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

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GPS Product Team

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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 #78, includes data collected from 1 April through 30 June 2012. The next quarterly report will be issued October 31, 2012.

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 April and 30 June 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 eight outages were reported in the NANU’s this quarter. Seven outages were scheduled while one was 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 27.529 meters on Satellite PRN 19. 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 2.512 recorded on satellite PRN 28. 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 7.79 meters at Santiago, Chile and 8.15 meters at Salta, Argentina respectively.

From the analysis performed on data collected between 1 April and 30 June 2012, the GPS performance met all SPS requirements that were evaluated. There was an issue with satellite PRN19 that caused high errors at Gander, NL Canada because it was the only site evaluated that had PRN19 in view at the time of the event. Please see section 7 (IGS Evaluation) and appendix A for further discussion of the event.

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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 2.755 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 – 7 April	2.735	100%	100%
8 – 14 April	2.739	100%	100%
15 – 21 April	2.745	100%	100%
22 – 28 April	2.751	100%	100%
29 Jan – 5 May	2.749	100%	100%
6 – 12 May	2.749	100%	100%
13 – 19 May	2.755	100%	100%
20 – 26 May	2.751	100%	100%
27 May – 2 June	2.752	100%	100%
3 – 9 June	2.752	100%	100%
10 – 16 June	2.752	100%	100%
17 – 23 June	2.745	100%	100%
24 – 30 June	2.750	100%	100%

Figure 2-1 World GPS Maximum PDOP

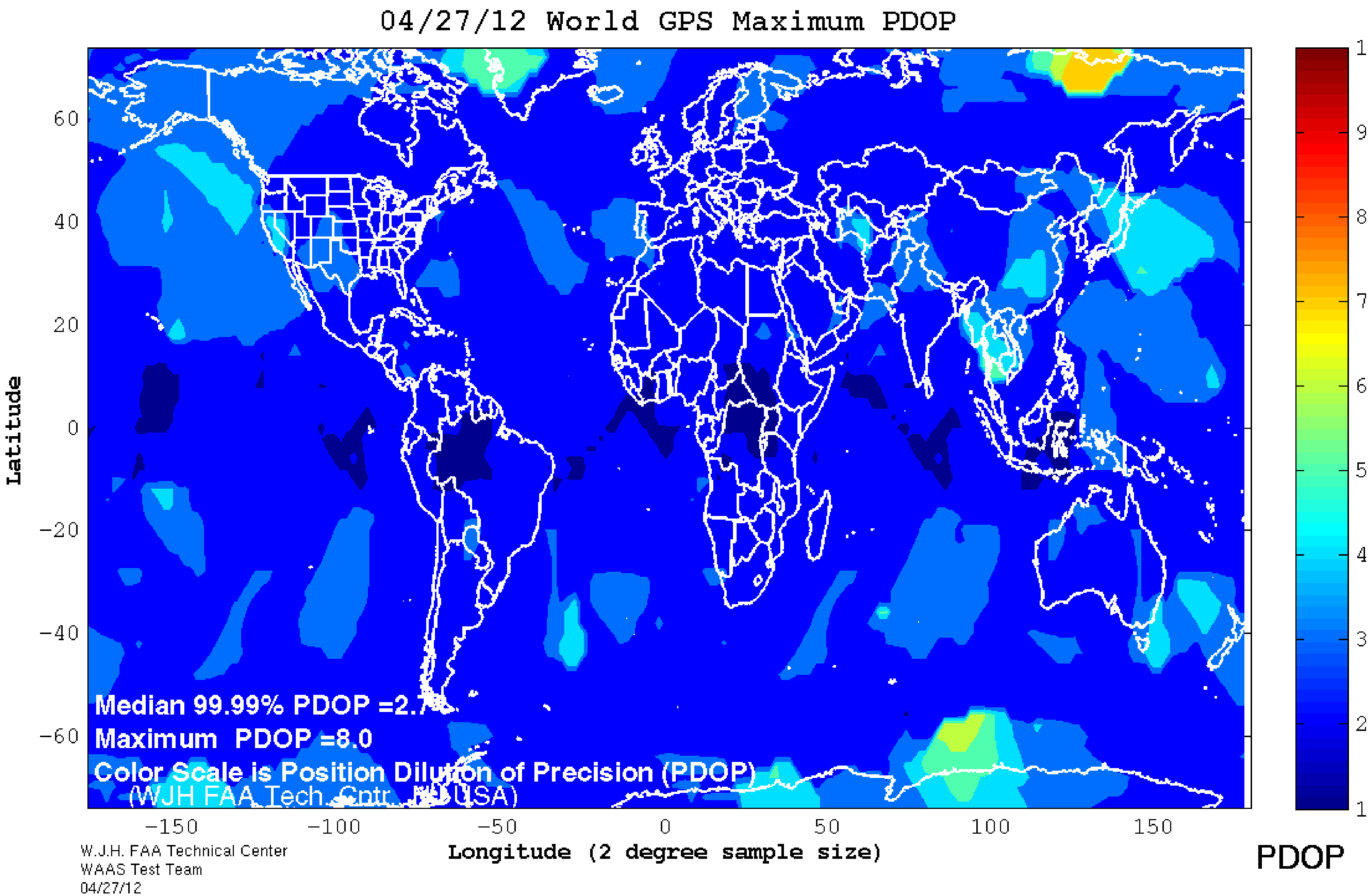
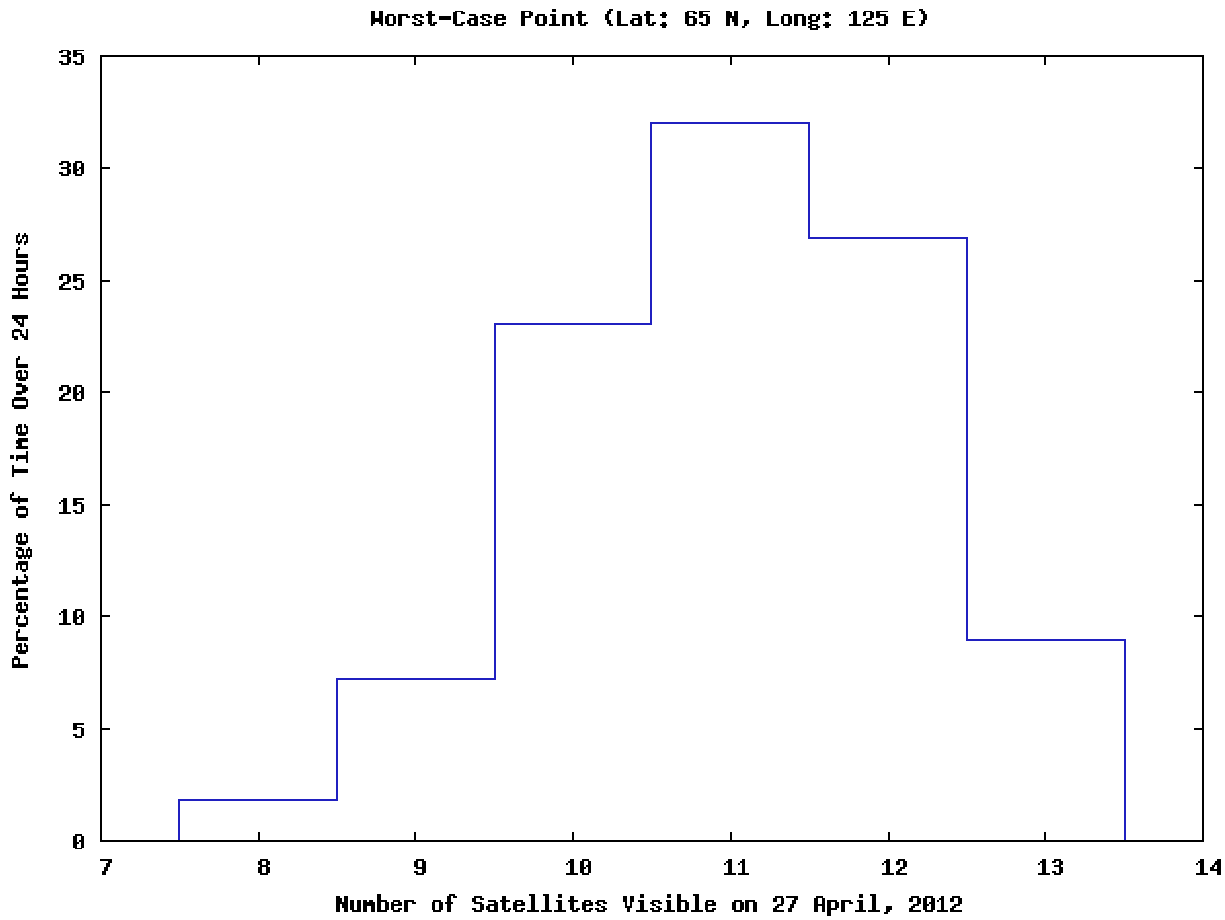


Figure 2-2 Satellite Visibility Profile for Worst-Case Point



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 April through 30 June 2012, there were a total of eight reported outages. Seven of these outages were maintenance activities and were reported in advance while one was 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 115.017 hours, which met the 48-hour requirement. The maximum response time for a NANU issued for an unscheduled outage was 46.70 hours.

Table 3-1 NANUs Affecting Satellite Availability

NANU#	PRN	TYPE	Start Date	Start Time	End Date	End Time	Total Unscheduled	Total Scheduled	Total
2012022	15	FCSTSUMM	12-Apr-12	12:00	12-Apr-12	18:12		6.2	6.2
2012027	28	FCSTSUMM	24-Apr-12	21:44	25-Apr-12	4:11		6.45	6.45
2012028	12	FCSTSUMM	27-Apr-12	1:17	27-Apr-12	6:35		5.3	5.3
2012029	19	FCSTSUMM	1-May-12	15:10	1-May-12	21:17		6.12	6.12
2012031	26	FCSTSUMM	7-May-12	14:18	7-May-12	15:56		1.63	1.63
2012033	30	FCSTSUMM	18-May-12	21:12	24-May-12	15:36		138.4	138.4
2012039	19	UNUNOREF	17-Jun-12	0:09	17-Jun-12	0:37	0.47		0.47
2012040	30	FCSTSUMM	19-Jun-12	14:16	20-Jun-12	1:15		10.98	10.98
Totals of Unscheduled, Scheduled & Total Downtime							0.47	175.08	175.55

GENERAL NANUs

2012024	19-Apr-12	PRN 24 resumes transmitting L-band signal. Will not be included in broadcast almanac
2012035	04-Jun-12	Announced integration assessment of the current software baseline
2012036	06-Jun-12	Completed integration assessment of the current software baseline
2012038	14-Jun-12	Forecast installation of new ground software

Table 3-2 NANUs Forecasted to Affect Satellite Availability

NANU #	PRN	Type	Start Date	Start Time	End Date	End Time	Total	Comments
2012021	15	FCSTDV	12-Apr	12:00	12-Apr	23:30	11.5	2012022
2012023	28	FCSTDV	24-Apr	21:15	25-Apr	9:15	12	2012027
2012025	12	FCSTDV	27-Apr	0:30	27-Apr	12:30	12	2012028
2012026	19	FCSTDV	1-May	14:30	2-May	2:30	12	2012029
2012030	26	FCSTMX	7-May	14:00	8-May	2:00	12	2012031
2012032	30	FCSTMX	18-May	21:00	24-May	21:00	144	2012033
2012037	30	FCSTMX	19-Jun	14:00	20-Jun	2:00	12	2012040
2012041	7	FCSTMX	27-Jun	17:00	28-Jun	5:00	0	2012042
2012043	7	FCSTDV	27-Jun	17:00	28-Jun	5:00	0	2012044
						Total Forecasted Downtime	215.50	

