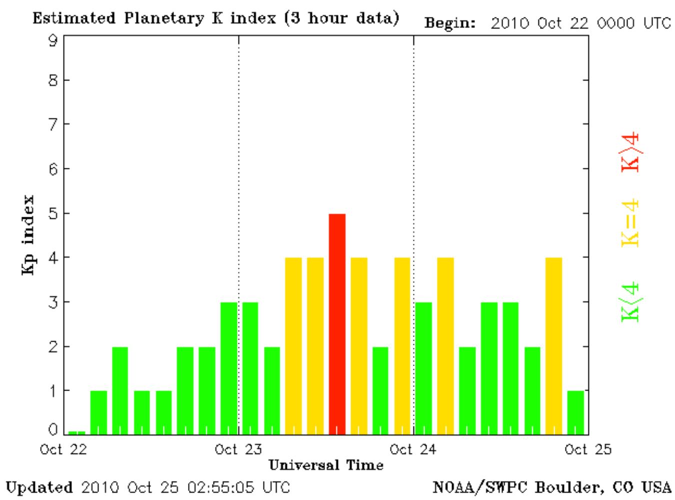


Figure 6-3 K-Index for 10-12 October 2010

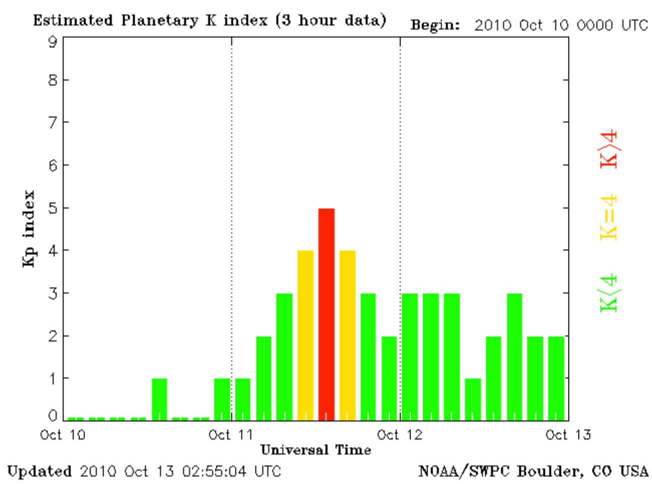


Table 6-1 shows the position accuracy information for the day corresponding to Figure 6-1. The GPS SPS performance met all requirements during all storms that occurred during this quarter.

Table 6-1 Horizontal & Vertical Accuracy Statistics for November 27, 2010

Site	95% Horizontal (Meters)	95% Vertical (Meters)	Maximum Horizontal (Meters)	Maximum Vertical (Meters)
Albuquerque	2.157	4.894	3.404	6.387
Anchorage	2.175	5.216	2.699	7.114
Atlanta	2.336	4.430	3.900	5.536
Barrow	1.924	5.836	2.508	9.261
Bethel	2.327	4.906	3.283	6.238
Billings	2.734	4.734	3.433	6.878
Boston	2.516	4.558	3.787	6.235
Cleveland	2.389	4.782	3.508	6.303
Cold Bay	2.352	4.872	3.631	5.452
Fairbanks	2.353	5.613	2.924	6.701
Gander	2.675	3.971	3.790	4.820
Honolulu	5.167	4.982	6.860	5.849
Houston	2.044	4.625	2.881	5.802
Iqaluit	2.167	4.150	3.584	6.050
Juneau	2.211	5.105	3.076	6.720
Kansas City	2.436	4.827	3.386	6.761
Kotzebue	2.371	5.223	3.180	7.121
Los Angeles	2.562	5.566	4.190	7.630
Merida	1.788	3.521	2.358	4.680
Miami	2.231	3.392	3.018	5.794
Minneapolis	2.553	5.151	3.229	6.956
Oakland	2.612	5.655	3.137	6.829
Salt Lake City	2.675	5.134	3.509	7.277
San Jose Del Cabo	2.439	4.754	3.477	5.793
San Juan	2.494	4.947	3.467	7.185
Seattle	2.737	5.469	3.723	7.998
Tapachula	-	-	-	-
Washington, DC	2.607	4.753	3.814	5.768

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 that had high availability in 2006, 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. 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. The MATE site had a large ramping error on day 267 that appears to be a receiver clock failure. The MATE data for this day has been removed from the statistics computation and trend lines, see figure 7-4.

