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

Submitted To

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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 (October 2001).

This report, Report #60, includes data collected from 1 October through 31 December 2007. The next quarterly report will be issued 30 April 2008.

Analysis of this data includes the following standards and categories: PDOP Availability, NANU Summary and Evaluation, Service Availability, Service Reliability, 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 99.988% 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 2007. 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 sixteen outages were reported in the NANU’s this quarter. Seven outages were scheduled while nine were unscheduled.

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

Accuracy standards were verified by calculating the 24-hour 95% horizontal and vertical position error values. The User Range Error and Service Reliability standards were 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 of the sites achieved 100% reliability; meeting the SPS specification. The maximum range error recorded was 16.871 meters on Satellite PRN 2. 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 2.671 was recorded on satellite 24. 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.

From the analysis performed on data collected between 1 October and 31 December 2007, 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

1.0 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 Summary of Performance Requirements and Metrics

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

1.3 Report Overview

Section 2 of this report summarizes the results obtained from the coverage calculation program called SPS_CoverageArea developed by the GPS test team. The SPS_CoverageArea 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.

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).

Table 1-1 SPS Performance Requirements

PDOP Availability Standard	Conditions and Constraints	Evaluated in This Report
≥ 98% global Position Dilution of Precision (PDOP) of 6 or less ≥ 88% worst site PDOP of 6 or less	• Defined for position solution meeting the representative user conditions and operating within the service volume over any 24-hour interval. • Based on using only satellites transmitting standard code and indicating "health" in the broadcast navigation message (sub-frame 1).	✓
Service Availability Standard	**Conditions and Constraints**	
≥ 99% Horizontal Service Availability average location ≥ 99% Vertical Service Availability average location	• 36 meter horizontal (SIS only) 95% threshold. • 77 meter vertical (SIS only) 95% threshold. • Defined for position solution meeting the representative user conditions and operating within the service volume over any 24-hour interval.	✓
≥ 95.87% global average on worst-case day	• Based on using only satellites transmitting standard code and indicating "healthy" in the broadcast navigation message (sub-frame 1).	✓
Service Reliability Standard	**Conditions and Constraints**	
≥ 99.94% global average	• 30-meter Not-to-Exceed (NTE) SPS SIS URE. • Standard based on a measurement interval of one year; average of daily values within the service volume. • Standard based on 3 service failures per year, lasting no more than 6 hours each.	✓
≥ 99.79% single point average	• 30-meter Not-to-Exceed (NTE) SPS SIS URE. • Standard based on a measurement interval of one year; average of daily values from the worst-case point within the service volume. • Standard based on 3 service failures per year, lasting no more than 6 hours each.	✓

Accuracy Standard	Conditions and Constraints	
Global Average Positioning Domain Accuracy • ≤ 13 meters 95% All-in-View horizontal error (SIS only) • ≤ 22 meters 95% All-in-View vertical error (SIS only)	• Defined for position solution meeting the representative user conditions. • Standard based on a measurement interval of 24 hours averaged over all points within the service volume.	✓
Worst Site Positioning Domain Accuracy • ≤ 36 meters 95% All-in-View Horizontal Error (SIS only) • ≤ 77 meters 95% All-in-View Vertical Error (SIS only)	• Defined for position solution meeting the representative user conditions. • Standard based on a measurement interval of 24 hours for any point within the service volume.	✓
Time Transfer Accuracy • ≤ 40 nanoseconds time transfer error 95% of time (SIS only)	• Defined for time transfer solution meeting the representative user conditions. • Standard based on a measurement interval of 24 hours averaged over all points within the service volume.	✓
SPS SIS URE STANDARD	**Conditions and Constraints**	
≤ 6 meters RMS SIS SPS URE across the entire constellation	• Average of the constellation's individual satellite SPS SIS RMS URE values over any 24-hours interval, for any point thing the service volume.	✓

2.0 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 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. .*

PDOP Availability Standard	Conditions and Constraints
≥ 98% global Position Dilution of Precision (PDOP) of 6 or less ≥ 88% worst site PDOP of 6 or less	• Defined for position solution meeting the representative user conditions and operating within the service volume over any 24-hour interval. • Based on using only satellites transmitting standard code and indicating “health” in the broadcast navigation message (sub-frame 1).

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 3.31729 or better 99.9% of the time for each of the 24-hour intervals.

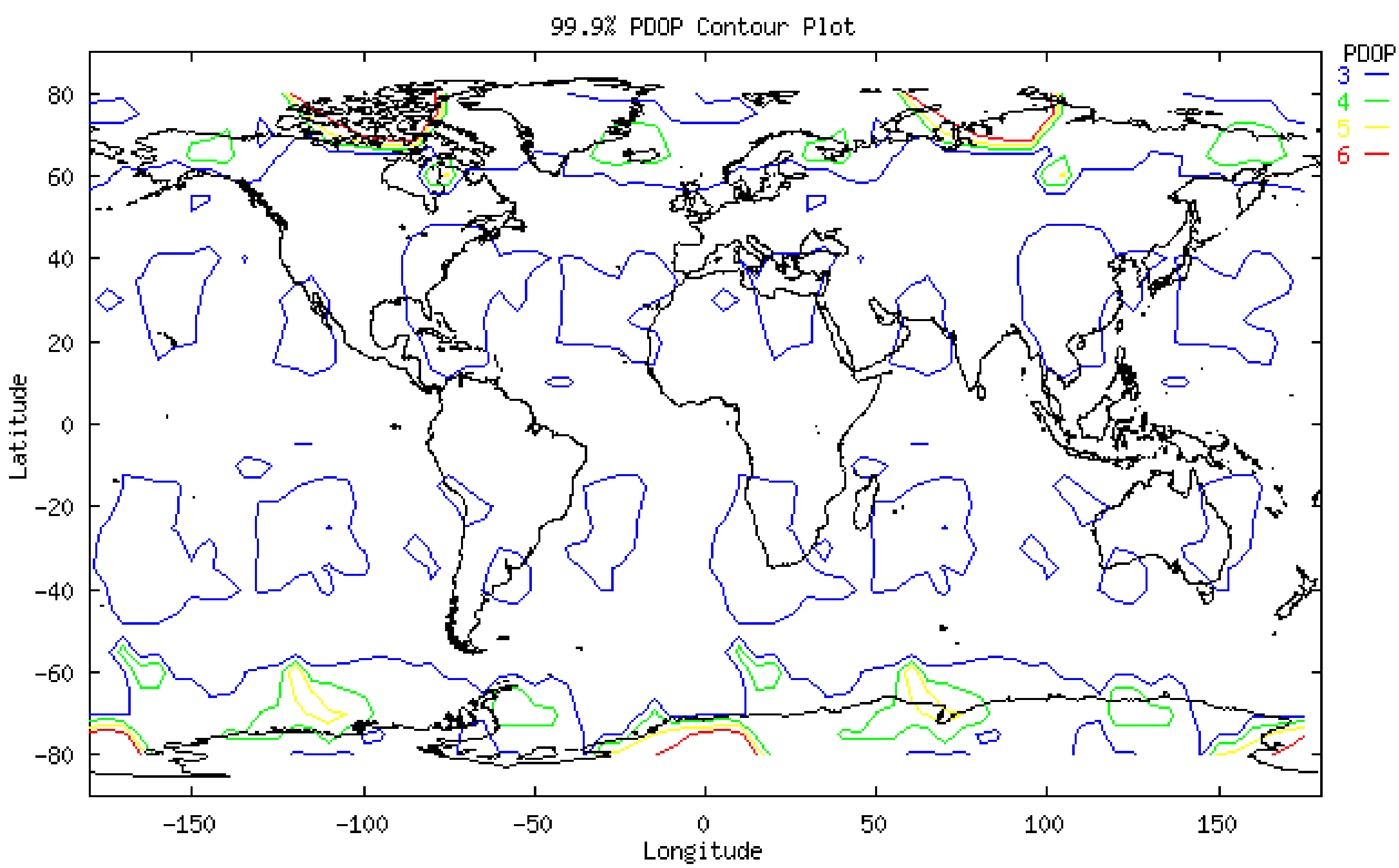
Figure 2-1 is a contour plot of PDOP values over the entire globe. Inside each contour area, the PDOP value is greater than or equal to the contour value shown in the legend for that color line. That areas’ value is also less than the next higher contour value, unless another contour line lies within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