Table 3-3 Cancelled NANUs

NANU#	PRN	Type	Start Date	Start Time	Comments
2012042	7	FCSTCANC	27-Jun	17:00	2012041
2012044	7	FCSTCANC	27-Jun	17:00	2012043

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-Apr-12 30-Jun-12	1-Jan-00 30-Jun-12
Total Forecast Downtime (hrs):	215.50	9382.82
Total Actual Downtime (hrs):	175.55	37779.27
Total Actual Scheduled Downtime (hrs):	175.08	5546.20
Total Actual Unscheduled Downtime (hrs):	0.47	32233.07
Total Satellite Observed MTTR (hrs):	21.94	52.62
Scheduled Satellite Observed MTTR (hrs):	25.01	9.85
Unscheduled Satellite Observed MTTR (hrs):	0.47	207.96
# Total Satellite Outages:	8	718
# Scheduled Satellite Outages:	7	563
# Unscheduled Satellite Outages:	1	155
Percent Operational -- Scheduled Downtime:	99.74	99.84
Percent Operational -- All Downtime:	99.74	98.89

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 April and 30 June 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	6978477	0	100%
Anchorage	7843698	0	100%
Atlanta	7839530	0	100%
Barrow	7842414	0	100%
Bethel	7842090	0	100%
Billings	7839118	0	100%
Boston	7847646	0	100%
Cleveland	7844481	0	100%
Cold Bay	7835776	0	100%
Fairbanks	7843209	0	100%
Gander	7847712	0	100%
Honolulu	7841589	0	100%
Houston	7840228	0	100%
Iqaluit	7841378	0	100%
Juneau	7835592	0	100%
Kansas City	7831310	0	100%
Kotzebue	7834861	0	100%
Los Angeles	7844677	0	100%
Merida	7843103	0	100%
Miami	7840163	0	100%
Minneapolis	7835035	0	100%
Oakland	7845036	0	100%
Salt Lake City	7842034	0	100%
San Jose Del Cabo	7842787	0	100%
San Juan	-	-	-
Seattle	7842995	0	100%
Tapachula	7822942	0	100%
Washington, DC	7820977	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 27.529 meters on satellite PRN 19.

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**	66,889,316	0	100%
1 Apr – 30 Jun 2012	**Honolulu**	69,755,993	0	100%
1 Apr – 30 Jun 2012	**Los Angeles**	69,306,472	0	100%
1 Apr – 30 Jun 2012	**Miami**	67,109,644	0	100%
1 Apr – 30 Jun 2012	**San Juan**	-	-	-
1 Apr – 30 Jun 2012	**Juneau**	69,452,465	0	100%
1 Apr – 30 Jun 2012	**Global**	342,513,890	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 April through 30 June 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. However, Gander did experience high errors due to an issue with satellite PRN 19. Please see the problem report in appendix A for further discussion.

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	3.804	2.720	8.717	6.936
Anchorage	3.646	2.892	11.968	4.786
Atlanta	4.102	2.674	9.228	5.366
Barrow	4.089	2.594	11.538	4.751
Bethel	3.614	2.900	10.392	5.263
Billings	3.556	2.010	8.546	4.322
Boston	3.726	2.294	10.551	6.436
Cleveland	3.929	2.079	9.438	6.392
Cold Bay	3.978	2.395	9.375	4.540
Fairbanks	3.725	3.018	9.634	4.868
Gander	3.540	2.347	101.762	37.202
Honolulu	7.482	6.796	22.081	11.842
Houston	4.420	3.435	9.754	6.533
Iqaluit	4.266	2.131	10.095	4.253
Juneau	3.569	2.785	9.040	4.759
Kansas City	3.903	2.105	8.606	5.478
Kotzebue	3.774	3.001	13.046	5.136
Los Angeles	4.185	3.372	10.928	9.219
Merida	6.079	4.565	12.774	11.859
Miami	5.164	3.813	10.253	7.884
Minneapolis	3.734	1.999	8.617	5.105
Oakland	4.163	3.055	10.700	9.384
Salt Lake City	3.769	2.190	9.551	6.031
San Jose Del Cabo	5.703	4.902	16.108	11.236
San Juan	Receiver	Down	No Data	Available
Seattle	3.682	2.145	10.027	5.207
Tapachula	8.206	5.753	18.302	13.918
Washington, DC	4.000	2.322	9.698	5.632

Figures 5-1 and 5-2 are the combined histograms of the vertical and horizontal errors for all twenty-eight WAAS sites from 1 April to 30 June 2012.

Figure 5-1 Global Vertical Error Histogram

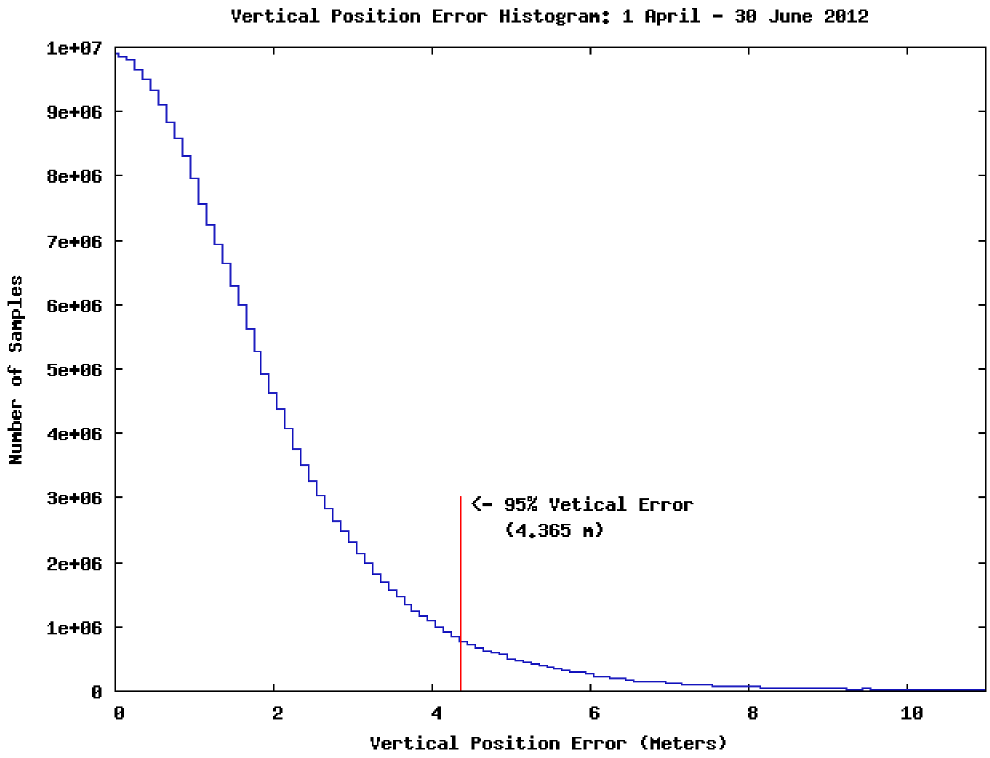
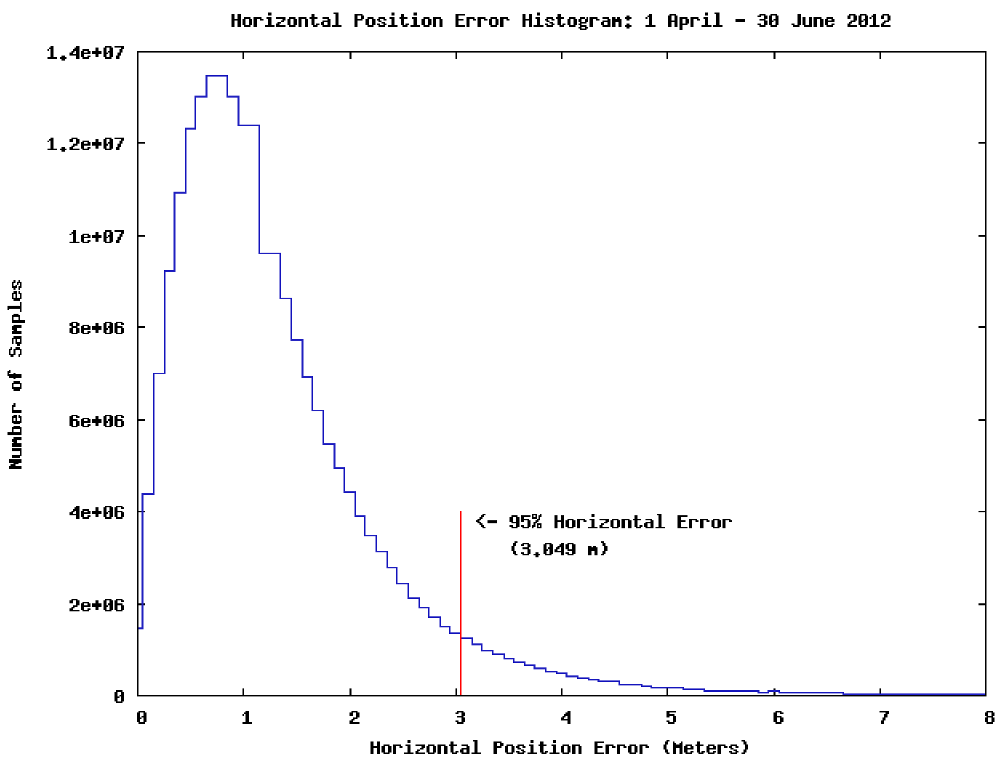


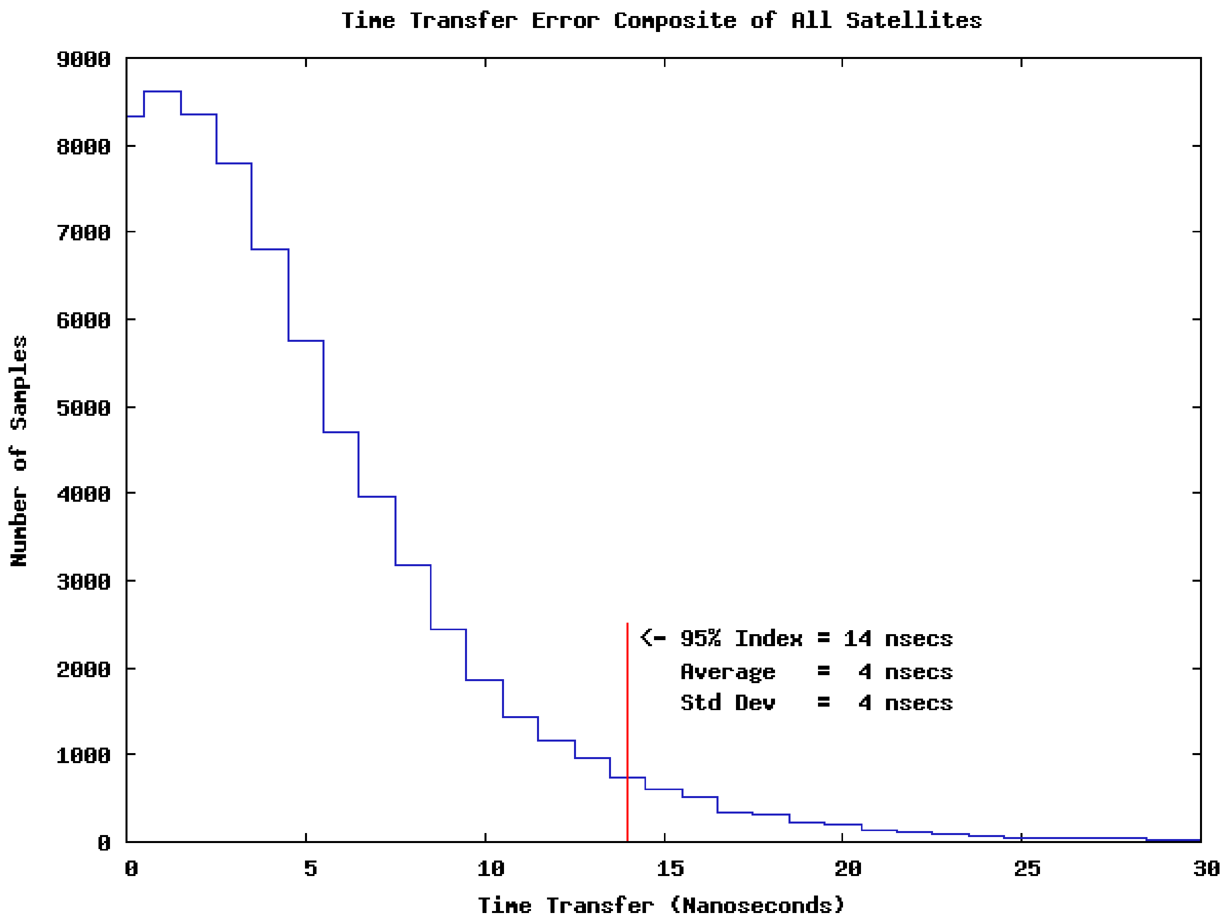
Figure 5-2 Global Horizontal Error Histogram



