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 (AND 730) has tasked the Navigation Branch (ACT 360) at the William J. Hughes Technical Center to document 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 the following NSTB and Wide Area Augmentation System (WAAS) Reference Station locations: Atlantic City, Columbus, Denver, Grand Forks, Green Bay, Greenwood, Prescott, Anchorage (WAAS), Billings (WAAS), Chicago (WAAS), Kansas City (WAAS), Salt Lake City (WAAS), Miami (WAAS) and Atlanta (WAAS). This analysis verifies the GPS SPS performance as compared to the performance parameters stated in the SPS Specification Annex A.

This report, Report #40, includes data collected from 1 October through 31 December 2002. The next quarterly report will be issued 30 April 2003.

Analysis of this data includes the following categories: Coverage performance, Service Availability Performance, Position Performance, Range Performance and Solar Storm Effects on GPS SPS performance.

Coverage performance was 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 coverage based on PDOP less than six for the CONUS was 98.333% or better.

Availability was verified by reviewing the “Notice: Advisory to Navstar Users” (NANU) reports issued between 1 October and 31 December 2002 and by calculating the satellite availability from the data obtained from the fourteen sites. A total of sixteen outages were reported in the NANU’s. All sixteen of the outages were scheduled. The quarterly availabilities Prescott, Anchorage, Atlantic City, Columbus, Denver, Grand Forks, Green Bay, Greenwood, Billings, Chicago, Atlanta, Kansas City, Salt Lake City and Miami was 99.99350% or better, with nine sites at 100%. Each of these availabilities is within the SPS value of 99.85%. These availability percentages were calculated using DOP data collected at one-second intervals.

The statistics on the days of significant solar activity met all GPS Standard Positioning Service (SPS) specifications.

Position accuracies were verified by calculating the 95% and 99.99% values of horizontal and vertical errors. Range performance was verified for each satellite using the data collected from the NSTB Atlantic City site. The data was collected in one-second samples. All of the satellites met the range error specifications. The maximum range error recorded was 30.122 meters on Satellite PRN 25. The SPS specification states that the range error should never exceed 150 meters. The maximum range rate error recorded was 0.94089 Meters/second on Satellite PRN 15. The SPS specification states that the range rate error should never exceed 2 meters/second. The maximum range acceleration error recorded was 8.90 Millimeters/second^2 on Satellite PRN 1. The SPS specification states that the range acceleration error should never exceed 19 Millimeters/second^2.

The GLONASS/GPS performance section has been permanently removed from this report.

From the analysis performed on data collected between 1 October and 31 December 2002, the GPS performance met all SPS requirements that were evaluated.

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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 for IFR and is developing Wide Area Augmentation System (WAAS) and Local Area Augmentation (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 Analysis report. This report contains data collected at the following National Satellite Test Bed (NSTB) and WAAS reference station locations:

- Atlantic City, NJ
- Columbus, NE
- Denver, CO
- Grand Forks, ND
- Elko, NV
- Green Bay, WI
- Greenwood, MS
- Prescott, AZ
- Billings, MT
- Anchorage, AK
- Chicago, IL
- Kansas City, KS
- Salt Lake City, UT
- Miami, FL
- Atlanta, GA

(Future reports will include all WAAS sites but a database that can handle all that data needs to be developed. ACT-360 is in the process of setting up an Oracle database for this purpose.)

The analysis of the data is divided into the four performance categories stated in the Standard Positioning Service Performance Specification (SPS) Annex A (June 2, 1995). These categories are:

- Coverage Performance
- Satellite Availability Performance
- 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.

Appendix E Table 1.2 contains the performance parameters evaluated for the WAAS 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 ACT-360. 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 availability 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 includes the maximum and minimum of the PDOP, HDOP and VDOP for each of the thirteen NSTB/WAAS sites.

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 a measurement interval of one year. Data for the quarter is provided for completeness.
Section 5 provides the position and repeatable 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. The SPS specification was met in all instances this quarter.