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

Table 2-1 PDOP Availability Statistics

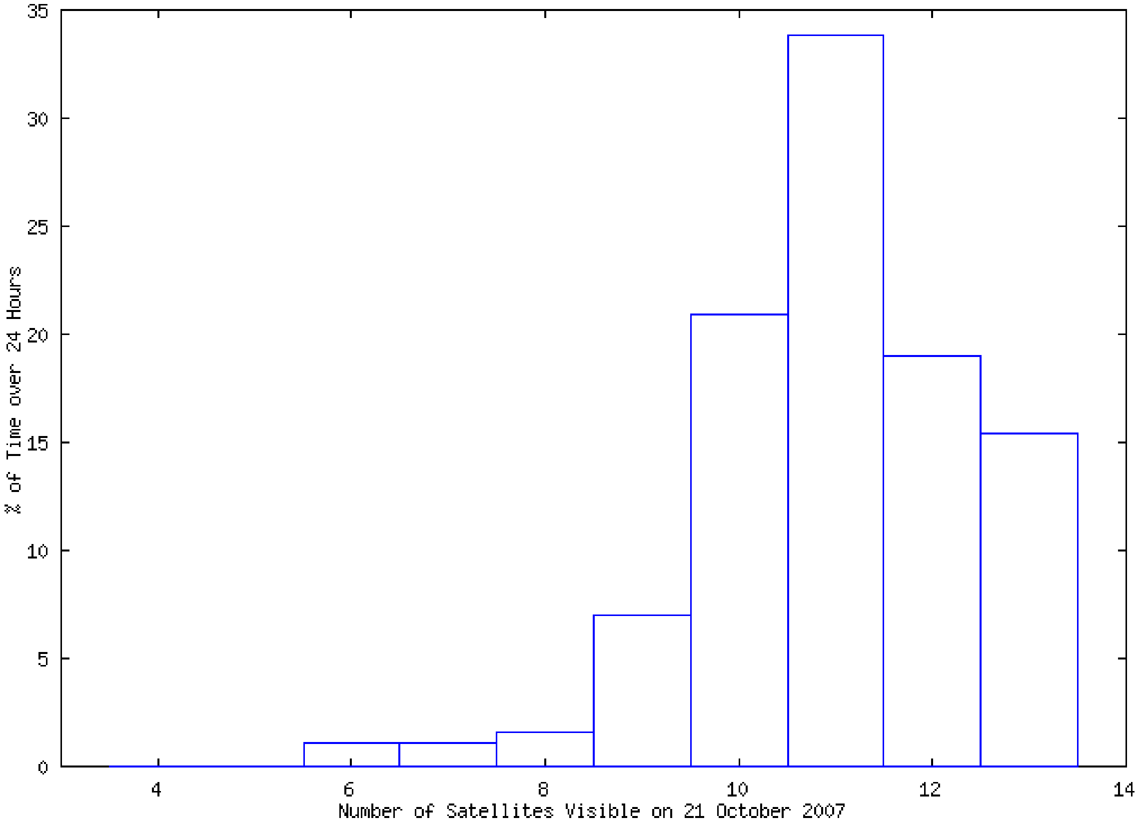
Date Range of Week	Global 99.9% PDOP Value*	Global Average* (Spec: ≥ 98%)	Worst-Case Point (Spec: ≥ 88%)
1-6 October	2.9957	99.989	99.028
7-13 October	3.0035	99.988	98.958
14-20 October	3.0130	99.988	99.028
21-27 October	3.0171	99.988	98.958
28 Oct – 3 Nov	3.0357	99.995	99.444
4-10 November	2.8878	100	100
11-17 November	2.8685	100	100
18-24 November	2.9065	99.997	99.583
25 Nov – 1 Dec	2.9386	99.996	99.306
2-8 Dec	2.9800	99.998	99.444
9-15 Dec	2.9881	99.996	99.444
16-22 Dec	2.9337	99.995	99.375
23-31 Dec	2.9526	100	99.861

Figure 2-1 PDOP Availability Plot (24-Hour Period: 21 October 2007)



Developed by FAA William J. Hughes Technical Center

Figure 2-2 Satellite Visibility Profile for Worst-Case Point (Lat: -90, Lon: 75)



3.0 NANU Summary and Evaluation

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

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 2007, there were a total of sixteen reported outages. Seven of these outages were maintenance activities and were reported in advance. Nine were unscheduled outages. 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 are provided in Table 3-3.

Table 3-1 NANUs Affecting Satellite Availability

NANU #	PRN	Type	Start Date	Start Time	End Date	End Time	Total Unscheduled	Total Scheduled	Total
2007116	1	FCSTSUMM	2-Oct	10:18	2-Oct	16:37		6.32	6.32
2007120	19	UNUSABLE	8-Oct	4:16	8-Oct	16:36	12.33		12.33
2007121	12	UNUSABLE	8-Oct	6:33	8-Oct	16:49	10.27		10.27
2007124	14	UNUSABLE	8-Oct	21:04	9-Oct	1:43	4.65		4.65
2007128	16	UNUSABLE	9-Oct	12:02	9-Oct	13:59	1.95		1.95
2007135	20	UNUSABLE	10-Oct	8:24	10-Oct	11:04	2.67		2.67
2007145	21	FCSTSUMM	26-Oct	1:21	26-Oct	8:53		7.53	7.53
2007155	12	FCSTSUMM	8-Nov	22:09	9-Nov	1:09		3.00	3.00
2007156	26	FCSTSUMM	8-Nov	11:37	9-Nov	1:27		13.83	13.83
2007157	12	FCSTSUMM	9-Nov	22:24	9-Nov	22:45		0.35	0.35
2007158	12	FCSTSUMM	10-Nov	1:45	10-Nov	1:58		0.22	0.22
2007161	30	UNUSABLE	18-Nov	2:18	18-Nov	2:28	0.17		0.17
2007162	30	UNUSABLE	18-Nov	2:18	18-Nov	2:28	0.17		0.17
2007163	30	UNUSABLE	18-Nov	2:18	18-Nov	2:28	0.17		0.17
2007166	1	UNUSABLE	25-Nov	10:27	25-Nov	11:19	0.87		0.87
2007167	27	FCSTSUMM	27-Nov	12:57	27-Nov	14:02		1.08	1.08
Total Actual Unscheduled and Scheduled Downtime and Total Actual Downtime							**33.23**	**32.33**	**65.56**

Table 3-2 NANUs Forecasted to Affect Satellite Availability

NANU #	PRN	Type	Start Date	Start Time	End Date	End Time	Total	Comments
2007117	27	FCSTMX	11-Oct	13:30	12-Oct	1:30	CANC	See Nanu 2007134
2007118	19	UNUSUFN	8-Oct	4:37	N/A	N/A	N/A	See Nanu 2007120
2007119	12	UNUSUFN	8-Oct	6:33	N/A	N/A	N/A	See Nanu 2007121
2007123	14	UNUSUFN	8-Oct	21:04	N/A	N/A	N/A	See Nanu 2007124
2007129	20	UNUSUFN	10-Oct	8:24	N/A	N/A	N/A	See Nanu 2007135
2007136	29	UNUSUFN	23-Oct	19:30	N/A	N/A	N/A	
2007143	21	FCSTDV	26-Oct	0:30	26-Oct	15:00	14.5	See Nanu 2007145
2007147	26	FCSTDV	8-Nov	11:30	9-Nov	6:00	18.5	See Nanu 2007156
2007148	12	FCSTMX	9-Nov	22:00	9-Nov	23:00	1	See Nanu 2007153
2007150	12	FCSTMX	9-Nov	1:30	9-Nov	2:30	CANC	See Nanu 2007154
2007151	12	FCSTMX	9-Nov	22:00	9-Nov	23:00	1	See Nanu 2007157
2007152	12	FCSTMX	10-Nov	1:30	10-Nov	2:30	1	See Nanu 2007158
2007153	12	FCSTEXTD	8-Nov	22:00	N/A	N/A	N/A	See Nanu 2007155
2007159	30	UNUSUFN	18-Nov	2:18	N/A	N/A	N/A	See Nanu 2007161
2007159	30	UNUSUFN	18-Nov	2:18	N/A	N/A	N/A	See Nanu 2007162
2007159	30	UNUSUFN	18-Nov	2:18	N/A	N/A	N/A	See Nanu 2007163
2007160	30	UNUSUFN	18-Nov	2:18	N/A	N/A	N/A	
2007164	27	FCSTMX	27-Nov	12:30	28-Nov	0:30	12	
2007165	1	UNUSUFN	25-Nov	10:27	N/A	N/A	N/A	See Nanu 2007166
2007168	7	UNUSUFN	12-Dec	1:46	N/A	N/A	N/A	
						Total Forecast Downtime	**48**	

Table 3-3 NANUs Canceled					
NANU#	PRN	Type	Start Date	Start Time	Comments
2007134	27	FCSTCANC	11-Oct	13:30	See Nanu 2007117
2007154	12	FCSTCANC	9-Nov	1:30	See Nanu 2007150

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 Block II/IIA Satellite RMA Data		
Satellite Reliability/Maintainability/Availability (RMA) Parameter	**1 Oct - 31 Dec. 2007**	**1 October, 1999- 31 Dec. 2007**
Total Forecast Downtime (hrs):	48.00	6708.48
Total Actual Downtime (hrs):	65.56	24924.92
Total Actual Scheduled Downtime (hrs):	32.33	3573.52
Total Actual Unscheduled Downtime (hrs):	33.23	21351.40
Total Satellite Observed MTTR (hrs):	4.10	46.59
Scheduled Satellite Observed MTTR (hrs):	4.62	9.38
Unscheduled Satellite Observed MTTR (hrs):	3.69	138.65
# Total Satellite Outages:	16	535
# Scheduled Satellite Outages:	7	381
# Unscheduled Satellite Outages:	9	154
Percent Operational -- Scheduled Downtime:	99.95	99.82
Percent Operational -- All Downtime:	100.00	98.75

3.2 Service Availability Standard

Service Availability: 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:** 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	• 36 meter horizontal (SIS only) 95% threshold. • 77 meter vertical (SIS only) 95% threshold. • Defined for position solution meeting the representative user conditions and operating within the service volume over any 24-hour interval.
≥ 95.87% global average on worst-case day	• Based on using only satellites transmitting standard code and indicating “healthy” in the broadcast navigation message (sub-frame 1).

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 2007.

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	7714597	0	100%
Anchorage	7803574	0	100%
Atlanta	7642612	0	100%
Barrow	7347776	0	100%
Bethel	7676434	0	100%
Billings	7716556	0	100%
Boston	7620860	0	100%
Cleveland	7635487	0	100%
Cold Bay	7710888	0	100%
Fairbanks	7676649	0	100%
Gander	7675787	0	100%
Honolulu	7725914	0	100%
Houston	7798033	0	100%
Iqaluit	4243216	0	100%
Juneau	7822714	0	100%
Kansas City	7729362	0	100%
Kotzebue	7598486	0	100%
Los Angeles	7661963	0	100%
Merida	6946341	0	100%
Miami	7731085	0	100%
Minneapolis	7712081	0	100%
Oakland	7623144	0	100%
Salt Lake City	7722204	0	100%
San Jose Del Cabo	6850835	0	100%
San Juan	7762684	0	100%
Seattle	7515211	0	100%
Tapachula	6296768	0	100%
Washington, DC	7618440	0	100%
Global Average over Reporting Period = 100% (SPS Spec. > 95.87%)			

4.0 Service Reliability Standard

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 Reliability Standard	Conditions and Constraints
≥ 99.94% global average	• 30-meter Not-to-Exceed (NTE) SPS SIS URE. • Standard based on a measurement interval of one year; average of daily values within the service volume. • Standard based on 3 service failures per year, lasting no more than 6 hours each.
≥ 99.79% single point average	• 30-meter Not-to-Exceed (NTE) SPS SIS URE. • Standard based on a measurement interval of one year; average of daily values from the worst-case point within the 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 on page 21. The maximum User Range Error recorded this quarter was 16.871 meters at Boston on satellite PRN 2.