5.2 Time Transfer Accuracy

The GPS time error data between 1 April and 30 June 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 April and 30 June 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 (≤ 6 m)	Range Error Mean	1σ	95% Range Error	Max Range Error (SPS Spec. ≤ 30 m)	Samples
1	1.784	-0.241	1.514	3.389	18.623	13624781
2	1.874	-0.386	1.614	3.629	15.472	14311306
3	2.073	0.039	1.649	3.762	20.960	12355518
4	2.131	-0.807	1.648	3.916	16.686	13432648
5	1.984	-0.991	1.569	3.520	14.893	13445490
6	1.762	-0.260	1.522	3.413	22.832	13515230
7	2.475	-1.431	1.639	4.236	13.893	12474031
8	2.414	-0.458	1.784	4.325	12.933	12886775
9	2.149	-0.541	1.731	3.975	19.182	14023123
10	2.009	0.147	1.584	3.658	14.305	12111422
11	1.865	-0.192	1.540	3.508	26.168	12669951
12	2.149	-1.068	1.671	4.004	18.485	13968994
13	2.080	-0.914	1.578	3.676	17.997	13048133
14	1.668	-0.224	1.418	3.257	14.388	14297510
15	1.722	-0.621	1.428	3.070	19.013	12667156
16	1.983	-0.411	1.599	3.731	14.408	13081038
17	2.352	-0.812	1.861	4.367	21.560	14361018
18	1.341	0.226	1.108	2.564	11.316	13475020
19	1.905	0.174	1.639	3.532	27.529	12313211
20	1.744	0.122	1.501	3.287	15.706	14111983
21	1.513	0.220	1.221	2.928	13.746	12690309
22	1.688	0.582	1.202	3.106	17.164	12723717
23	1.883	-0.679	1.387	3.323	15.639	12534707
25	1.869	-0.691	1.535	3.650	14.039	14326238
26	2.085	-0.582	1.721	3.919	17.933	13443847
27	2.217	-0.247	1.846	4.165	19.843	14666054
28	2.512	-0.549	1.828	4.451	15.542	13244945
29	1.960	-0.740	1.559	3.683	18.416	13008139
30	2.437	0.019	1.865	4.444	14.889	11568713
31	2.021	-0.961	1.480	3.712	15.093	13784327
32	1.761	0.555	1.391	3.288	21.060	13296999

Table 5-3 Range Rate Error Statistics

(Millimeters/ Second)

PRN	Range Rate Error RMS	95% Range Rate Error	Max Range Rate Error	Samples
1	1.521	2.835	178.91	13624781
2	1.630	3.085	169.32	14311306
3	1.926	3.077	165.62	12355518
4	1.617	3.043	119.86	13432648
5	1.541	2.943	139.89	13445490
6	1.515	2.719	145.58	13515230
7	1.599	3.002	155.16	12474031
8	2.105	3.281	154.18	12886775
9	1.904	3.164	144.77	14023123
10	1.912	3.070	144.60	12111422
11	1.648	3.041	174.84	12669951
12	1.693	3.232	160.95	13968994
13	1.604	3.046	127.30	13048133
14	1.591	2.988	135.34	14297510
15	1.538	2.954	147.59	12667156
16	1.599	3.002	167.51	13081038
17	1.742	3.212	122.65	14361018
18	1.473	2.811	195.24	13475020
19	1.538	2.925	128.31	12313211
20	1.559	2.976	112.25	14111983
21	1.547	2.945	89.72	12690309
22	1.634	2.804	143.92	12723717
23	1.536	2.819	183.67	12534707
25	1.500	2.831	192.15	14326238
26	1.545	3.008	115.10	13443847
27	2.282	3.237	235.92	14666054
28	1.699	3.036	137.85	13244945
29	1.620	3.031	145.64	13008139
30	2.889	2.840	315.81	11568713
31	1.615	2.892	190.39	13784327
32	1.608	2.715	140.83	13296999

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
1	10.917	20.784	1770	13624781
2	10.820	21.792	1690	14311306
3	14.462	22.202	1660	12355518
4	11.179	21.506	1200	13432648
5	10.865	21.965	1380	13445490
6	11.529	21.239	1450	13515230
7	11.151	21.919	1580	12474031
8	15.781	22.154	1530	12886775
9	13.692	22.015	1460	14023123
10	14.270	21.967	1440	12111422
11	11.568	21.909	1740	12669951
12	10.845	22.010	1600	13968994
13	11.160	21.817	1270	13048133
14	11.165	21.853	1350	14297510
15	10.749	22.055	1440	12667156
16	11.204	22.154	1660	13081038
17	11.886	21.825	1230	14361018
18	10.607	21.738	1970	13475020
19	10.690	22.037	1300	12313211
20	10.847	21.688	1110	14111983
21	10.512	21.960	910	12690309
22	12.529	21.428	1430	12723717
23	11.003	21.171	1820	12534707
25	10.556	20.555	1900	14326238
26	10.575	21.188	1150	13443847
27	17.467	21.868	2350	14666054
28	11.906	21.811	1390	13244945
29	11.113	21.635	1460	13008139
30	24.308	21.603	3120	11568713
31	11.556	21.788	1900	13784327
32	12.017	20.600	1390	13296999

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 17 with an error of 26.645 meters. Satellite 27 had the lowest maximum range error of 9.032 meters.