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

Table 1-1 SPS Performance Requirements

Coverage Standard	Conditions and Constraints	Evaluated in This Report
≥ 99.9% global average	• Probability of 4 or more satellites in view over any 24 hour interval, averaged over the globe • 4 satellites must provide PDOP of 6 or less • 5° mask angle with no obscura • Standard is predicated on 24 operational satellites, as the constellation is defined in the almanac	✓
≥ 96.9% at worst-case point	• Probability of 4 or more satellites in view over any 24 hour interval, for the worst-case point on the globe • 4 satellites must provide PDOP of 6 or less • 5° mask angle with no obscura • Standard is predicated on 24 operational satellites, as the constellation is defined in the almanac	✓
Satellite Availability Standard	**Conditions and Constraints**	
≥ 99.85% global average	• Conditioned on coverage standard • Standard based on a typical 24 hour interval, averaged over the globe • Typical 24 hour interval defined using averaging period of 30 days	✓
≥ 99.16% single point average	• Conditioned on coverage standard • Standard based on a typical 24 hour interval, for the worst-case point on the globe • Typical 24 hour interval defined using averaging period of 30 days	✓
≥ 95.87% global average on worst-case day	• Conditioned on coverage standard • Standard represents a worst-case 24 hour interval, averaged over the globe	✓
≥ 83.92% at worst-case point on worst-case day	• Conditioned on coverage standard • Standard based on a worst-case 24 hour interval, for the worst-case point on the globe	✓
Service Availability Standard	**Conditions and Constraints**	
≥ 99.97% global average	• Conditioned on coverage and service availability standards • 500 meter NTE predictable horizontal error reliability threshold • Standard based on a measurement interval of one year; average of daily values over the globe • Standard predicated on a maximum of 18 hours of major service failure behavior over the sample interval	✓

≥ 99.79% single point average	• Conditioned on coverage and service availability standards • 500 meter Not-to-Exceed (NTE) predictable horizontal error reliability threshold • Standard based on a measurement interval of one year; average of daily values from the worst-case point on the globe • Standard based on a maximum of 18 hours of major service failure behavior over the sample interval	✓
Accuracy Standard	Conditions and Constraints	
Predictable Accuracy ≤ 100 m horz. error 95% of time ≤ 156 m vert. error 95% of time ≤ 300 m horz. error 99.99% of time ≤ 500 m vert. error 99.99% of time	• Conditioned on coverage, service availability and service reliability standards • Standard based on a measurement interval of 24 hours, for any point on the globe	✓
<u>Repeatable Accuracy</u> ≤ 141 m horz. error 95% of time ≤ 221 m vert. error 95% of time	• Conditioned on coverage, service availability and service reliability standards • Standard based on a measurement interval of 24 hours, for any point on the globe	✓
<u>Relative Accuracy</u> ≤ 1.0 m horz. error 95% of time ≤ 1.5 m vert. error 95% of time	• Conditioned on coverage, service availability and service reliability standards • Standard based on a measurement interval of 24 hours, for any point on the globe • Standard presumes that the receivers base their position solutions on the same satellites, with position solutions computed at approximately the same time	Future Reports
<u>Time Transfer Accuracy</u> ≤ 340 nanoseconds time transfer error 95% of time	• Conditioned on coverage, service availability and service reliability standards • Standard based upon SPS receiver time as computed using the output of the position solution • Standard based on a measurement interval of 24 hours, for any point on the globe • Standard is defined with respect to Universal Coordinated Time, as it is maintained by the United States Naval Observatory	✓
<u>Range Domain Accuracy</u> ≤ 150 m NTE range error ≤ 2 m/s NTE range rate error ≤ 8 mm/s^2 range acceleration error 95% of time ≤ 19 mm/s^2 NTE range acceleration error	• Conditioned on satellite indicating healthy status • Standard based on a measurement interval of 24 hours, for any point on the globe • Standard restricted to range domain errors allocated to space/control segments • Standards are not constellation values -- each satellite is required to meet the standards • Assessment requires minimum of four hours of data over the 24 hour period for a satellite in order to evaluate that satellite against the standard	✓

2.0 Coverage Performance

Coverage: *The percentage of time over a specified time interval that a sufficient number of satellites are above a specified mask angle and provide an acceptable position solution geometry at any point on or near the Earth.*