Table 4-1 Service Reliability Based on User Range Error

Date Range of Data Collection	Site	Number of Samples This Quarter	Number of Samples where SPS URE > 30m NTE	Service Reliability Percentage
1 Oct. – 31 Dec 2007	**Boston**	56,663,362	0	100%
1 Oct. – 31 Dec 2007	**Honolulu**	60,769,231	0	100%
1 Oct. – 31 Dec 2007	**Los Angeles**	57,285,705	0	100%
1 Oct. – 31 Dec 2007	**Miami**	58,863,420	0	100%
1 Oct. – 31 Dec 2007	**San Juan**	61,981,486	0	100%
1 Oct. – 31 Dec 2007	**Juneau**	62,234,964	0	100%
1 Oct. – 31 Dec 2007	**Global**	357,798,168	0	100%

5.0 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 horiz 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.

Accuracy Standard	Conditions and Constraints
Global Average Positioning Domain Accuracy • ≤ 13 meters 95% All-in-View horizontal error (SIS only) • ≤ 22 meters 95% All-in-View vertical error (SIS only)	• Defined for position solution meeting the representative user conditions. • Standard based on a measurement interval of 24 hours averaged over all points within the service volume.
Worst Site Positioning Domain Accuracy • ≤ 36 meters 95% All-in-View Horizontal Error (SIS only) • ≤ 77 meters 95% All-in-View Vertical Error (SIS only)	• Defined for position solution meeting the representative user conditions. • Standard based on a measurement interval of 24 hours for any point within the service volume.
Time Transfer Accuracy • ≤ 40 nanoseconds time transfer error 95% of time (SIS only)	• Defined for time transfer solution meeting the representative user conditions. • Standard based on a measurement interval of 24 hours averaged over all points within the service volume.
SPS SIS URE STANDARD	**Conditions and Constraints**
≤ 6 meters RMS SIS SPS URE across the entire constellation	• Average of the constellation’s individual satellite SPS SIS RMS URE values over any 24-hours interval, for any point thing the service volume.

5.1 Position Accuracy

The data used for this section was collected for every second from 1 October through 31 December 2007 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	2.318	4.289	9.302	9.563
Anchorage	2.051	4.966	4.182	10.568
Atlanta	2.648	4.846	9.470	12.328
Barrow	1.840	6.946	4.038	12.863
Bethel	2.111	5.111	4.612	9.862
Billings	2.391	4.384	9.095	10.308
Boston	3.319	4.760	7.742	12.681
Cleveland	2.738	4.782	8.682	13.329
Cold Bay	2.319	5.040	5.197	9.476
Fairbanks	1.901	5.102	4.671	13.484
Gander	2.728	4.461	9.518	9.022
Honolulu	3.751	5.062	6.564	11.635
Houston	2.406	4.733	7.888	10.226
Iqaluit	2.685	5.064	5.201	12.892
Juneau	2.101	4.573	3.970	12.758
Kansas City	2.594	4.649	10.519	10.451
Kotzebue	1.881	5.264	4.339	9.902
Los Angeles	2.302	5.083	8.381	10.501
Merida	2.334	5.190	6.189	10.144
Miami	2.515	5.504	8.542	13.103
Minneapolis	2.550	4.586	8.949	9.911
Oakland	2.282	5.007	7.697	9.626
Salt Lake City	2.356	4.395	9.574	9.304
San Jose Del Cabo	2.369	5.020	6.313	8.794
San Juan	2.351	5.652	7.644	13.181
Seattle	2.391	4.518	6.573	8.947
Tapachula	2.820	4.981	6.564	9.936
Washington, DC	2.750	5.042	8.378	13.719

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 2007.

Figure 5-1 Global Vertical Error Histogram

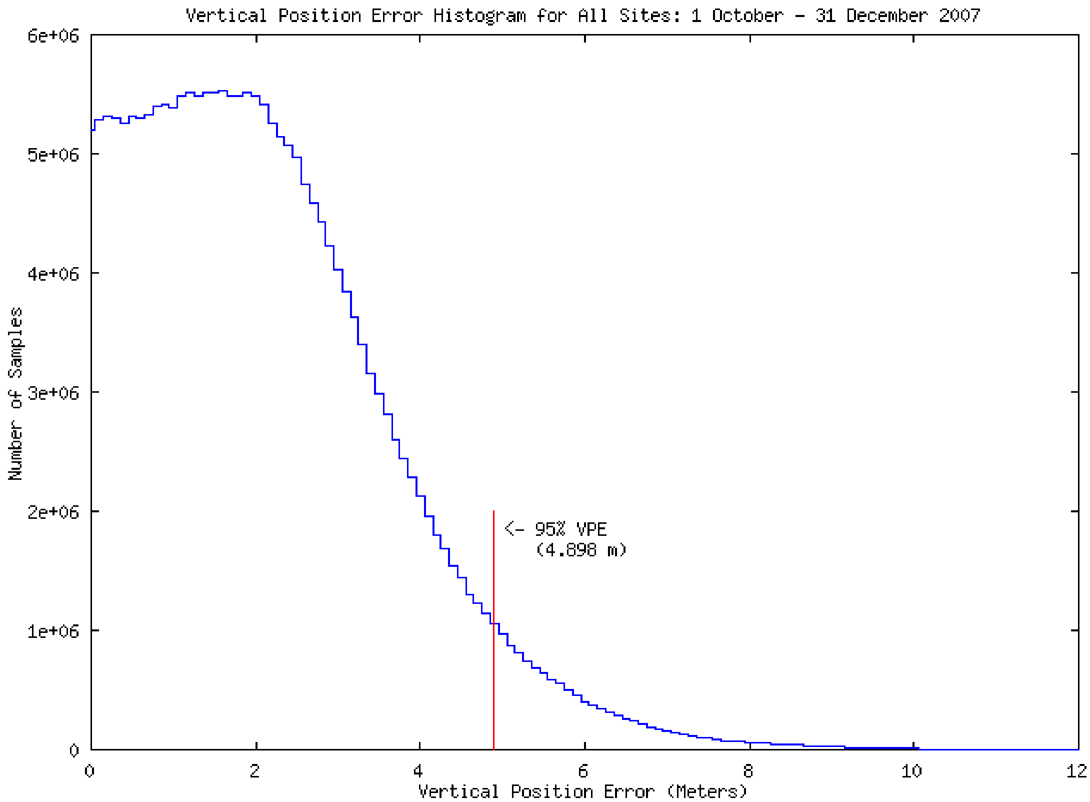
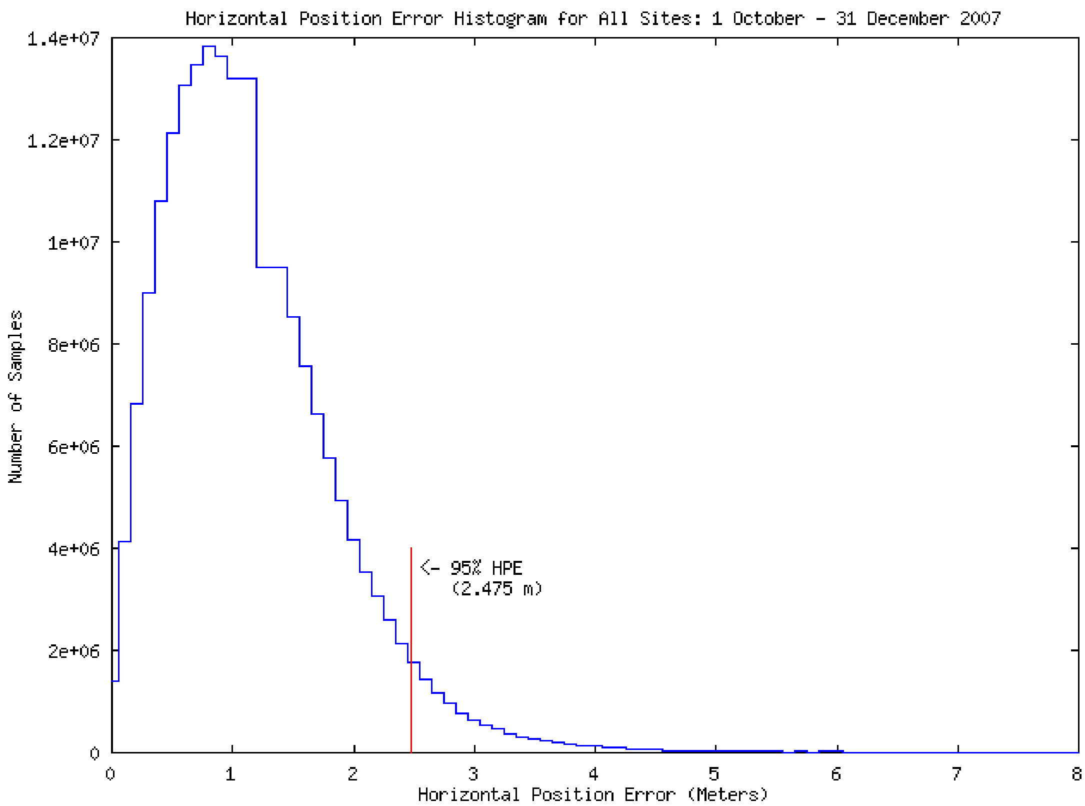