Figure 5-4 Distribution of Daily Max Range Errors

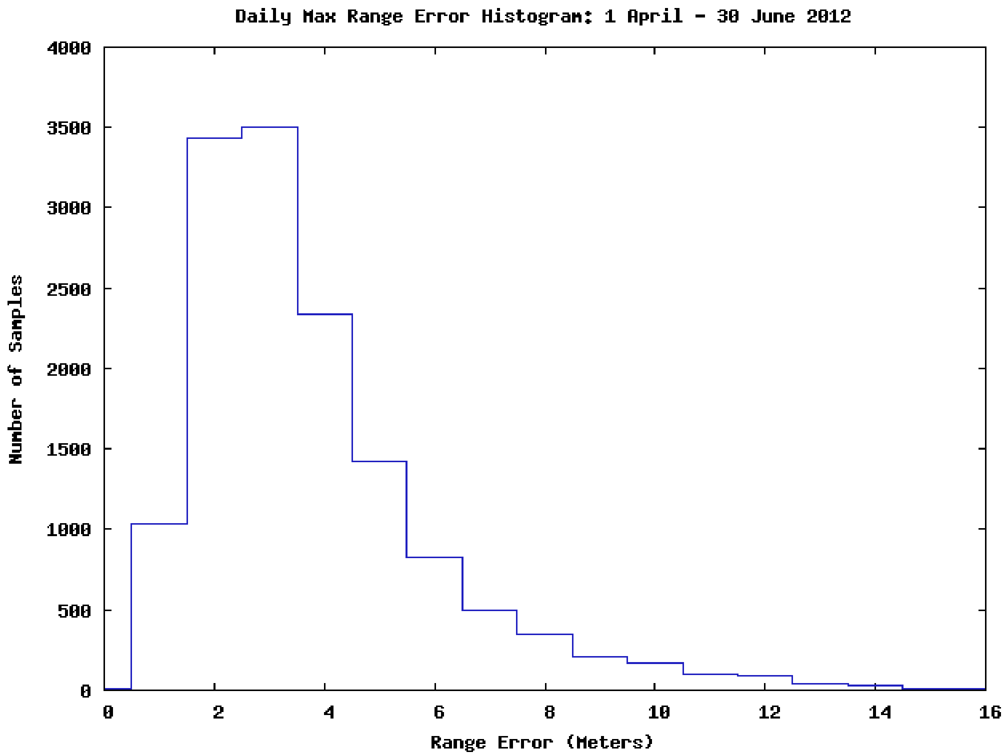


Figure 5-5 Distribution of Daily Max Range Rate Errors

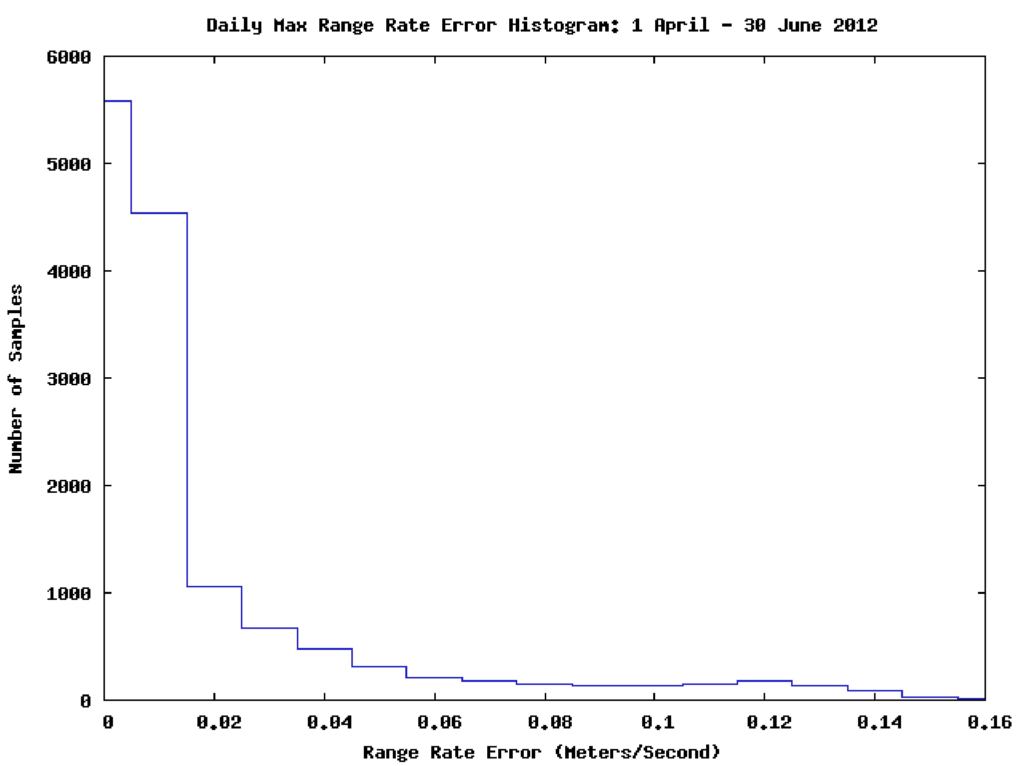


Figure 5-6 Distribution of Daily max Range Acceleration Errors

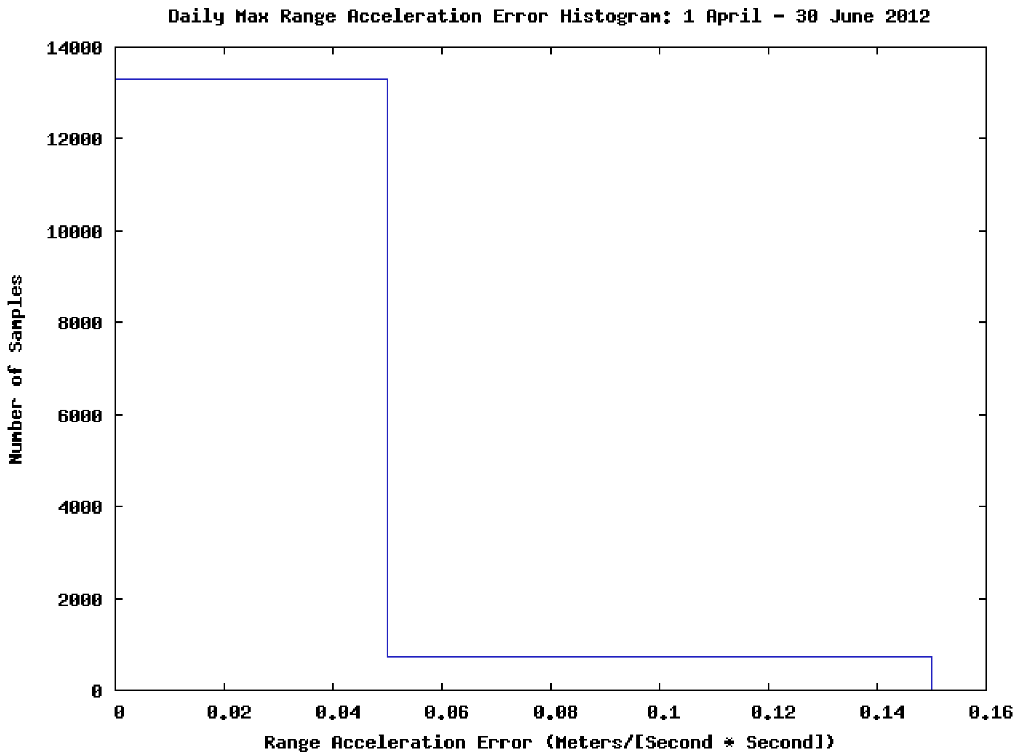


Figure 5-7 Range Error Histogram

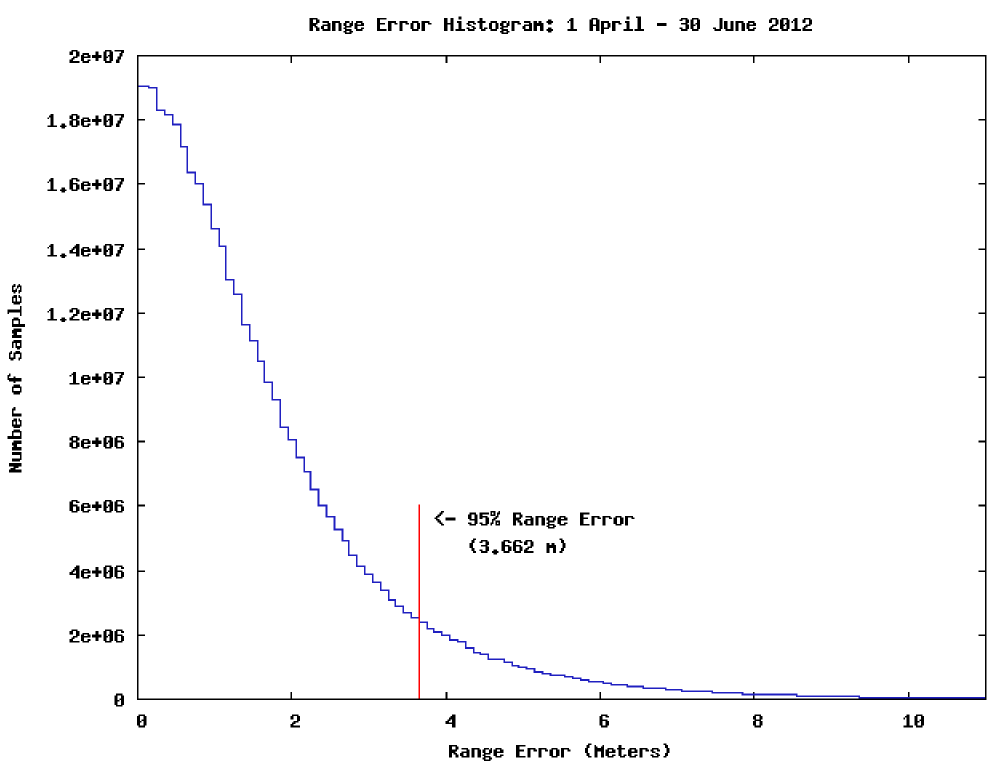


Figure 5-8 Maximum Range Error Per Satellite

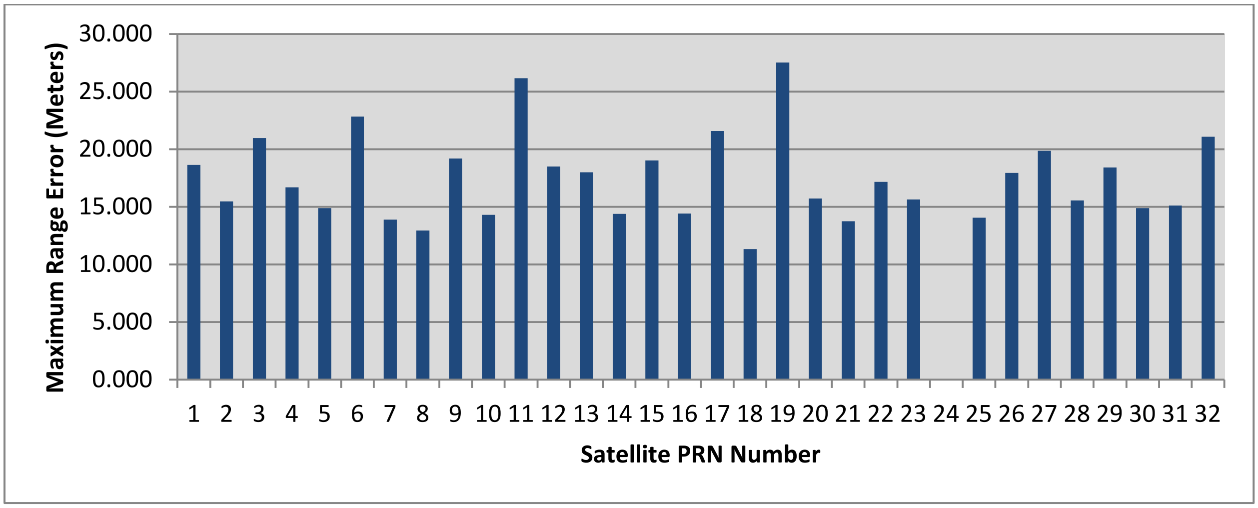


Figure 5-9 Maximum Range Rate Error Per Satellite

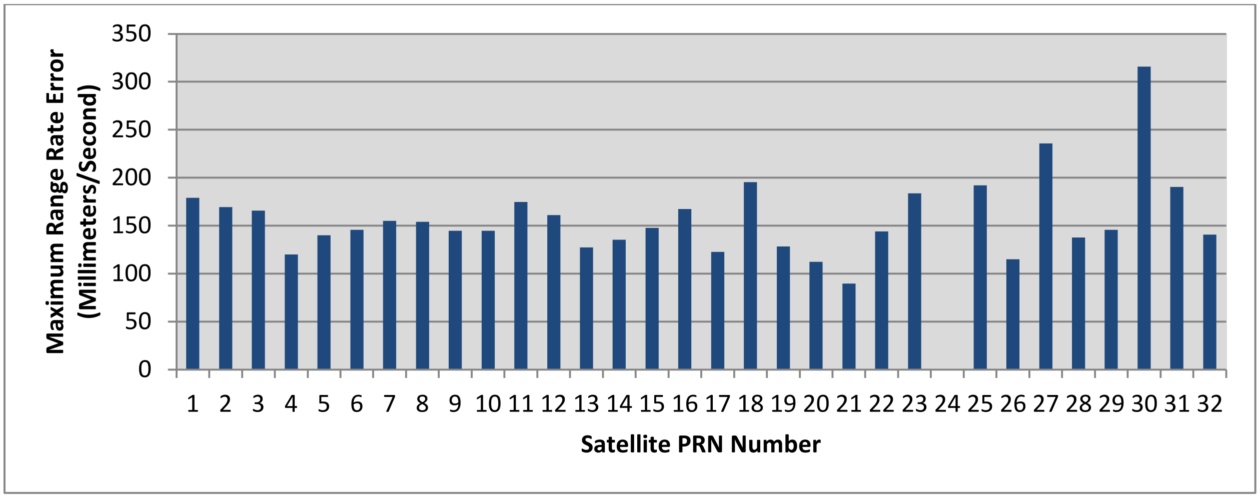
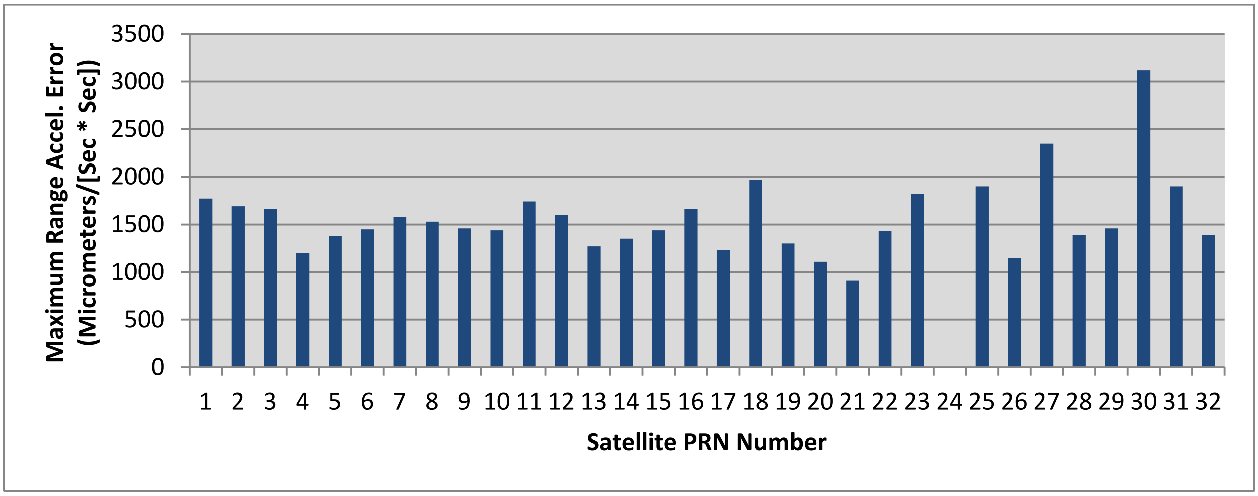