The Klobachar ionspheric correction model parameters in the global broadcast RINEX navigation data files from the cddis.gsfc.nas/gps/data/daily/2010 ftp site were corrupted and caused large daily errors for the equatorial locations. The data was re-processed using Klobachar parameters obtained from the FAA NSTB network or receivers. High quality navigation data is created by voting across all available IGS high rate navigation data. The IGS global navigation data file is not used because it contains occasional errors. (Round off precision, false track records, truncated numbers, probable bit errors in the parent subframe data, and missing updates)

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.

(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
GLPS	Puerto Ayora	Ecuador
GUAM	Dededo	Guam
IISC	Bangalore	India
KIRU	Kiruna	Sweden
KOUR	Kourou	French Guyana
MADR	Robledo	Spain
MAL2	Malindi	Kenya
MAS1	Maspalomas	Spain
MOBN	Obninsk	Russian Federation
NNOR	New Norcia	Australia
NRIL	Norilsk	Russian Federation
PETS	Petropavlovsk-Kamchatka	Russian Federation
POL2	Bishkek	Kyrgyzstan
SANT	Santiago	Chile
SUTM	Sutherland	South Africa
TIDB	Tidbinbilla	Australia
USUD	Usuda	Japan

Figure 7-1 Selected IGS Site Locations

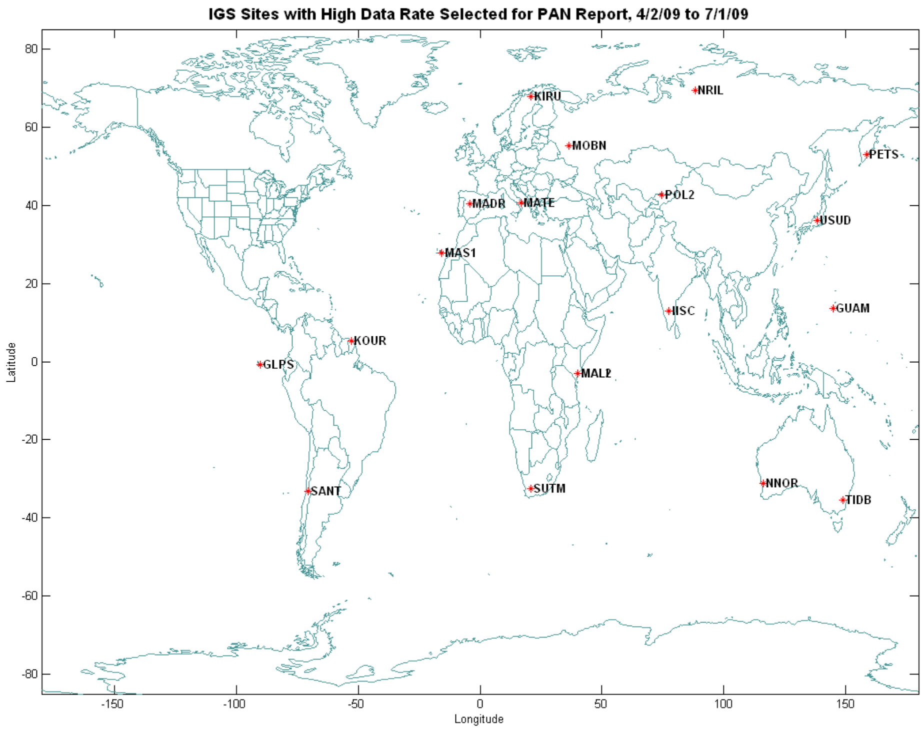


Table 7-2 GPS SPS Performance at Selected High Rate IGS Sites

Site	95% Horizontal Error (m)	95% Vertical Error (m)	99.99% Horizontal Error (m)	99.99% Vertical Error (m)	Percent Data Available
GLPS	2.91	4.48	5.41	13.60	81.57%
GUAM	2.21	4.81	5.81	15.87	70.52%
IISC	2.35	4.41	5.53	12.51	99.30%
KIRU	1.95	4.59	4.23	10.13	99.99%
KOUR	2.85	4.26	5.57	12.64	99.99%
MADR	2.03	3.98	5.97	9.47	96.80%
MAL2	2.57	4.30	5.75	9.78	97.30%
MAS1	5.03	4.67	8.98	16.44	100.00%
MATE	2.07	4.40	3.68	8.06	90.51%
MOBN	2.67	4.51	5.35	9.92	86.30%
NNOR	2.09	5.11	5.21	11.06	99.90%
NRIL	1.74	4.48	4.61	10.95	95.95%
PETS	2.37	4.65	4.88	10.95	96.38%
POL2	2.56	5.33	17.86	27.14	59.65%
SANT	4.32	4.49	9.30	10.19	99.97%
SUTM	2.00	4.25	5.72	9.86	98.79%
TIDB	2.18	4.67	11.82	15.08	97.56%

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

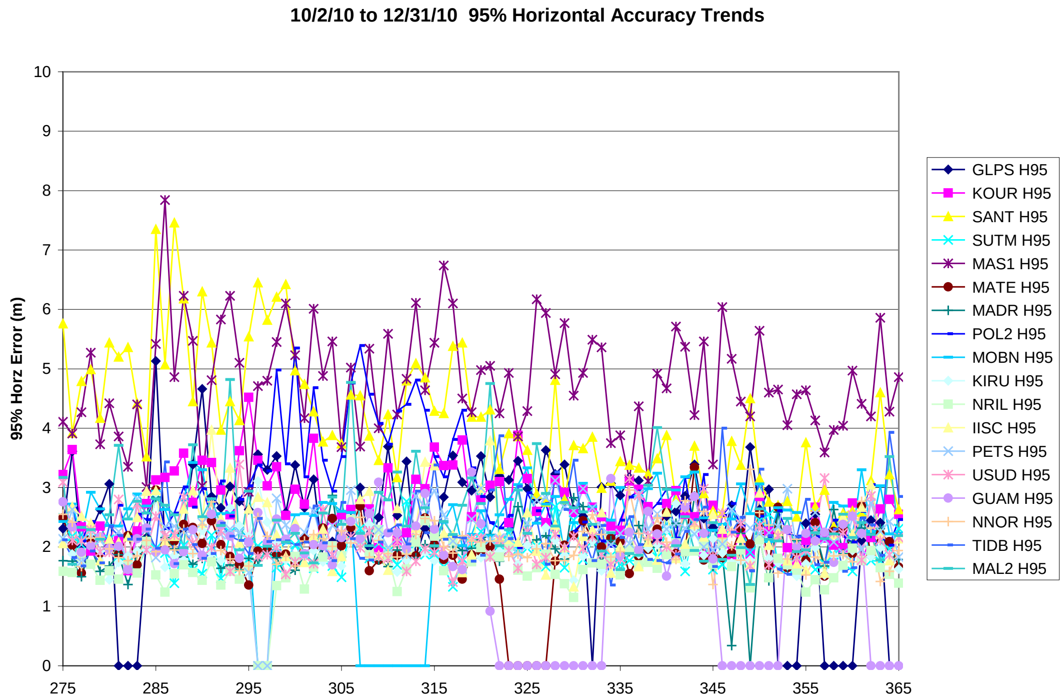
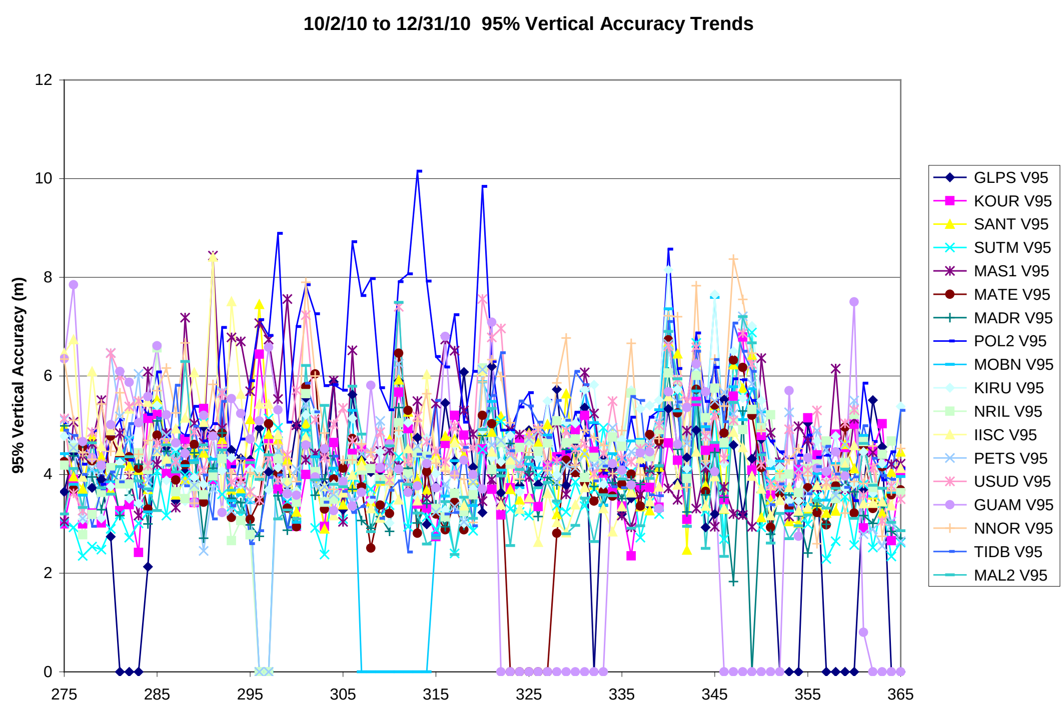