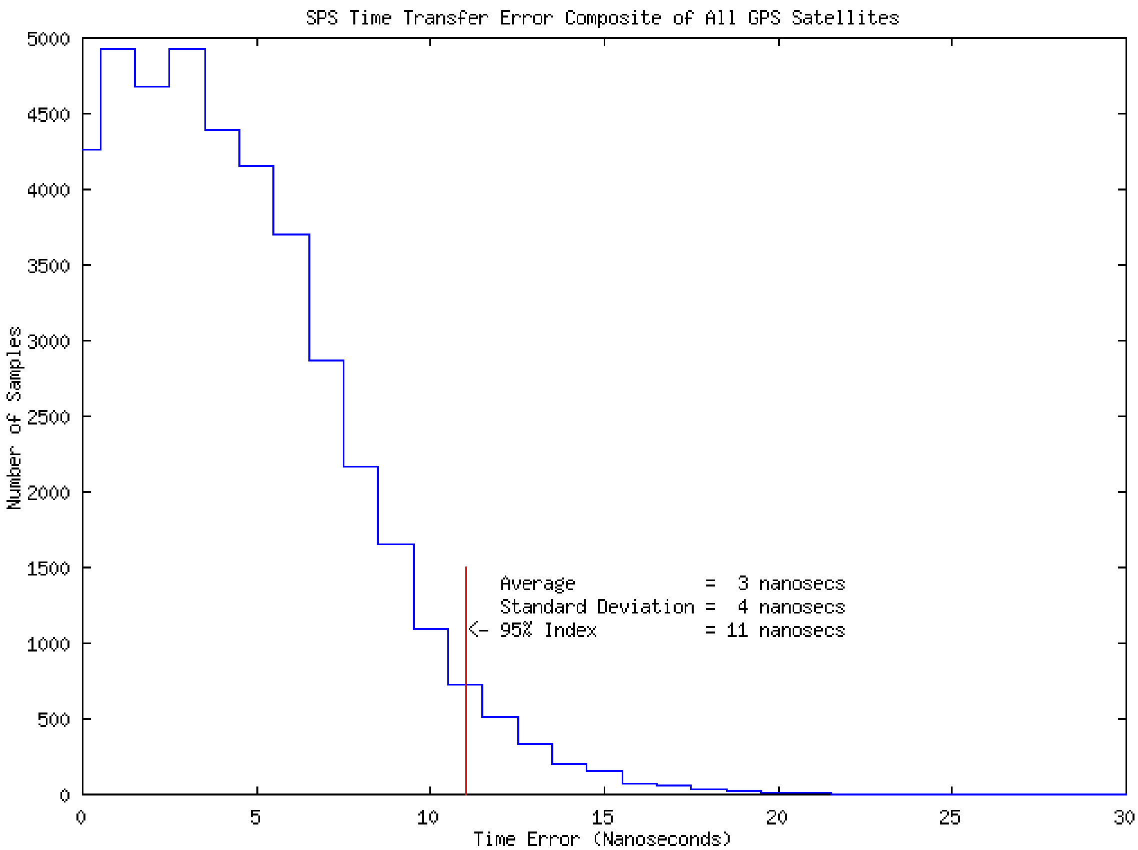
Figure 5-2 Global Horizontal Error Histogram



5.2 Time Transfer Accuracy

The GPS time error data between 1 October and 31 December 2007 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 Errors



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 2007. The WAAS receiver at Houston was used to collect range measurement.

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	1s	95% Range Error	Max Range Error (SPS Spec. ≤ 30 m)	Samples
1	2.31102	1.08628	1.65461	4.03964	9.878	11625145
2	1.80696	1.13660	1.25334	3.21850	16.871	13086145
3	1.95170	0.87924	1.38771	3.38400	9.530	11082007
4	1.92979	1.03752	1.37852	3.62104	11.323	12943645
5	2.04389	1.50068	1.26725	3.58594	10.326	12702592
6	1.60410	0.60277	1.25605	2.97529	10.460	12846933
7	2.29066	1.50781	1.44408	3.99678	10.392	10481723
8	2.34712	1.10448	1.65564	4.30494	14.195	11699755
9	1.86813	0.71187	1.51092	3.43703	9.623	11939058
10	2.48871	1.47599	1.72885	4.38028	16.581	12554368
11	1.84534	1.18586	1.27052	3.30367	8.841	11207843
12	1.53132	0.60839	1.24899	2.87386	10.286	13255122
13	1.34038	0.47986	1.11427	2.54241	7.669	12624749
14	1.75252	1.21454	1.15878	3.16308	10.011	12849405
15	1.50310	0.56981	1.26781	2.86402	9.783	7754807
16	1.66659	1.00179	1.20419	2.97645	15.062	11794124
17	1.66288	0.57183	1.28789	3.19079	12.482	12966419
18	2.08189	1.50129	1.31766	3.58702	11.285	11952590
19	2.09621	1.56987	1.26391	3.55855	9.302	11272478
20	1.95231	1.39272	1.27856	3.65517	15.568	12881247
21	2.23231	1.65570	1.30909	3.71461	14.175	10704280
22	2.06844	1.48712	1.20150	3.53931	9.471	11221120
23	1.56231	0.88681	1.17602	2.83662	6.810	11581274
24	2.67178	1.91539	1.52838	4.43389	9.124	11640020
25	1.63253	0.40257	1.24522	3.01996	8.562	11097462
26	1.64156	0.89217	1.22194	3.06203	9.202	11083459
27	2.15593	0.63498	1.58827	3.87544	12.990	11474834
28	2.38773	1.38859	1.49233	4.22735	12.456	11525941
29	2.09925	1.17834	1.53189	3.74398	10.307	2928702
30	1.79685	0.24455	1.47706	3.34511	9.432	12233802
31	1.45837	0.42902	1.22236	2.75284	7.877	12787119

Table 5-3 Range Rate Error Statistics (meters/second)

PRN	Range Rate Error RMS	Range Rate Error Mean	Range Rate Error 1s	95% Range Rate Error	Max Range Rate Error	Samples
1	0.002387	-0.000029	0.002383	0.002893	0.24701	11625145
2	0.001426	-0.000013	0.001421	0.002736	0.10207	13086145
3	0.001829	-0.000023	0.001824	0.003037	0.16638	11082007
4	0.001462	-0.000067	0.001454	0.002734	0.15347	12943645
5	0.001422	0.000035	0.001416	0.002729	0.10016	12702592
6	0.001376	0.000004	0.001372	0.002626	0.10109	12846933
7	0.002098	-0.000032	0.002095	0.002653	0.16855	10481723
8	0.002030	-0.000038	0.002026	0.003062	0.25318	11699755
9	0.001834	0.000022	0.001829	0.003054	0.17682	11939058
10	0.002219	0.000001	0.002213	0.002768	0.23874	12554368
11	0.001522	-0.000010	0.001518	0.002831	0.14611	11207843
12	0.001471	-0.000007	0.001467	0.002866	0.07621	13255122
13	0.001492	0.000014	0.001489	0.002850	0.10221	12624749
14	0.001443	0.000006	0.001440	0.002738	0.11764	12849405
15	0.001502	-0.000056	0.001497	0.002707	0.16314	7754807
16	0.001416	0.000015	0.001412	0.002717	0.11184	11794124
17	0.001573	0.000019	0.001569	0.002853	0.15187	12966419
18	0.001467	-0.000032	0.001461	0.002848	0.05958	11952590
19	0.001407	0.000019	0.001403	0.002724	0.05134	11272478
20	0.001440	0.000015	0.001436	0.002787	0.11444	12881247
21	0.001501	-0.000001	0.001496	0.002899	0.12623	10704280
22	0.001590	-0.000037	0.001585	0.002847	0.15167	11221120
23	0.001370	0.000011	0.001366	0.002634	0.12703	11581274
24	0.001623	-0.000038	0.001618	0.002883	0.16881	11640020
25	0.001294	0.000033	0.001289	0.002533	0.04462	11097462
26	0.001469	-0.000025	0.001464	0.002645	0.13124	11083459
27	0.001793	0.000005	0.001788	0.002947	0.20995	11474834
28	0.001724	0.000032	0.001720	0.002854	0.16741	11525941
29	0.001975	-0.000026	0.001971	0.003166	0.14895	2928702
30	0.001860	-0.000026	0.001853	0.003132	0.16295	12233802
31	0.001540	0.000018	0.001537	0.002726	0.14367	12787119

Table 5-4 Range Acceleration Error Statistics (meters/second^2)

PRN	Range Acceleration Error RMS	Range Acceleration Error Mean	Range Acceleration 1s	Max Range Acceleration Error	Samples
1	0.000019	0	0.000019	0.000021	11625145
2	0.000011	0	0.000011	0.000021	13086145
3	0.000014	0	0.000014	0.000023	11082007
4	0.000011	0	0.000011	0.000020	12943645
5	0.000011	0	0.000011	0.000020	12702592
6	0.000011	0	0.000011	0.000021	12846933
7	0.000018	0	0.000018	0.000021	10481723
8	0.000016	0	0.000016	0.000021	11699755
9	0.000014	0	0.000014	0.000022	11939058
10	0.000019	0	0.000019	0.000021	12554368
11	0.000012	0	0.000012	0.000021	11207843
12	0.000011	0	0.000011	0.000021	13255122
13	0.000012	0	0.000012	0.000022	12624749
14	0.000011	0	0.000011	0.000021	12849405
15	0.000012	0	0.000012	0.000021	7754807
16	0.000011	0	0.000011	0.000021	11794124
17	0.000012	0	0.000012	0.000021	12966419
18	0.000011	0	0.000011	0.000021	11952590
19	0.000011	0	0.000011	0.000021	11272478
20	0.000011	0	0.000011	0.000021	12881247
21	0.000011	0	0.000011	0.000021	10704280
22	0.000012	0	0.000012	0.000021	11221120
23	0.000011	0	0.000011	0.000021	11581274
24	0.000012	0	0.000012	0.000021	11640020
25	0.000011	0	0.000011	0.000020	11097462
26	0.000012	0	0.000011	0.000020	11083459
27	0.000014	0	0.000014	0.000021	11474834
28	0.000014	0	0.000014	0.000021	11525941
29	0.000016	0	0.000016	0.000023	2928702
30	0.000014	0	0.000014	0.000022	12233802
31	0.000012	0	0.000012	0.000021	12787119

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 10 with an error of 16.581 meters. Satellite 23 had the lowest maximum range error of 6.810 meters.