Figure 5-10 Maximum Range Acceleration Error Per Satellite



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 16-18 June 2012

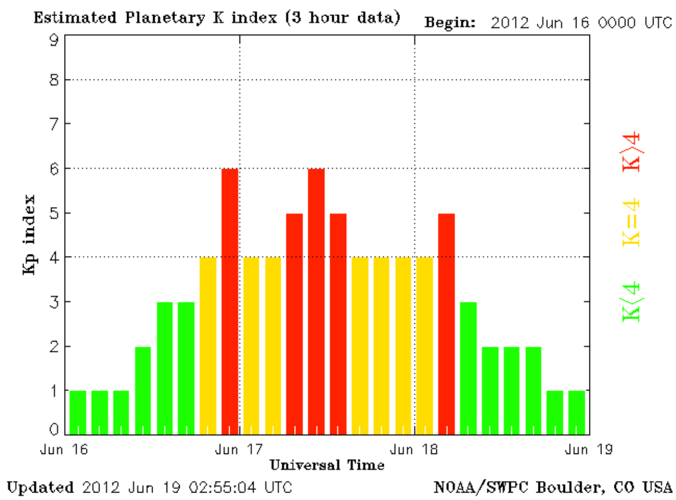


Figure 6-2 K-Index for 23-25 April 2012

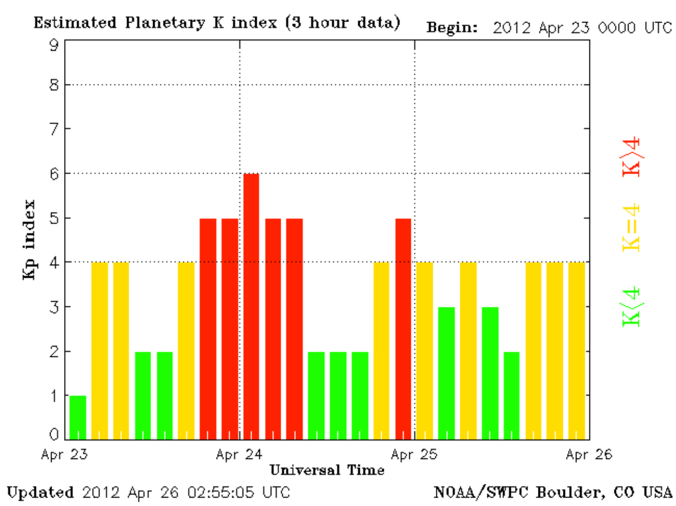


Figure 6-3 K-Index for 12-14 April 2012

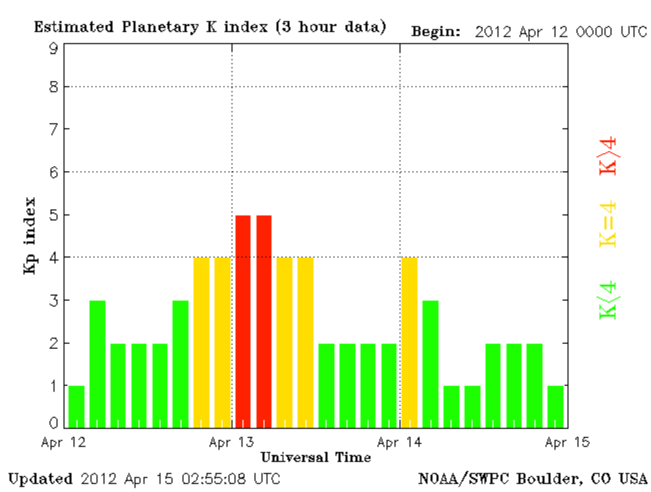


Table 6-1 shows the position accuracy information for the day corresponding to Figure 6-1. The GPS SPS performance met all requirements during all storms that occurred during this quarter.

Table 6-1 Horizontal & Vertical Accuracy Statistics for June 17, 2012

Site	95% Horizontal (Meters)	95% Vertical (Meters)	Maximum Horizontal (Meters)	Maximum Vertical (Meters)
Albuquerque	2.762	3.448	4.087	5.672
Anchorage	3.090	2.408	3.433	4.935
Atlanta	2.914	5.724	3.484	6.522
Barrow	1.601	3.093	2.740	6.173
Bethel	3.319	2.573	3.796	4.519
Billings	3.421	3.974	3.734	4.659
Boston	2.269	5.787	2.919	6.414
Cleveland	2.631	5.459	4.152	6.669
Cold Bay	3.268	2.628	4.139	3.343
Fairbanks	2.326	2.848	3.072	5.260
Gander	2.287	3.599	2.824	4.642
Honolulu	3.872	2.956	4.535	5.313
Houston	2.681	6.947	3.520	9.827
Iqaluit	1.333	4.658	2.201	6.889
Juneau	3.035	2.765	3.320	5.054
Kansas City	3.252	5.011	3.719	5.613
Kotzebue	2.325	2.732	3.051	5.045
Los Angeles	3.478	5.851	4.410	7.399
Merida	2.265	7.494	2.852	11.016
Miami	2.943	7.954	3.357	10.363
Minneapolis	3.241	4.288	4.266	5.463
Oakland	3.483	5.214	4.552	7.030
Salt Lake City	3.170	4.330	3.920	5.092
San Jose Del Cabo	3.264	5.944	3.705	6.510
San Juan	Site	Down	Data Not	Available
Seattle	3.315	3.792	3.671	5.529
Tapachula	2.363	13.448	2.770	7.887
Washington, DC	2.340	2.408	3.074	15.672

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 7-12 for an example plot. 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.

During this quarter, there was a large satellite position error on PRN-19 on 17 June 2012 due bad ephemeris data being broadcast from that satellite. See Discrepancy Report #109 for details. The duration of the PRN-19 event was approximately 27 minutes (00:10:00 to 00:37:00 GPS) and therefore does not impact the 95 % statistics, but does impact the 99.99% statistics. Figure 7-4 shows the maximum magnitude of the range error projected onto users. Figures 7-5 to 7-10 show the position errors at the IGS sites that were impacted.

High quality broadcast navigation data and Klobachar data is created by voting across all available IGS high rate RINEX navigation data. The IGS high rate navigation data for the MATE was excluded for 6/17/12 because of erroneous Time of Transmit (ToT) data, but the observation data for MATE was still utilized. RINEX navigation data updates for the period PRN-26 was out of service on 5/7/12 (see NANU 2012032) was not available, but the IGS RINEX receiver observation were still available, this 4 hour period has been edited out of the statistics.

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. The declining errors are related to effect of the equinox / solstice cycle on the accuracy of the Klobachar ionosphere model. This results in a twice a year cycle, with peak errors near the equinoxes and minimum errors near the solstices.

(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
UNSA	Salta	Argentina
USUD	Usuda	Japan

Figure 7-1 Selected IGS Site Locations

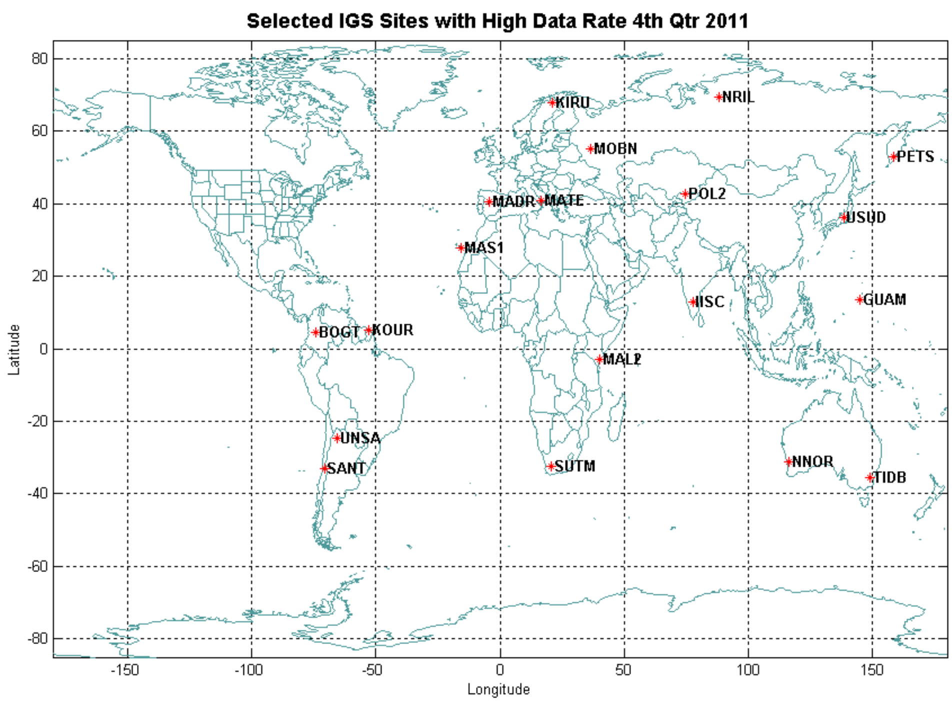


Table 7-2 GPS SPS Performance at Selected High Rate IGS Sites

Site	95% Horizontal Error (m)	95% Vertical Error (m)	99.99% Horizontal Error (m)	99.99% Vertical Error (m)	Percent Data Available
BOGT	3.77	6.57	10.11	19.63	98.23%
GUAM	3.14	7.79	7.38	21.16	98.75%
IISC	3.16	6.84	> 50.01	> 50.01	97.74%
KIRU	2.41	4.53	10.33	20.23	99.86%
KOUR	6.56	7.61	7.98	11.69	1.64%
MADR	3.15	5.32	9.71	14.66	25.76%
MAL2	4.32	5.36	> 50.01	> 50.01	94.28%
MAS1	6.65	6.84	> 50.01	> 50.01	99.84%
MATE	3.17	4.24	9.59	12.96	95.26%
MOBN	2.41	4.34	> 50.01	38.79	92.97%
NNOR	2.42	4.49	> 50.01	> 50.01	99.58%
NRIL	2.25	4.4	30.5	> 50.01	97.20%
PETS	2.65	5.16	12.77	15.41	93.14%
POL2	3.21	5.02	> 50.01	> 50.01	87.53%
SANT	7.79	6.59	16.32	15.9	39.00%
SUTM	2.08	4.29	> 50.01	> 50.01	95.87%
TIDB	2.6	4.18	> 50.01	> 50.01	98.74%
UNSA	6.66	8.15	17.73	30.8	98.50%
USUD	4.21	4.87	12.37	20.18	99.82%