Figure 7-3 GPS SPS 95% Vertical Accuracy Trends at Selected IGS Sites



8 Appendices

8.1 Appendix A: Performance Summary

Table 8-1 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	≤ 4.087 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	≤ 2.970 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	≤ 0.024192 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	≥ 62.30 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	≤ 14 minutes
Operational Satellite Count	**Conditions and Constraints**	
• ≥ 0.95 Probability that the constellation will have a t 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	≥ 99.986 % ≥ 98.472 %
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.	≤ 2.199 m Horizontal ≤ 4.130 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.	≤ 4.449 m Horizontal ≤ 4.764 m Vertical
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.	≤ 10 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 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.	99.968% 99.685%
Constellation Availability	**Conditions and Constraints**	
• ≥ 0.98 Probability that at least 21 slots out of the 24 will be occup0ied 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 a n 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%

8.2 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
2010 10 01	0	0 1 0 0 0 0 0 0	0	0 0 0 0 0 0 0 0	3	1 0 0 0 2 1 1 1
2010 10 02	0	0 0 0 0 0 1 0 0	0	0 0 0 0 0 0 0 0	2	0 0 0 0 2 1 1 1
2010 10 03	1	1 1 0 1 0 0 0 0	0	0 0 0 1 0 0 0 0	3	1 0 0 1 1 1 0 1
2010 10 04	2	0 0 0 0 1 1 1 1	0	0 0 0 0 1 0 0 0	3	0 0 0 0 2 1 1 2
2010 10 05	6	1 2 3 2 2 1 1 0	12	2 0 4 4 4 2 0 0	6	1 2 3 2 1 2 1 1
2010 10 06	5	1 0 2 2 3 1 1 1	13	0 0 3 4 5 2 1 0	8	1 0 2 2 3 2 3 1
2010 10 07	2	1 1 1 0 1 1 0 1	10	0 0 4 4 4 0 0 0	4	1 2 1 1 1 1 0 1
2010 10 08	3	2 1 0 1 1 1 0 1	5	3 1 1 3 0 0 1 0	4	3 1 1 1 0 1 0 1
2010 10 09	3	1 1 1 1 1 2 1 0	4	0 0 0 4 0 1 1 0	4	1 1 1 1 1 1 0 1
2010 10 10	1	0 0 0 0 1 0 0 1	3	0 0 0 2 3 0 0 1	2	0 0 0 0 1 0 0 1
2010 10 11	10	1 2 2 3 4 2 2 2	49	0 0 4 6 6 7 5 3	20	1 2 3 4 5 4 3 2
2010 10 12	7	3 2 2 1 2 1 1 2	15	2 3 3 3 4 4 1 2	10	3 3 3 1 2 3 2 2
2010 10 13	3	1 1 1 1 0 1 1 1	4	2 1 1 2 2 1 0 0	4	2 1 2 1 1 1 1 1