Figure 5-4 Distribution of Daily Max Range Errors

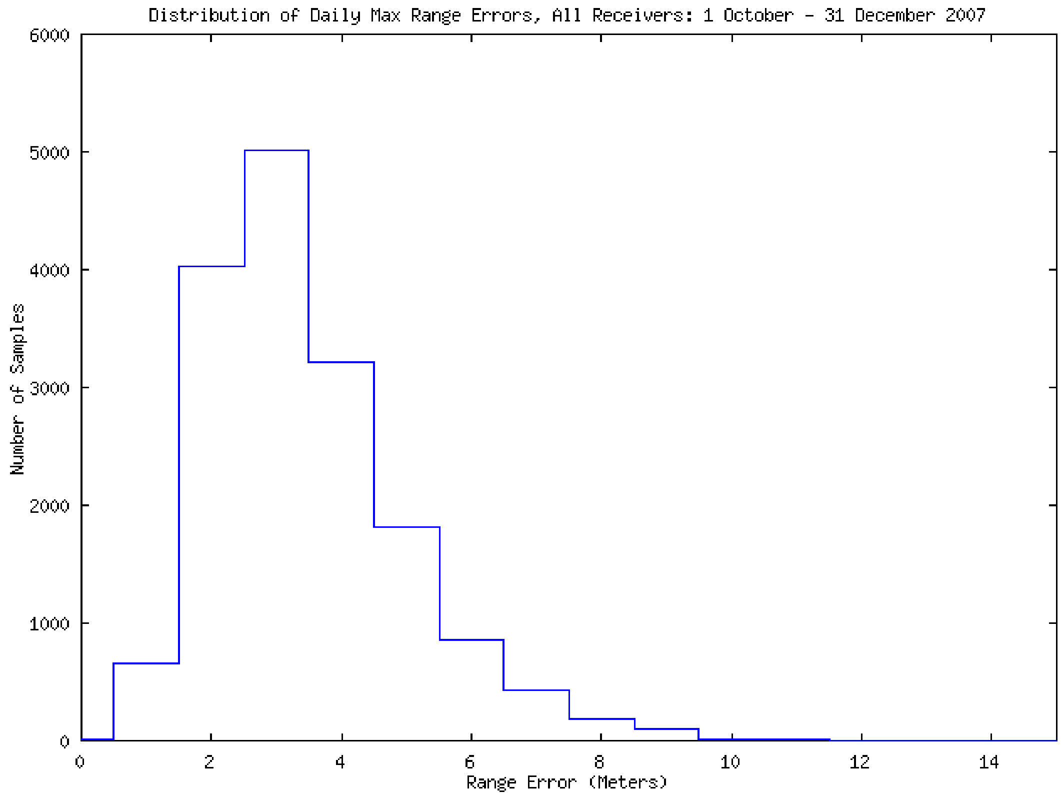


Figure 5-5: Distribution of Daily Max Range Rate Errors

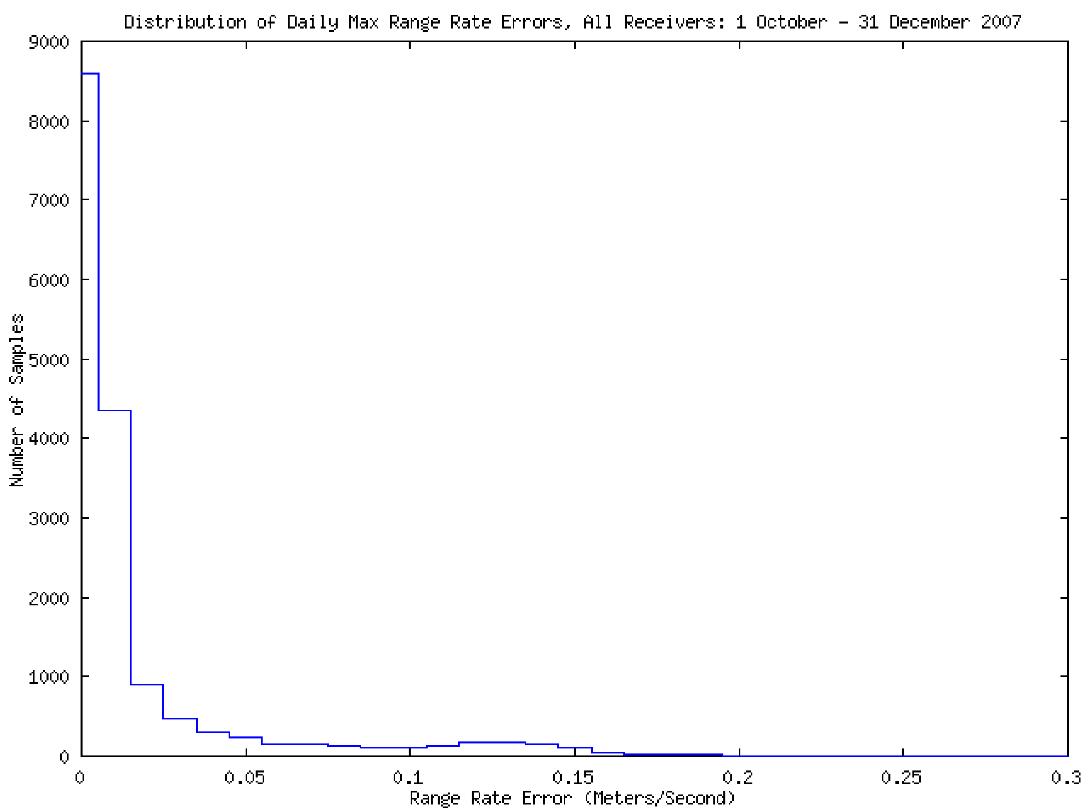


Figure 5-6: Distribution of Daily Max Acceleration Rate Errors

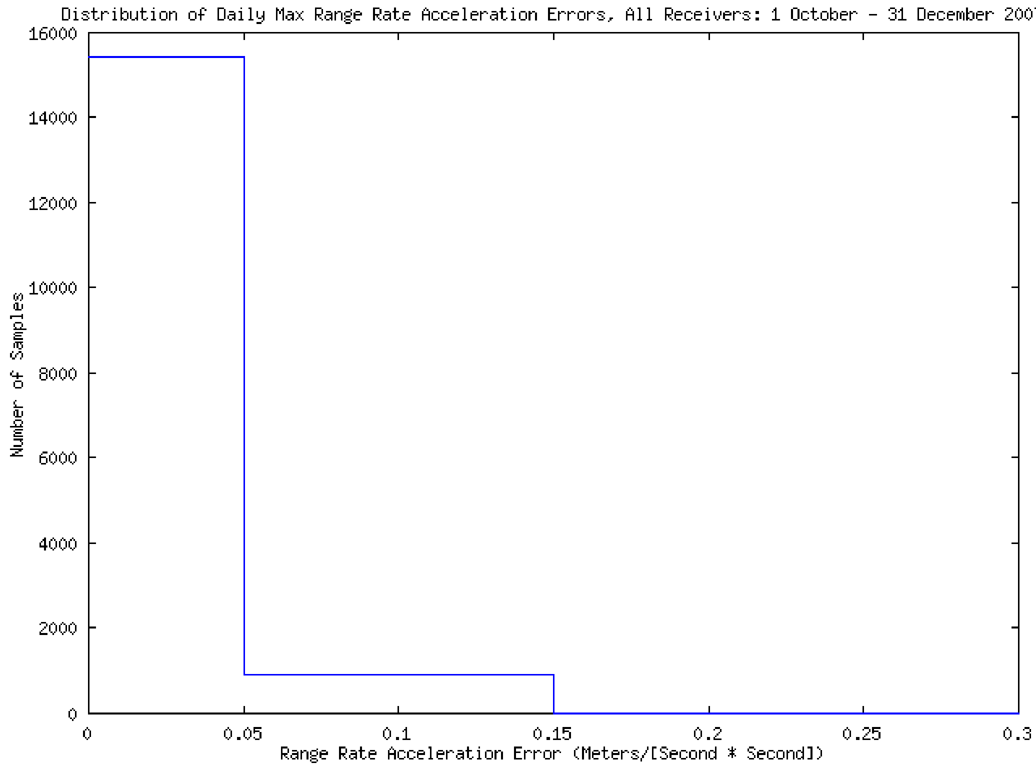