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

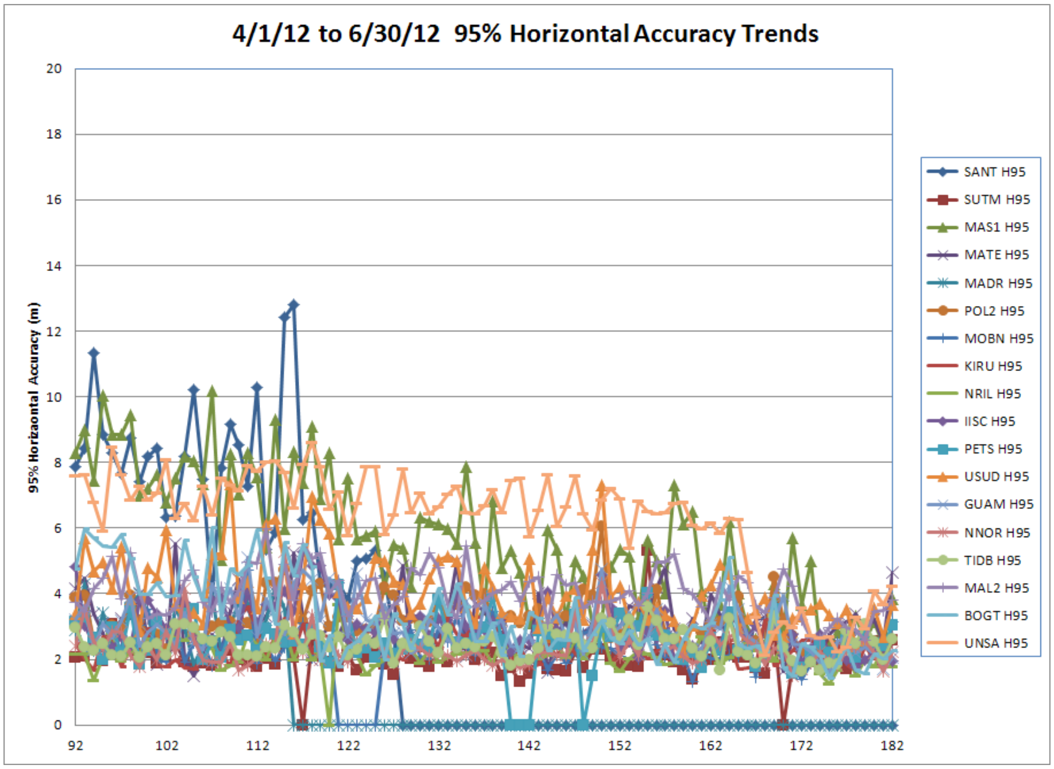


Figure 7-3 GPS SPS 95% Vertical Accuracy Trends at Selected IGS Sites

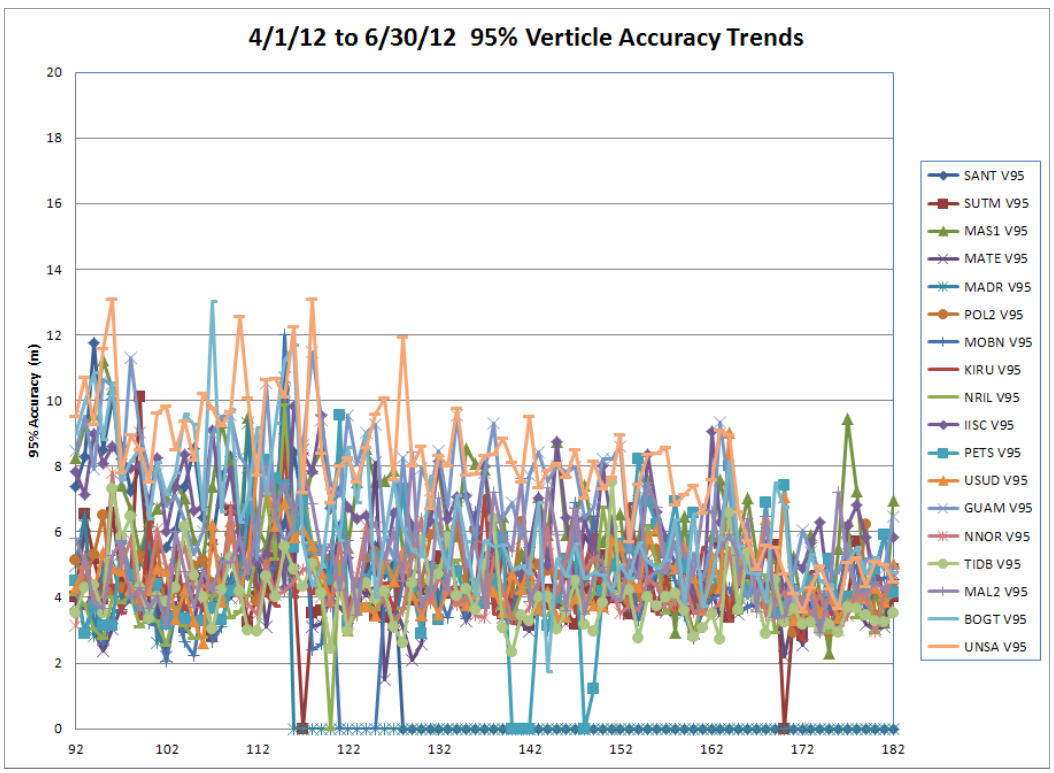


Figure 7-4 PRN-19 Anomaly Projected Range Errors 6/17/2012

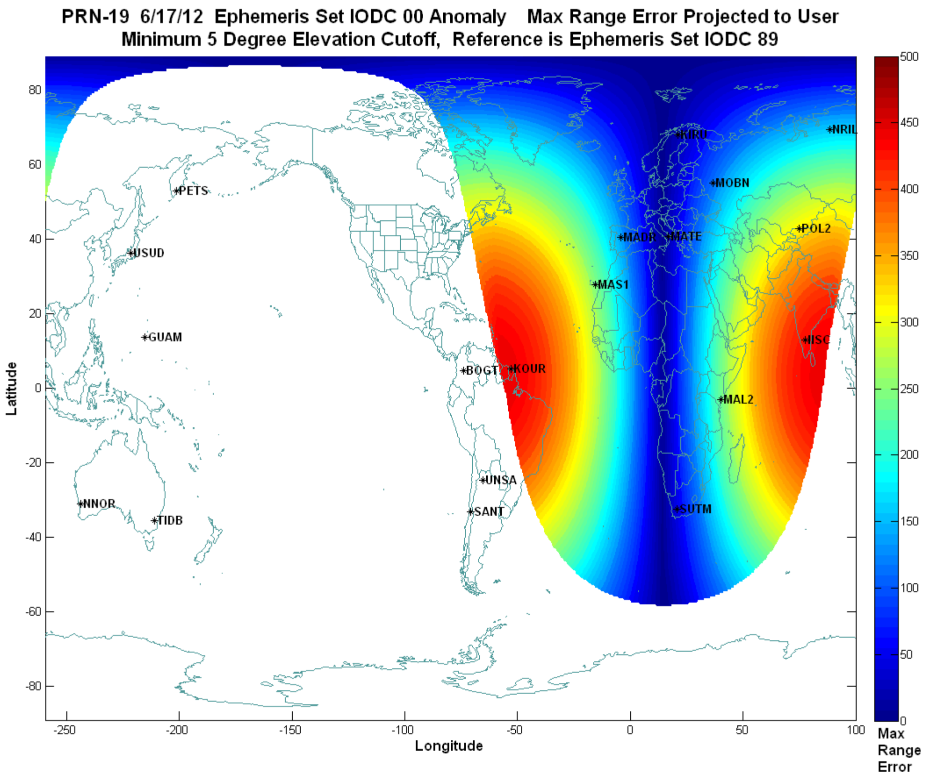


Figure 7-5 Example PRN-19 Anomaly, IISC Position Erros 6/17/2012

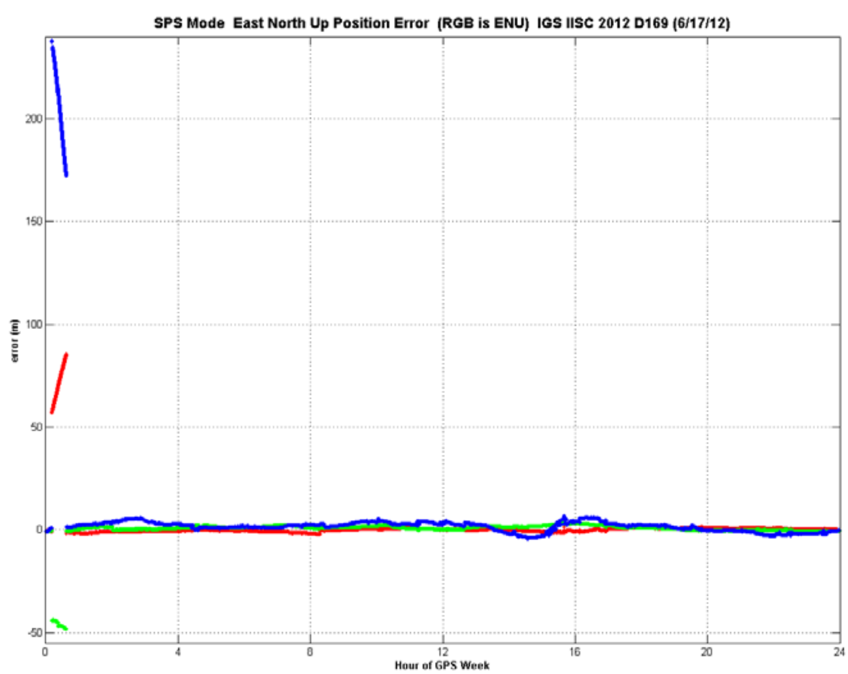


Figure 7-6 PRN-19 Anomaly, KIRU Position Errors 6/17/2012

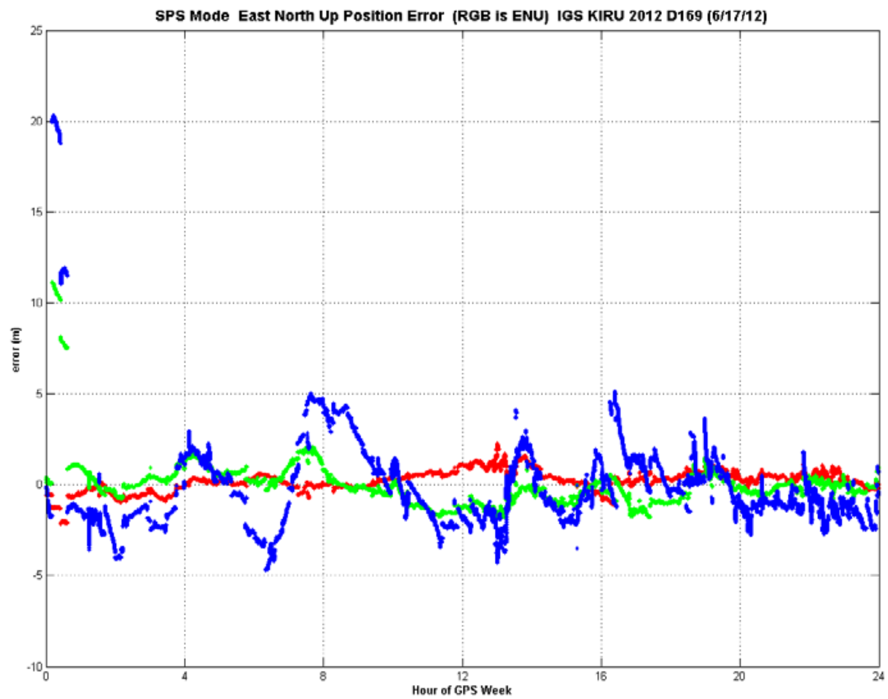
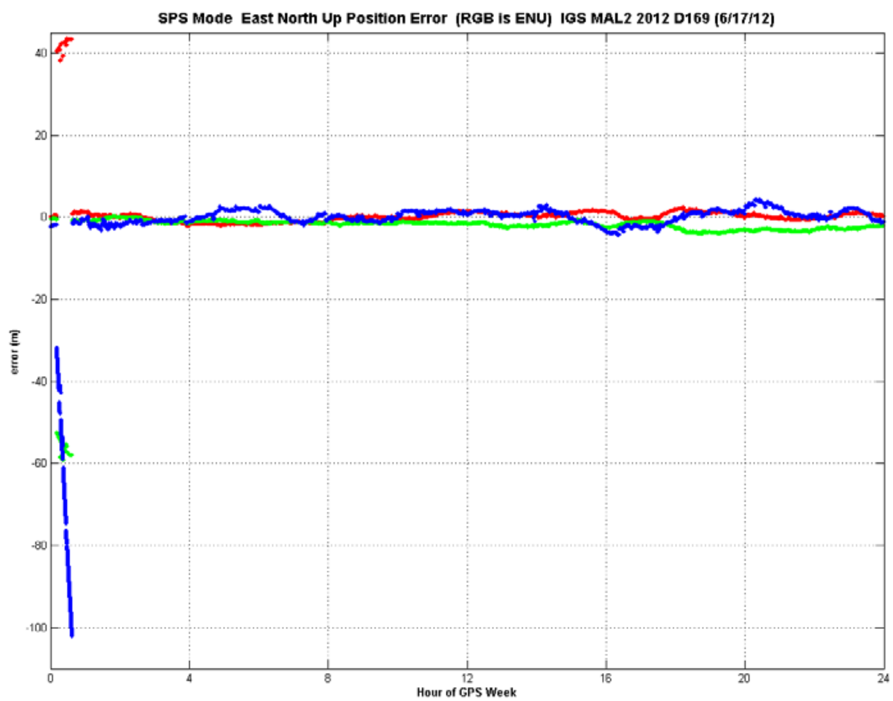


Figure 7-7 PRN-19 Anomaly, MAL2 Position Errors 6/17/2012



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, April 1 through June 30 2012, there were a total of 9 GPS test NOTAMs (Note that GPS Test NOTAMs issued for the month of June are not included. This data was unavailable due to technical issues). The total number of days affected in this reporting period is 27. 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	72.75 hours
Minimum duration	1.50 hours
Average duration	6.61 hours
Maximum duration	21.0 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	453,066	323,848	136,298	120,235	67,102
Average	561,469	416,635	237,645	230,469	175,616
Maximum	1,048,434	853,749	655,714	642,568	548,210