2010 10 14	0	1 0 0 0 0 0 0 0	0	0 0 0 0 0 0 0 0	2	1 0 0 0 0 0 0 1
2010 10 15	3	0 1 0 1 1 1 1 2	3	0 0 0 1 3 0 1 0	5	0 1 0 1 1 1 3 1
2010 10 16	3	1 1 1 0 1 1 2 1	5	1 0 1 0 2 3 1 2	6	1 2 1 0 1 1 3 2
2010 10 17	10	2 3 4 2 1 1 2 2	22	2 2 6 5 4 1 1 1	11	2 3 4 3 1 0 2 3
2010 10 18	3	2 0 0 1 0 0 1 2	4	1 0 1 3 1 0 1 2	5	2 0 0 1 1 1 2 3
2010 10 19	7	2 2 2 1 2 1 3 1	7	2 3 3 3 1 0 0 1	5	2 2 2 1 1 0 0 2
2010 10 20	3	2 0 0 1 2 0 1 0	5	1 1 0 1 4 0 0 0	4	2 0 0 1 2 0 1 1
2010 10 21	1	1 0 0 0 1 1 0 0	2	1 0 0 0 2 1 0 0	3	1 0 0 0 2 1 1 1
2010 10 22	4	0 1 2 1 1 1 2 2	5	0 0 3 2 2 1 1 1	6	0 1 2 1 1 2 2 3
2010 10 23	16	4 2 3 3 3 3 2 4	40	2 3 4 6 7 4 2 3	23	3 2 4 4 5 4 2 4
2010 10 24	10	3 3 2 2 2 2 3 1	24	3 4 3 5 5 3 3 2	14	3 4 2 3 3 2 4 1
2010 10 25	4	1 1 1 1 2 1 2 1	9	1 1 2 3 4 2 1 2	6	2 1 1 1 2 1 3 1
2010 10 26	6	3 1 2 2 1 1 2 1	7	2 1 2 2 1 2 3 2	8	3 2 2 2 1 2 2 2
2010 10 27	3	0 1 1 1 1 1 2 1	2	1 1 0 1 1 0 1 0	4	1 1 1 0 1 0 2 2
2010 10 28	2	0 0 0 1 1 1 1 0	4	1 0 0 3 2 1 1 0	3	0 0 0 0 1 1 1 1
2010 10 29	2	1 1 1 0 1 0 0 0	2	1 0 0 0 2 2 0 0	3	1 1 0 0 1 2 0 0
2010 10 30	2	0 0 0 1 1 1 0 1	0	0 0 0 0 0 1 0 0	2	0 0 0 1 1 2 0 0
2010 10 31	4	0 2 1 2 2 1 1 1	1	0 0 0 0 1 0 1 0	3	0 2 0 1 2 0 0 1
2010 11 01	2	0 0 1 0 2 0 1 0	0	0 0 0 0 0 0 0 0	2	0 1 1 0 1 0 0 1
2010 11 02	1	0 0 1 1 1 0 0 0	2	0 0 2 2 1 0 0 0	2	0 0 1 1 1 1 0 0
2010 11 03	2	1 1 1 1 1 0 1 0	6	0 0 2 2 4 1 1 0	4	1 1 1 1 1 1 1 1
2010 11 04	2	1 1 0 1 1 1 0 1	7	0 0 1 4 4 0 0 0	3	1 1 0 1 2 0 0 1
2010 11 05	2	0 0 1 1 1 2 1 0	4	0 0 2 3 2 0 0 0	2	0 0 1 1 1 1 0 0
2010 11 06	1	0 0 0 0 0 2 0 0	0	0 0 0 1 0 0 0 0	1	0 0 0 0 0 1 0 1
2010 11 07	1	1 0 0 0 1 0 1 0	1	0 0 0 0 0 0 1 1	1	1 0 0 0 0 0 1 0
2010 11 08	2	0 0 1 1 2 1 1 0	3	0 0 0 1 3 1 1 0	3	0 0 1 0 2 2 1 1
2010 11 09	1	0 2 0 0 0 0 0 0	1	0 0 1 1 1 0 0 0	3	1 2 1 1 0 0 0 0
2010 11 10	3	0 0 0 0 0 1 2 3	1	0 0 1 0 0 0 1 1	4	0 0 0 0 0 1 2 3
2010 11 11	12	3 2 1 3 3 2 1 4	24	1 0 2 5 6 4 3 3	15	3 1 2 3 4 3 2 4
2010 11 12	9	3 3 2 3 2 1 1 2	24	3 3 3 6 5 2 1 2	15	4 3 3 4 3 2 2 2
2010 11 13	4	1 1 1 1 1 1 2 1	6	1 0 1 3 3 1 1 2	8	2 0 1 1 2 2 3 3
2010 11 14	5	1 2 1 1 1 2 2 2	6	1 0 0 2 1 3 3 2	7	1 2 0 0 1 3 3 3
2010 11 15	5	1 3 1 2 1 1 0 2	8	2 1 3 4 2 0 0 2	7	2 3 1 2 1 1 1 3