Figure 5-7: Range Error Histogram

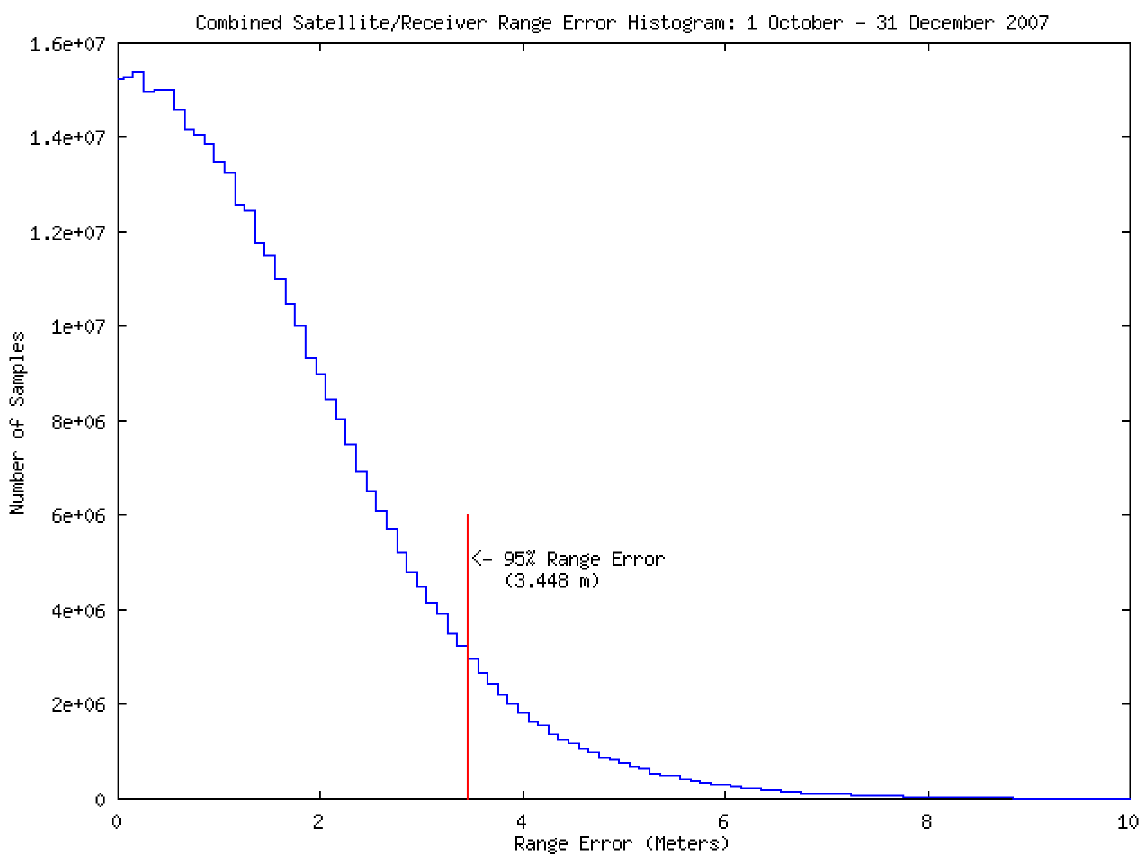


Figure 5-8: Maximum Range Error Per Satellite

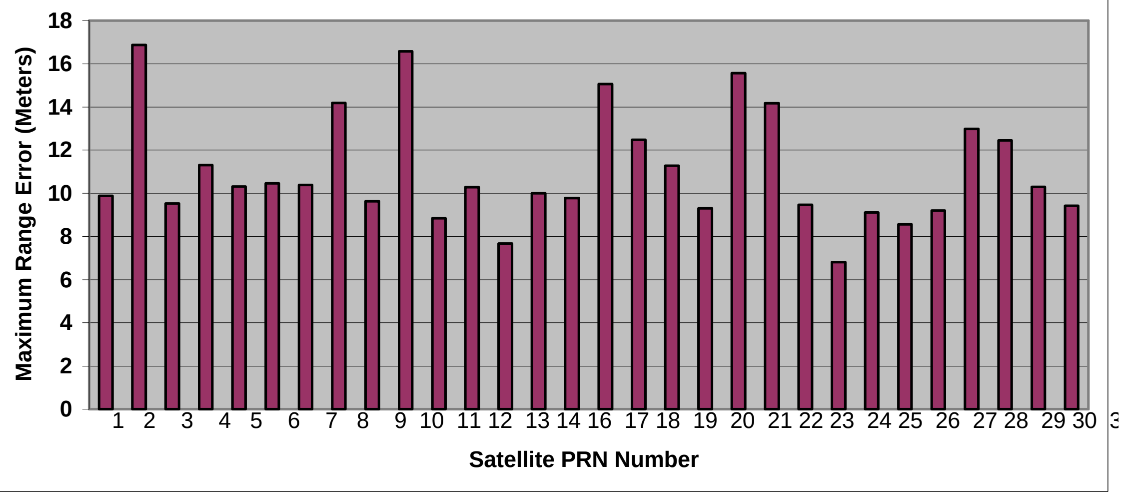


Figure 5-9: Maximum Range Rate Error Per Satellite

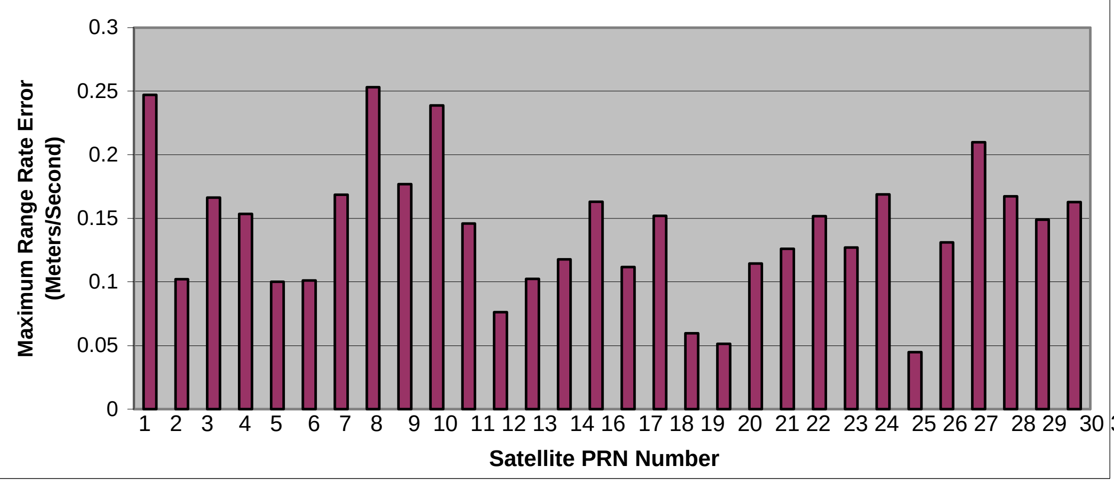
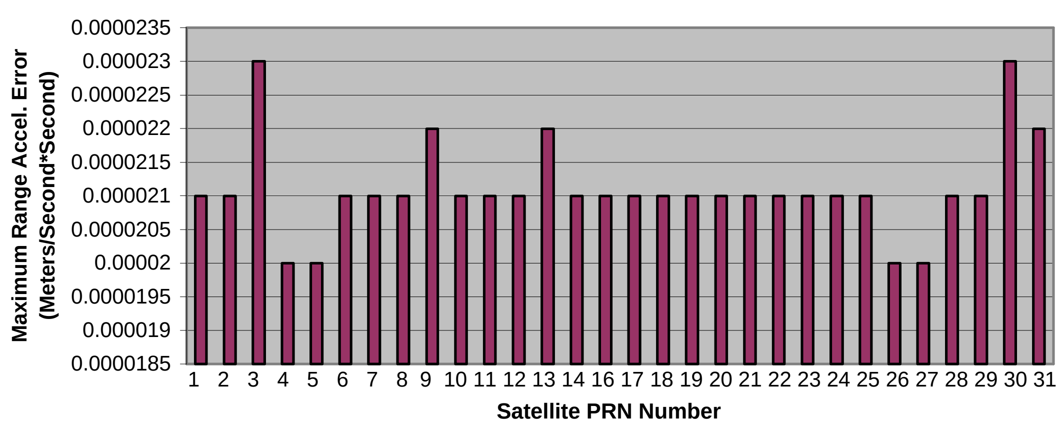