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

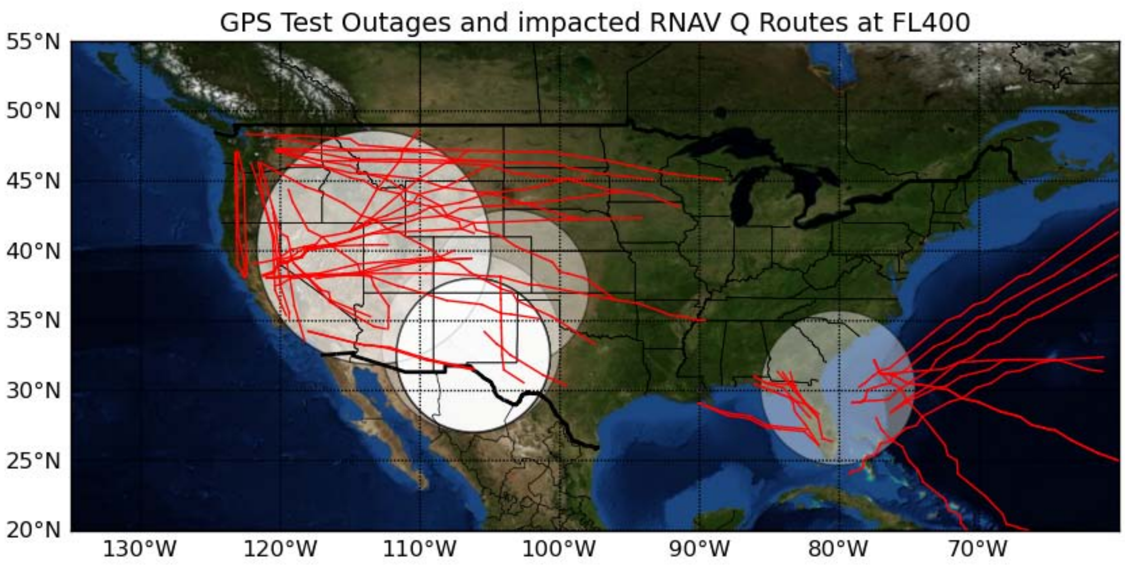


Figure 8-2 GPS NOTAMs @ FL250

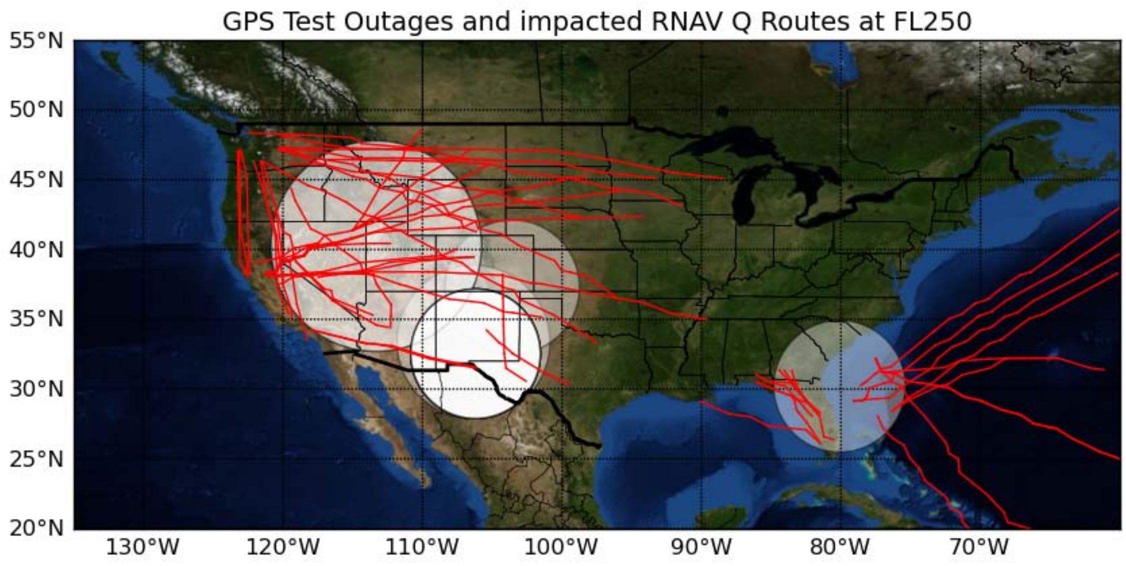


Figure 8-3 GPS NOTAMs @ 10k Feet

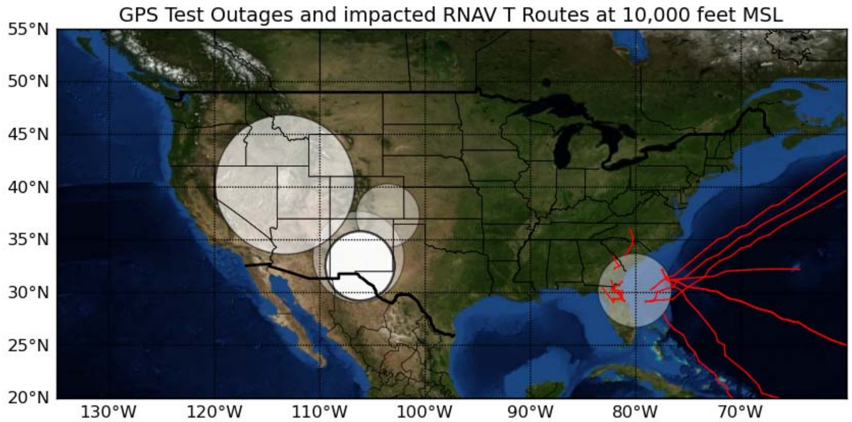


Figure 8-4 GPS NOTAMs @ 4k Feet

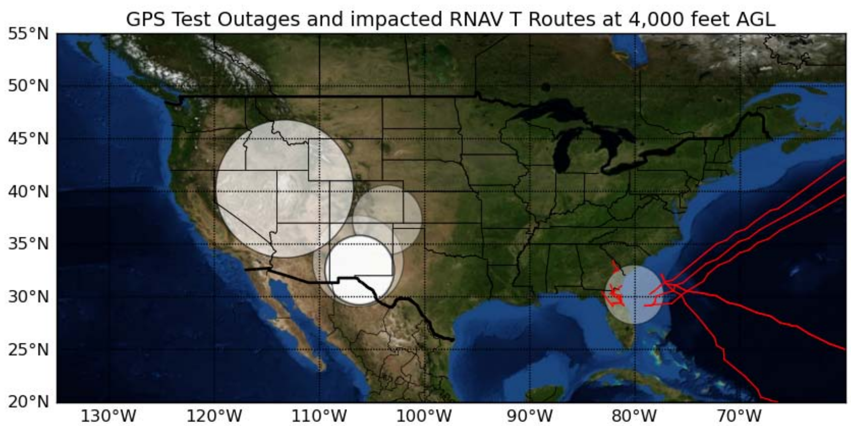
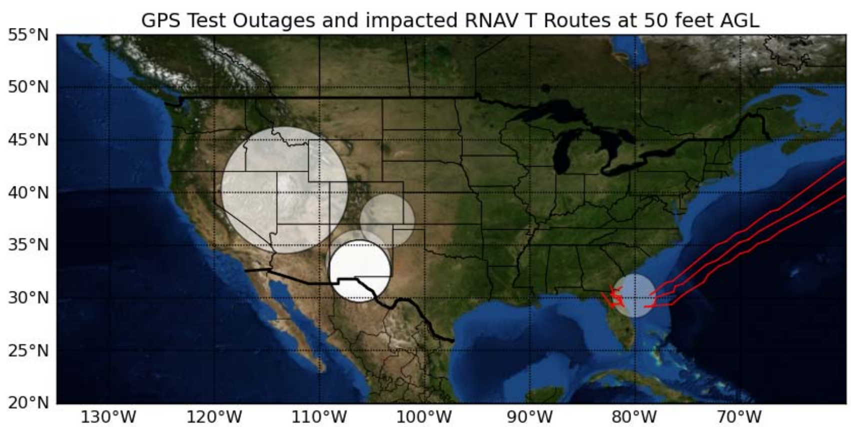


Figure 8-5 GPS NOTAMs @ 50 Feet



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
April 17 - 21	02:00 – 12:00	33.3747N/106.3400W	3.81	5.15	4.74	7.94	10.3
April 18 – 19	16:00 – 22:00	37.3003N/103.5621W	2.78	4.43	3.71	9.49	12.7
May 3	19:00 – 23:00	32.5301N/106.1931W	3.19	3.61	3.81	7.01	9.28
May 4 – May 13	20:00 - 01:45	30.2000N/80.1000W	1.03	1.85	2.88	4.85	6.70
May 12	19:00 – 23:00	32.5301N/106.1931W	3.19	3.61	3.81	7.01	9.28
May 13 – 19	02:00 – 23:00	32.5301N/106.1931W	3.19	3.61	3.81	7.01	9.28
May 14 – 17	15:00 – 17:30, 18:30 – 20:00	40.2430N/113.3118W	3.19	18.1	18.5	24.4	29.6
May 19	19:00 – 23:00	32.5301N/106.1931W	3.19	3.61	3.81	7.01	9.28
May 20 – 24	02:00 – 12:00, 19:00 – 23:00	32.5301N/106.1931W	3.19	3.81	3.61	7.01	9.28