2010 11 16	4	3	0	0	1	1	2	1	1	8	2	1	0	3	4	3	0	0	6	3	1	0	1	2	3	1	1
2010 11 17	3	1	2	1	1	1	1	0	0	2	0	2	1	0	0	0	1	0	4	1	3	1	0	1	1	0	1
2010 11 18	4	0	2	1	2	2	1	1	0	4	0	2	1	3	1	1	1	0	5	1	2	1	1	1	1	2	1
2010 11 19	2	1	1	0	1	1	0	0	0	1	0	0	1	1	0	0	0	0	2	1	1	0	0	1	1	0	0
2010 11 20	2	0	0	2	1	1	0	0	0	1	0	0	1	0	1	0	0	0	2	0	0	1	0	0	0	0	0
2010 11 21	2	1	0	0	2	1	0	1	1	5	0	0	0	4	2	1	1	0	3	1	0	0	2	1	0	0	1
2010 11 22	4	0	1	1	2	2	2	1	1	6	0	0	1	4	3	1	1	0	4	1	1	1	2	2	1	0	1
2010 11 23	7	1	1	3	1	1	3	2	1	10	0	1	3	1	3	4	2	2	8	2	1	3	1	1	3	3	2
2010 11 24	3	0	1	1	1	1	1	2	1	7	1	0	2	3	3	1	2	1	4	1	1	1	1	1	1	2	2
2010 11 25	2	0	1	1	1	1	0	1	0	3	0	1	1	2	2	0	0	0	4	1	2	1	1	1	1	1	0
2010 11 26	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	2	0	0	0	0	1	1	1	1
2010 11 27	5	0	0	0	0	1	2	3	3	4	0	0	0	0	0	1	3	3	12	0	0	0	0	1	1	6	4
2010 11 28	7	2	3	2	1	1	2	2	1	7	3	3	1	0	2	2	1	2	6	2	2	1	0	1	2	3	1
2010 11 29	2	0	0	1	1	1	0	1	1	4	0	0	2	3	2	0	0	0	3	0	0	1	1	1	1	1	0
2010 11 30	2	1	1	0	1	1	1	1	0	3	0	0	0	3	0	2	1	1	3	0	1	0	1	1	1	1	0
2010 12 01	1	0	0	0	0	0	1	1	0	1	0	0	1	0	0	0	1	0	2	1	0	0	0	0	0	1	1
2010 12 02	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	2	1	0	0	1	0	0	0
2010 12 03	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0
2010 12 04	1	0	0	0	0	0	1	1	0	0	0	0	1	0	0	0	0	0	1	0	0	1	0	0	0	0	0
2010 12 05	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	1
2010 12 06	3	0	1	1	0	1	2	2	0	2	0	0	0	2	0	1	1	0	2	0	0	0	1	1	1	1	1
2010 12 07	3	0	0	1	1	2	2	1	1	3	0	0	0	1	3	1	1	1	4	1	0	1	0	2	1	1	1
2010 12 08	3	1	1	0	0	1	2	2	0	6	1	0	1	1	2	3	2	2	3	1	1	0	0	1	0	3	1
2010 12 09	0	0	0	1	0	0	0	0	0	1	1	0	2	0	0	0	0	0	2	1	1	1	0	0	0	0	1