Figure 5-10: Maximum Range Acceleration Per Satellite



6.0 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 19-21 November 2007

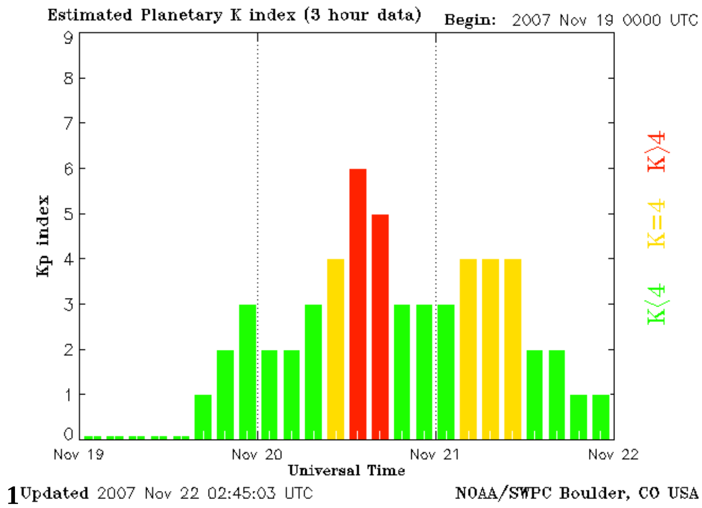


Figure 6-2 K-Index for 24-26 October 2007

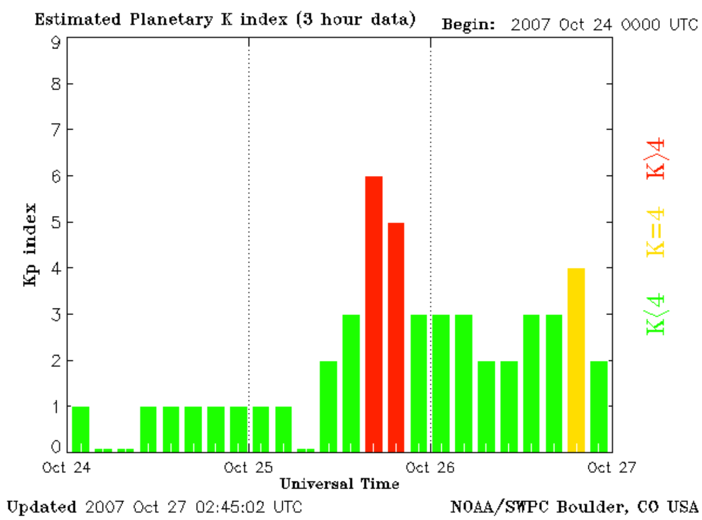
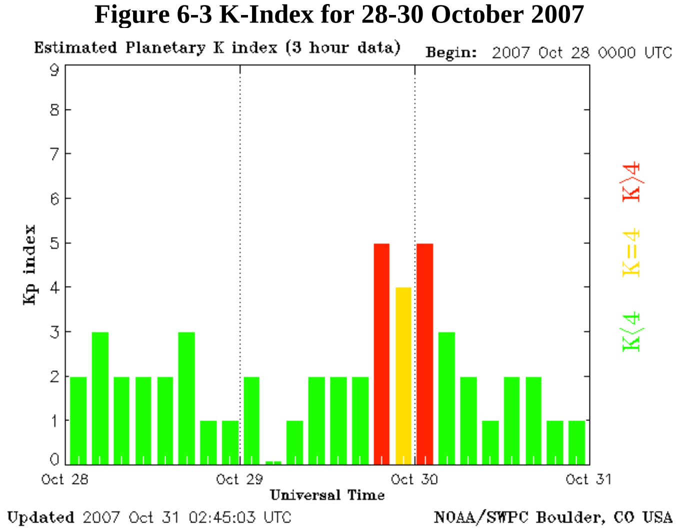


Figure 6-3 K-Index for 28-30 October 2007



Tables 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 20 November 2007

Site	95% Horizontal (Meters)	95% Vertical (Meters)	99.99% Horizontal (Meters)	99.99% Vertical (Meters)
Albuquerque	4.25	3.38	5.26	4.96
Anchorage	1.65	4.18	2.31	5.46
Atlanta	4.56	6.00	5.09	8.74
Barrow	1.48	6.33	2.33	7.64
Bethel	1.85	4.95	2.33	7.01
Billings	3.42	4.11	3.95	8.36
Boston	3.81	6.32	4.38	7.81
Cleveland	4.18	5.93	5.54	8.1
Cold Bay	2.48	4.89	3.07	6.05
Fairbanks	1.56	4.47	2.27	6.84
Gander	3.08	5.76	3.75	8.43
Honolulu	2.65	5.05	3.61	7.18
Houston	4.46	5.28	5.63	7.97
Iqaluit	1.84	3.50	2.27	5.87
Juneau	4.58	5.73	5.09	9.12
Kansas City	1.48	4.80	2.22	7.34
Kotzebue	3.89	3.50	5.21	4.75
Los Angeles	3.24	5.46	3.77	7.33
Merida	3.58	6.30	4.36	9.31
Miami	4.15	5.87	4.56	9.69
Minneapolis	3.53	3.27	4.40	4.65
Oakland	3.54	3.63	4.37	6.32
Salt Lake City	2.72	5.70	4.90	7.34
San Jose Del Cabo	3.13	3.20	3.55	5.32
San Juan	3.54	5.13	3.94	5.48
Seattle	4.07	5.88	5.08	8.17
Tapachula	4.25	3.38	5.26	4.96
Washington, DC	1.65	4.18	2.31	5.46

APPENDICES A – D

Conditions and Constraints	***PDOP Availability Standard***	***Measured Performance***
• Defined for position solution meeting the representative user conditions and operating within the service volume over any 24-hour interval. • Based on using only satellites transmitting standard code and indicating “health” in the broadcast navigation message (sub-frame 1).	≥ 98% global Position Dilution of Precision (PDOP) of 6 or less ≥ 88% worst site PDOP of 6 or less	≥ 99.988% ≥ 98.958%
Conditions and Constraints	***Service Availability Standard***	***Measured Performance***
• 36 meter horizontal (SIS only) 95% threshold. • 77 meter vertical (SIS only) 95% threshold. • Defined for position solution meeting the representative user conditions and operating within the service volume over any 24-hour interval.	≥ 99% Horizontal Service Availability average location ≥ 99% Vertical Service Availability average location	100%
• Based on using only satellites transmitting standard code and indicating “healthy” in the broadcast navigation message (sub-frame 1).	≥ 95.87% global average on worst-case day	100%
Conditions and Constraints	***Service Reliability Standard***	***Measured Performance***
• 30-meter Not-to-Exceed (NTE) SPS SIS URE. • Standard based on a measurement interval of one year; average of daily values within the service volume. • Standard based on 3 service failures per year, lasting no more than 6 hours each.	≥ 99.94% global average	100%
• 30-meter Not-to-Exceed (NTE) SPS SIS URE. • Standard based on a measurement interval of one year; average of daily values from the worst-case point within the service volume. • Standard based on 3 service failures per year, lasting no more than 6 hours each.	≥ 99.79% single point average	≥ 100%

Conditions and Constraints	***Accuracy Standard***	***Measured Performance***
• Defined for position solution meeting the representative user conditions. • Standard based on a measurement interval of 24 hours averaged over all points within the service volume.	Global Average Positioning Domain Accuracy • ≤ 13 meters 95% All-in-View horizontal error (SIS only) • ≤ 22 meters 95% All-in-View vertical error (SIS only)	2.457 m 4.964 m
• Defined for position solution meeting the representative user conditions. • Standard based on a measurement interval of 24 hours for any point within the service volume.	Worst Site Positioning Domain Accuracy • ≤ 36 meters 95% All-in-View Horiz Error (SIS only) • ≤ 77 meters 95% All-in-View Vertical Error (SIS only)	3.319 m 6.946 m
• Defined for time transfer solution meeting the representative user conditions. • Standard based on a measurement interval of 24 hours averaged over all points within the service volume.	Time Transfer Accuracy • ≤ 40 nanoseconds time transfer error 95% of time (SIS only)	11 nanoseconds 95%
• Average of the constellation's individual satellite SPS SIS RMS URE values over any 24-hours interval, for any point in the service volume.	≤ 6 meters RMS SIS SPS URE across the entire constellation	1.928 meters

Prepared by the U.S. Dept. of Commerce, NOAA, Space Environment Center.
Please send comment and suggestions to SEC.Webmaster@noaa.gov
#
Current Quarter Daily Geomagnetic Data
#