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	≤ 4.451 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	≤ 3.281mm/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	≥ 115.017 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	≤ 46.70 hours
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.	≤ 3.049 m Horizontal ≤ 4.365 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.	≤ 6.796 m Horiz. ≤ 8.206 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.	≤ 14 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 04 01	6	1 2 1 2 2 2 2 1	11	0 1 2 3 4 4 2 1	6	1 2 1 2 2 2 2 2
2012 04 02	9	3 2 2 1 3 2 2 2	17	2 4 3 4 5 2 1 1	8	3 3 2 1 2 2 1 2
2012 04 03	4	1 2 1 0 2 1 1 2	4	1 2 1 2 2 0 1 1	5	2 2 1 0 1 1 1 2
2012 04 04	6	2 2 1 1 2 2 2 2	5	2 2 0 1 1 2 2 2	6	2 2 0 1 1 2 2 3
2012 04 05	11	2 2 3 3 3 2 3 2	35	2 4 4 7 4 5 1 1	13	3 3 3 4 3 3 2 2
2012 04 06	3	1 1 1 0 1 0 1 2	2	1 1 0 0 0 0 1 1	4	1 1 1 1 1 1 0 2
2012 04 07	3	1 -1 -1 -1 -1 -1 -1 -1	24	2 3 4 6 5 1 1 2	10	2 3 2 3 3 1 0 2
2012 04 08	-1	-1 -1 -1 -1 -1 -1 -1 -1	6	2 1 0 4 1 1 1 0	5	2 1 1 2 2 1 1 1
2012 04 09	7	-1 -1 -1 -1 -1 -1 2 2	1	0 0 0 0 0 0 2 1	4	0 1 1 0 1 1 2 2
2012 04 10	6	3 2 2 0 1 1 1 2	2	2 0 1 0 0 0 1 1	8	3 2 2 1 1 1 1 3
2012 04 11	5	1 1 2 2 2 1 1 2	3	1 1 1 3 0 0 0 0	5	2 1 2 2 1 1 1 2
2012 04 12	11	1 4 2 2 2 2 3 3	16	1 3 3 4 2 3 4 3	13	1 3 2 2 2 3 4 4
2012 04 13	13	3 4 3 3 2 2 2 2	26	3 4 5 6 3 3 2 1	19	5 5 4 4 2 2 2 2
2012 04 14	7	3 3 0 2 2 1 2 1	8	3 2 0 3 2 2 2 1	9	4 3 1 1 2 2 2 1
2012 04 15	5	1 2 1 1 2 1 2 1	6	1 1 3 3 2 1 1 0	5	1 2 2 2 1 1 2 1
2012 04 16	5	2 2 0 0 2 1 2 2	3	2 1 0 1 2 1 1 0	5	2 2 0 1 2 1 1 2
2012 04 17	8	2 0 3 2 2 2 3 2	12	0 0 3 4 3 2 4 2	8	1 0 2 2 2 2 3 2
2012 04 18	7	3 2 2 2 2 1 1 1	10	3 3 3 2 3 2 1 1	8	3 3 2 1 2 1 1 2
2012 04 19	5	1 1 1 1 2 1 2 2	3	1 1 2 1 0 0 1 2	5	1 1 1 1 1 1 2 2
2012 04 20	7	1 3 2 2 2 2 2 0	10	1 4 3 4 2 1 0 0	7	1 3 3 2 2 2 1 1
2012 04 21	6	2 0 0 2 2 1 3 2	3	1 0 0 0 0 1 2 2	6	2 1 1 1 1 1 3 3
2012 04 22	7	3 2 2 2 2 1 1 1	14	3 3 3 4 3 3 2 1	7	3 2 2 2 2 1 1 1
2012 04 23	21	1 3 3 2 3 3 3 6	37	2 5 5 1 3 5 6 5	23	1 4 4 2 2 4 5 5
2012 04 24	30	6 4 5 2 2 2 3 5	28	4 4 6 2 4 3 3 4	35	6 5 5 2 2 2 4 5
2012 04 25	18	3 3 4 3 3 3 4 3	49	4 4 7 5 4 4 6 3	21	4 3 4 3 2 4 4 4
2012 04 26	17	5 5 2 2 2 2 2 2	19	5 5 3 3 2 2 2 1	17	5 5 2 1 2 1 2 2
2012 04 27	7	3 2 2 1 2 1 2 2	8	2 2 2 3 2 1 2 2	8	3 2 2 1 1 1 2 3
2012 04 28	5	1 0 1 2 2 1 2 2	10	1 1 1 4 3 3 2 1	5	1 1 1 2 1 2 1 2
2012 04 29	5	2 3 1 1 1 1 2 0	4	2 2 1 2 2 0 0 0	5	2 2 1 1 1 1 1 0
2012 04 30	2	0 1 1 1 1 1 1 0	1	0 0 1 2 0 0 0 0	3	1 1 1 1 0 1 0 0
2012 05 01	3	0 0 1 1 2 2 1 1	0	0 1 0 0 0 0 0 0	4	0 1 1 1 1 1 1 1
2012 05 02	4	1 1 0 1 2 1 1 2	4	2 1 0 3 2 0 0 1	5	2 1 0 1 1 1 1 3
2012 05 03	9	3 2 2 2 2 2 1 3	10	2 2 3 4 2 2 1 2	8	3 2 2 2 1 1 1 3
2012 05 04	4	2 2 0 1 1 1 1 1	2	1 2 0 0 0 1 0 0	4	2 2 0 0 1 1 1 1
2012 05 05	4	0 0 0 2 3 1 1 1	1	0 0 0 1 1 0 0 1	4	0 1 1 1 2 1 1 1
2012 05 06	5	1 1 2 1 3 1 1 0	3	0 0 1 3 1 0 1 0	5	1 1 2 2 2 1 1 0
2012 05 07	4	0 1 0 2 2 2 2 0	1	0 1 0 1 0 1 0 0	4	0 1 1 2 1 1 1 1
2012 05 08	8	1 2 1 2 3 2 2 3	4	1 2 0 2 1 1 1 2	9	1 2 1 2 2 2 2 4
2012 05 09	19	3 3 4 3 3 2 4 4	36	3 4 5 6 5 4 3 4	24	4 4 3 3 4 3 4 4
2012 05 10	11	3 3 2 2 2 2 3 3	19	4 3 3 5 3 2 2 3	12	3 3 2 2 2 2 3 4
2012 05 11	10	4 3 2 2 2 2 2 1	16	4 4 4 3 2 2 2 2	12	4 3 2 2 2 2 2 2
2012 05 12	8	3 2 2 2 2 2 2 2	13	2 2 2 4 4 3 2 2	10	3 2 2 2 3 2 2 3
2012 05 13	10	2 3 3 2 2 1 3 2	24	3 3 5 5 4 4 2 2	12	3 3 3 2 2 2 3 3
2012 05 14	7	3 2 1 1 2 2 2 1	3	2 2 1 0 0 0 0 2	6	3 2 1 1 1 1 1 2
2012 05 15	5	2 2 2 1 2 0 1 2	5	2 3 2 0 0 0 0 2	5	2 2 2 1 1 1 0 2
2012 05 16	8	2 1 1 1 3 1 3 3	10	2 1 1 1 4 3 2 3	9	2 2 1 1 2 2 3 4
2012 05 17	5	2 1 1 2 2 1 1 2	3	2 2 1 1 1 0 0 1	6	2 2 2 1 1 1 1 1
2012 05 18	8	3 2 1 2 2 2 2 2	8	2 2 1 3 3 2 1 2	8	3 2 2 2 2 2 2 2
2012 05 19	5	2 2 1 1 2 1 1 1	5	2 2 1 2 2 1 1 1	5	2 2 1 1 1 1 1 1
2012 05 20	12	3 4 3 2 3 2 1 1	13	2 4 3 3 4 2 1 1	13	3 4 3 2 3 2 2 2
2012 05 21	7	0 1 0 2 2 2 4 2	2	1 1 0 0 0 0 2 1	7	1 1 1 1 1 1 4 2

2012 05 22	15	2	4	2	2	4	3	3	3	25	2	4	4	4	5	5	2	2	16	2	4	2	2	3	3	4	3
2012 05 23	13	3	4	3	3	2	2	2	2	25	4	4	5	5	4	2	2	2	18	4	5	4	3	2	2	2	2
2012 05 24	11	2	2	3	1	3	2	3	3	11	2	2	4	3	3	2	1	1	8	2	3	2	2	2	2	2	2
2012 05 25	8	2	1	1	3	3	2	2	1	13	2	2	2	5	3	3	1	1	6	2	2	1	2	2	2	1	1
2012 05 26	5	2	1	1	1	3	1	1	0	4	2	2	1	3	0	0	0	0	4	2	1	1	1	1	1	1	0
2012 05 27	3	1	1	0	1	2	2	1	0	2	1	2	1	0	0	0	0	0	4	1	2	1	1	1	1	1	0
2012 05 28	3	0	0	0	1	2	2	2	1	3	0	0	0	2	1	2	1	1	6	0	1	1	1	2	3	3	1
2012 05 29	5	1	1	0	1	2	2	2	2	4	1	2	0	0	1	1	2	2	6	1	2	1	1	2	2	2	2
2012 05 30	5	2	1	1	1	2	2	2	1	14	3	2	2	5	3	2	2	1	6	2	2	1	2	2	2	2	1
2012 05 31	7	2	1	2	2	2	2	3	1	9	3	1	2	4	1	2	2	0	10	3	2	2	2	2	3	3	1
2012 06 01	6	1	2	0	2	2	2	2	2	4	1	2	1	1	1	1	1	1	6	1	2	1	2	2	2	2	2
2012 06 02	8	1	1	1	2	3	2	2	3	4	1	1	1	1	1	1	1	2	9	1	1	1	1	2	3	2	4
2012 06 03	16	2	3	3	3	4	4	3	1	33	2	2	3	3	6	6	5	3	19	3	2	2	2	4	5	4	1
2012 06 04	14	2	3	2	3	4	3	3	2	28	2	3	4	6	5	3	3	3	16	2	3	3	4	4	3	3	3
2012 06 05	15	2	4	3	2	3	3	3	3	33	3	4	5	5	6	3	3	3	17	3	4	3	2	4	3	3	3
2012 06 06	17	4	4	2	3	3	3	3	3	29	4	4	2	5	5	5	3	3	17	3	4	2	3	3	3	4	3
2012 06 07	8	2	2	1	2	2	2	3	2	10	3	3	1	4	1	1	2	1	8	2	2	2	2	2	2	3	2
2012 06 08	9	1	2	3	3	2	1	3	2	11	2	3	4	4	2	0	1	0	8	2	2	3	3	1	1	2	1
2012 06 09	9	2	2	1	2	2	2	3	3	7	2	3	1	3	1	0	2	1	8	2	2	1	1	2	1	3	2
2012 06 10	6	0	0	1	2	3	2	2	2	2	0	1	0	0	1	1	0	1	6	1	1	1	1	2	2	2	2
2012 06 11	11	2	2	2	2	2	2	3	4	22	2	2	5	4	4	4	3	3	14	2	2	3	2	2	3	3	5
2012 06 12	10	4	4	1	1	2	1	1	1	8	4	3	2	0	2	1	2	0	13	5	4	1	1	1	1	1	1
2012 06 13	7	2	2	2	1	3	1	2	1	3	1	2	1	1	0	1	1	1	6	2	2	2	2	1	1	2	1
2012 06 14	4	0	1	1	2	2	2	2	0	3	1	2	1	2	1	0	1	0	4	1	1	1	1	1	1	1	0
2012 06 15	4	0	0	0	2	2	2	2	1	1	0	0	0	0	0	1	0	1	4	0	0	0	1	1	1	1	1
2012 06 16	19	0	1	1	2	3	3	4	6	12	0	1	0	3	4	3	2	4	19	1	1	1	2	3	3	4	6
2012 06 17	36	4	4	5	6	5	3	4	3	55	2	5	6	6	6	6	5	3	39	4	4	5	6	5	4	4	4
2012 06 18	13	3	5	2	2	2	2	1	2	28	3	5	5	5	4	4	2	1	15	4	5	3	2	2	2	1	1
2012 06 19	5	1	1	1	1	2	2	2	1	2	0	1	2	1	0	0	0	0	3	0	1	1	1	1	1	1	1
2012 06 20	4	1	2	1	1	2	1	2	0	2	1	2	0	0	0	1	0	0	4	2	2	1	1	1	1	1	1
2012 06 21	3	1	0	0	1	2	1	2	1	2	1	1	0	0	0	0	1	1	3	1	1	0	0	1	1	1	1
2012 06 22	5	1	1	1	2	2	2	1	1	8	1	1	2	3	4	2	1	0	5	1	1	1	2	2	2	1	1
2012 06 23	4	1	0	2	1	1	1	1	2	4	1	0	2	3	1	1	1	0	4	1	1	1	1	1	2	1	1
2012 06 24	5	1	1	1	1	2	2	2	1	2	1	1	0	0	0	1	1	1	5	2	1	1	1	1	2	1	1
2012 06 25	5	1	1	2	2	-1	-1	2	1	13	2	3	3	3	4	3	2	1	9	1	2	2	2	3	3	2	2
2012 06 26	7	2	3	2	2	2	1	1	2	14	3	4	2	5	2	1	1	1	8	2	3	2	2	2	1	1	2
2012 06 27	8	1	1	1	2	3	3	2	2	11	1	1	1	3	3	4	2	3	6	1	1	1	1	2	2	2	2
2012 06 28	7	2	2	3	2	2	2	1	1	11	2	2	3	3	3	2	3	1	6	2	2	3	2	1	1	1	1
2012 06 29	6	1	1	1	1	2	1	2	3	2	1	1	0	0	1	0	1	2	5	1	1	1	1	2	1	1	3
2012 06 30	21	2	3	4	3	5	3	3	4	41	3	4	5	6	6	5	3	3	22	3	3	4	4	4	4	3	4

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:

On June 17, 2012, there was an event on PRN-19. Please see discrepancy report #109 for more details.

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.