2010 12 10	0	0	0	0	0	0	0	0	0	1	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
2010 12 11	1	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
2010 12 12	3	0	0	0	0	2	2	1	2	2	0	0	0	0	0	2	2	1	4	0	0	0	0	1	3	1	2
2010 12 13	5	2	2	1	0	1	1	2	2	7	2	1	3	2	2	1	1	2	5	2	2	2	0	0	0	2	2
2010 12 14	10	1	2	2	2	2	3	3	3	19	2	1	2	4	5	4	3	3	11	1	2	2	3	3	3	2	3
2010 12 15	8	3	4	1	1	2	1	1	0	11	3	2	2	2	4	3	1	1	9	3	4	1	1	1	1	1	1
2010 12 16	4	2	1	2	1	0	2	1	0	4	1	1	3	1	0	1	2	0	5	2	1	2	1	0	1	1	1
2010 12 17	2	2	1	0	0	1	1	1	0	4	1	1	0	0	1	2	3	1	3	2	1	0	0	1	1	1	1
2010 12 18	2	0	1	0	0	1	1	1	0	3	0	1	0	0	3	1	0	0	2	1	1	0	0	1	0	0	1
2010 12 19	2	1	1	0	0	0	0	0	2	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	2
2010 12 20	6	1	3	1	2	1	1	2	2	17	0	2	4	5	4	3	2	2	8	1	3	2	2	2	2	2	3
2010 12 21	1	0	0	0	0	0	1	1	0	1	0	0	0	1	1	0	0	0	1	0	1	0	0	1	0	0	0
2010 12 22	1	0	0	0	0	1	2	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
2010 12 23	1	0	0	0	0	0	2	0	1	1	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
2010 12 24	3	1	2	1	0	1	2	0	0	3	0	0	2	2	2	1	0	0	3	1	2	1	0	1	1	0	0
2010 12 25	4	1	1	2	1	0	2	1	1	4	0	0	2	2	2	2	1	0	5	1	2	2	1	1	2	1	1
2010 12 26	2	1	0	1	0	1	1	1	1	1	0	0	1	1	1	0	0	0	2	1	0	1	0	0	0	0	1
2010 12 27	1	1	0	0	0	0	0	0	1	1	0	1	0	0	0	0	0	1	2	1	0	0	0	0	0	0	1
2010 12 28	8	0	0	0	1	4	3	3	1	40	0	0	0	2	7	7	4	1	13	0	0	0	1	5	4	3	1
2010 12 29	3	2	1	1	0	1	1	1	0	4	0	0	1	2	3	0	1	0	3	1	0	1	0	1	1	1	0
2010 12 30	4	0	0	1	2	2	2	2	0	6	0	0	1	2	2	4	1	0	5	0	0	1	1	1	3	2	1
2010 12 31	2	0	0	1	1	1	1	0	0	9	0	1	3	4	3	3	0	0	4	1	1	1	2	1	2	0	0

8.3 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:

There were no problems to report for the quarter.

8.4 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.