	Middle Latitude - Fredericksburg -		High Latitude ---- College ----		Estimated --- Planetary ---	
Date	A	K-indices	A	K-indices	A	K-indices
2007 10 01	7	2 2 2 2 1 1 3 1	14	1 2 3 5 4 2 0 1	8	2 2 3 2 2 2 1 2
2007 10 02	5	2 2 2 1 0 0 1 3	4	1 1 2 3 0 0 0 1	9	2 2 2 1 2 3 2 3
2007 10 03	9	2 3 2 2 3 2 2 2	30	2 4 5 5 6 3 2 2	18	3 4 3 3 4 3 3 3
2007 10 04	8	4 2 2 2 1 2 2 0	18	3 3 2 5 4 3 2 2	10	4 3 2 2 2 2 1 1
2007 10 05	5	2 3 2 1 1 0 1 0	10	1 4 4 1 3 1 0 0	7	2 3 2 1 1 2 2 2
2007 10 06	3	1 0 1 1 1 1 2 1	7	0 0 1 3 4 2 1 0	5	1 0 1 2 2 2 1 2
2007 10 07	1	1 0 0 0 1 0 0 0	2	1 0 1 1 2 0 0 0	4	1 0 0 1 2 2 1 1
2007 10 08	0	0 0 0 0 0 0 1 0	0	0 0 0 0 0 0 0 0	3	0 0 0 0 1 2 1 1
2007 10 09	0	0 0 0 0 0 0 0 0	0	0 0 1 0 0 0 0 0	3	1 0 0 0 2 1 1 1
2007 10 10	1	0 1 1 0 0 0 0 0	1	0 0 2 0 1 0 0 0	3	0 1 1 0 1 1 0 1
2007 10 11	0	0 0 0 0 0 0 0 0	0	0 0 0 0 0 0 0 0	1	0 0 0 0 0 0 0 1
2007 10 12	3	2 0 1 0 1 1 1 1	2	0 0 0 1 1 1 1 1	4	0 1 1 0 1 1 1 2
2007 10 13	2	0 0 0 0 2 1 1 1	1	0 0 0 0 2 0 0 0	2	0 0 0 0 1 1 0 1
2007 10 14	3	1 1 2 2 1 0 0 0	5	0 1 2 3 3 0 0 0	5	1 1 2 2 2 1 0 1
2007 10 15	1	1 0 0 0 1 0 0 0	0	0 0 0 1 0 0 0 0	2	1 0 0 0 0 1 0 1
2007 10 16	1	0 0 0 1 1 0 0 0	5	0 0 0 2 3 3 0 0	2	0 0 0 1 1 1 0 1
2007 10 17	0	1 0 0 0 0 0 0 0	0	0 0 0 0 0 0 0 0	1	1 0 0 0 0 0 0 1
2007 10 18	11	1 3 3 3 2 2 3 2	13	0 2 3 5 2 1 2 3	10	1 2 3 3 2 1 3 3
2007 10 19	11	3 2 2 2 3 2 3 3	20	2 2 3 3 6 3 3 2	15	3 2 2 2 5 3 3 3
2007 10 20	8	3 3 2 2 1 1 2 1	17	2 4 4 5 3 2 2 0	12	4 4 3 3 2 3 2 1
2007 10 21	5	1 2 2 1 1 1 2 2	3	0 1 1 2 2 0 1 1	4	0 1 1 1 1 1 1 2
2007 10 22	3	1 1 0 0 1 1 2 2	4	0 1 0 0 3 1 2 2	5	1 1 0 0 1 2 3 3
2007 10 23	6	3 3 1 1 2 0 1 0	6	2 1 2 3 2 1 1 0	7	3 3 2 1 1 1 1 1
2007 10 24	2	0 0 0 1 1 1 1 0	2	0 0 0 2 2 0 0 0	3	1 0 0 1 1 1 1 1
2007 10 25	10	0 1 0 2 3 3 4 3	32	0 0 1 3 6 6 5 4	20	1 1 0 2 3 6 5 3
2007 10 26	10	3 3 1 2 2 2 3 2	36	3 2 4 6 6 5 4 1	14	3 3 2 2 3 3 4 2
2007 10 27	8	2 3 1 3 2 2 0 2	25	3 1 4 6 5 3 2 2	10	2 3 2 4 2 2 2 2
2007 10 28	4	2 2 1 1 1 2 1 0	9	3 2 2 2 2 3 2 1	7	2 3 2 2 2 3 1 1
2007 10 29	8	1 0 1 1 1 2 4 3	16	1 1 2 4 4 3 3 4	14	2 0 1 2 2 2 5 4
2007 10 30	10	4 2 2 1 2 2 3 1	12	3 3 3 4 2 2 1 2	10	5 3 2 1 2 2 1 1
2007 10 31	3	1 1 2 1 1 0 1 0	6	1 0 2 3 3 1 1 0	4	1 1 2 1 1 0 1 0
2007 11 01	4	3 0 2 1 0 0 1 0	3	1 0 2 2 0 1 1 1	3	2 0 2 1 0 0 0 1
2007 11 02	1	0 2 0 0 0 0 0 0	2	0 1 0 2 1 0 0 0	2	0 1 1 1 0 0 0 1
2007 11 03	2	1 1 1 0 1 0 0 0	2	0 0 1 1 2 0 0 0	2	1 1 0 0 1 1 0 0
2007 11 04	2	1 0 0 0 2 1 1 1	3	0 0 0 1 3 1 1 1	3	1 0 0 0 1 1 2 2
2007 11 05	1	0 1 1 1 0 0 0 0	6	0 0 3 4 1 0 0 0	3	1 1 1 1 0 0 0 0
2007 11 06	0	0 0 0 0 1 0 0 0	0	0 0 0 1 0 0 0 0	1	0 0 0 0 0 0 0 1
2007 11 07	0	0 0 0 0 0 0 0 0	0	0 0 0 0 0 0 0 0	1	0 0 0 0 0 0 0 1
2007 11 08	3	1 2 1 0 0 1 1 1	1	0 0 1 0 1 0 0 1	3	0 2 1 0 0 0 1 1
2007 11 09	2	1 0 0 0 2 1 0 1	1	0 0 0 0 1 1 0 0	2	1 0 0 0 1 1 0 1
2007 11 10	2	1 0 1 1 1 1 0 0	3	0 0 1 3 3 1 0 0	3	1 0 1 2 1 1 0 0
2007 11 11	1	0 0 0 0 1 1 0 0	0	0 0 0 0 1 0 0 0	1	0 0 1 0 0 0 0 1
2007 11 12	2	0 0 0 0 0 1 1 2	0	0 0 0 0 0 0 0 1	2	1 0 0 0 0 1 1 2
2007 11 13	7	2 2 2 2 3 1 1 2	10	2 2 1 3 4 1 2 2	8	3 3 1 2 2 1 2 3
2007 11 14	9	3 3 1 2 2 3 2 1	17	2 2 3 4 5 4 1 1	9	3 3 1 2 2 3 1 1
2007 11 15	5	1 1 1 1 2 2 2 2	4	1 0 0 1 2 2 1 2	5	1 1 0 0 1 2 2 2
2007 11 16	5	1 0 1 2 1 1 2 3	6	1 1 1 2 3 2 1 2	6	1 0 1 2 2 1 1 3
2007 11 17	5	3 2 2 0 1 1 1 0	6	3 2 3 0 1 1 1 0	5	3 2 2 0 1 1 1 1
2007 11 18	1	0 1 0 0 1 1 0 0	0	0 0 0 0 0 0 0 0	2	1 2 0 0 0 0 0 1
2007 11 19	2	0 0 0 0 0 0 2 2	1	0 0 0 0 0 0 1 1	3	0 0 0 0 0 1 2 3
2007 11 20	10	2 2 2 3 3 3 2 2	48	2 2 3 6 7 6 4 4	28	2 2 3 4 6 5 3 3
2007 11 21	9	3 3 3 3 2 1 1 0	31	5 4 5 5 5 3 2 1	13	3 4 4 4 2 2 1 1
2007 11 22	6	1 2 1 1 1 2 2 3	20	0 2 1 4 3 5 5 3	13	1 3 2 1 2 4 4 4
2007 11 23	8	3 3 2 2 2 1 1 2	14	3 2 3 4 4 2 2 1	10	3 3 3 2 2 2 1 1
2007 11 24	8	3 1 2 1 2 3 2 2	24	1 1 3 4 6 5 3 1	12	3 2 3 2 2 4 3 2
2007 11 25	8	2 2 3 1 2 2 2 2	-1	2 2 3 5 3 4 2 5	11	3 3 3 2 2 3 2 3
2007 11 26	6	2 2 2 2 1 1 1 2	8	2 2 2 4 2 1 1 1	8	3 3 2 2 1 1 1 2
2007 11 27	5	1 3 1 1 1 1 1 1	6	1 2 2 3 2 1 1 0	4	1 2 1 1 1 0 1 2

2007 11 28	3	2	0	0	1	1	2	0	0	5	1	0	1	2	3	3	0	0	3	2	0	0	1	1	2	0	1
2007 11 29	2	0	0	1	1	0	1	1	0	4	0	0	1	1	3	2	1	0	3	0	0	1	0	1	1	1	1
2007 11 30	1	0	0	0	0	1	0	1	1	3	0	0	0	3	1	0	1	0	2	0	0	0	1	1	1	1	1
2007 12 01	2	2	0	1	1	0	0	0	0	3	1	0	2	3	0	0	0	0	2	2	0	1	1	0	0	0	0
2007 12 02	2	0	1	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	2	0	1	0	0	0	0	0	1
2007 12 03	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0
2007 12 04	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	2	0	0	0	0	1	1	0	1
2007 12 05	1	2	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	2	1	0	0	0	1	1	0	1
2007 12 06	1	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0
2007 12 07	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
2007 12 08	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2007 12 09	1	0	0	0	0	1	1	1	0	2	0	0	0	0	1	2	1	0	2	0	0	0	0	0	1	1	1
2007 12 10	5	0	1	2	1	1	1	2	3	9	0	1	3	3	3	1	2	3	8	0	2	2	2	2	1	2	4
2007 12 11	9	3	2	2	2	2	2	3	2	32	3	2	3	5	6	5	4	3	12	3	2	3	3	2	3	3	3
2007 12 12	7	2	2	2	3	1	1	1	2	12	2	3	3	5	2	1	0	1	7	2	3	3	3	1	0	0	2
2007 12 13	3	1	2	1	1	1	1	1	0	7	1	3	2	1	3	1	1	1	4	1	2	1	1	1	0	1	0
2007 12 14	2	0	1	0	2	0	1	1	0	1	0	0	0	2	0	0	0	0	2	0	1	0	2	0	0	1	0
2007 12 15	2	0	0	0	1	1	2	1	0	1	0	0	0	0	1	0	1	0	1	0	0	0	0	0	0	0	1
2007 12 16	1	0	0	0	0	0	1	1	1	1	0	0	0	0	0	1	0	1	2	1	0	0	0	0	0	0	2
2007 12 17	12	2	2	3	3	3	3	1	3	32	2	1	5	5	6	5	3	2	17	2	2	4	4	4	4	2	4
2007 12 18	11	3	3	2	2	3	2	2	3	43	3	4	4	7	6	4	3	3	18	3	4	3	4	4	2	3	3
2007 12 19	7	2	3	1	2	2	2	2	1	14	2	3	4	4	3	1	2	2	8	2	4	2	2	2	1	2	2
2007 12 20	10	3	3	1	2	2	3	2	2	18	2	2	3	3	4	5	3	2	12	3	3	2	2	2	4	3	2
2007 12 21	9	3	2	3	2	2	2	2	1	17	3	3	3	4	3	4	3	1	11	3	3	3	2	2	3	3	1
2007 12 22	7	1	3	2	1	2	2	2	2	9	0	0	2	3	4	3	2	1	7	1	2	2	1	2	2	3	2
2007 12 23	4	2	2	2	1	1	1	0	1	10	2	3	2	4	3	2	0	1	6	2	2	2	2	2	1	0	2
2007 12 24	1	0	0	1	0	0	1	1	0	1	0	0	1	0	1	0	0	0	2	0	1	1	0	0	0	0	1
2007 12 25	2	0	0	1	0	1	2	1	0	0	0	0	0	0	1	0	0	0	2	0	0	0	0	0	0	1	0
2007 12 26	1	0	0	0	0	1	1	0	0	1	0	0	0	1	1	0	0	0	2	0	0	1	1	0	0	0	1
2007 12 27	4	1	1	1	1	1	1	2	1	4	0	0	3	2	2	0	0	1	4	1	2	2	1	1	1	1	1
2007 12 28	2	2	2	0	0	1	0	0	0	1	0	1	0	1	0	0	0	0	2	2	2	0	0	0	0	0	0
2007 12 29	2	0	0	0	1	0	1	1	1	1	0	0	1	1	0	0	0	0	2	0	0	0	1	0	0	0	1
2007 12 30	3	1	2	0	0	1	2	0	0	1	0	0	0	1	0	1	0	0	2	1	1	0	0	0	1	0	0
2007 12 31	2	0	1	0	0	1	1	2	1	1	0	0	0	1	0	0	1	1	2	0	0	0	0	1	1	2	1

Background:
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.

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 (Ok) 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, ?, 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 Ok when the argument of latitude (?) 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, ?, 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 Ok when the argument of latitude (?) 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 (1ó) 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.