Dilution of Precision (DOP): *A Root Mean Square (RMS) measure of the effects that any given position solution geometry has on position errors. Geometry effects may be assessed in the local horizontal (HDOP), local vertical (VDOP), three-dimensional position (PDOP), or time (TDOP) for example.*

Coverage Standard	Conditions and Constraints
≥ 99.9% global average	• Probability of 4 or more satellites in view over any 24 hour interval, averaged over the globe • 4 satellites must provide PDOP of 6 or less • 5° mask angle with no obscura • Standard is predicated on 24 operational satellites, as the constellation is defined in the almanac
≥ 96.9% at worst-case point	• Probability of 4 or more satellites in view over any 24 hour interval, for the worst-case point on the globe • 4 satellites must provide PDOP of 6 or less • 5° mask angle with no obscura • Standard is predicated on 24 operational satellites, as the constellation is defined in the almanac

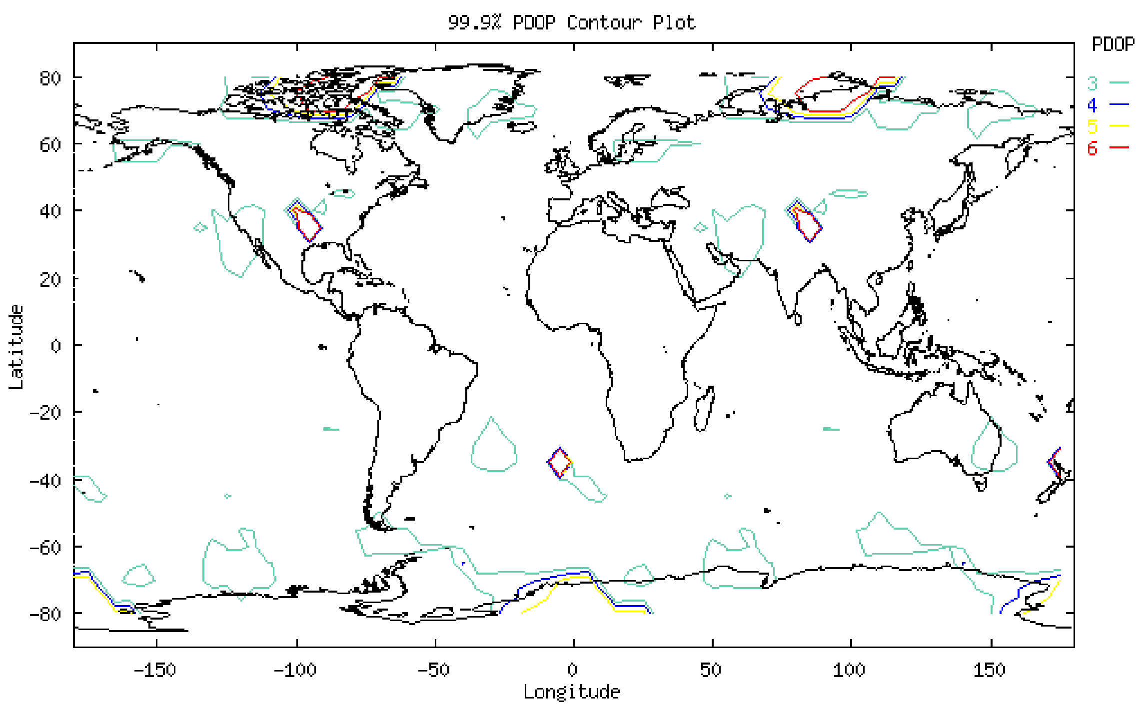
Almanacs for GPS weeks 149-162 used for this coverage portion of the report were obtained from the Coast Guard web site (www.navcen.uscg.mil). Using these almanacs, an SPS coverage area program developed by ACT-360 was used to calculate the PDOP at every 5^{o} point between longitudes of 180W to 180E 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 4.206 or better 99.9% of the time for each of the 24-hour intervals.

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

Table 2-1 Coverage Statistics

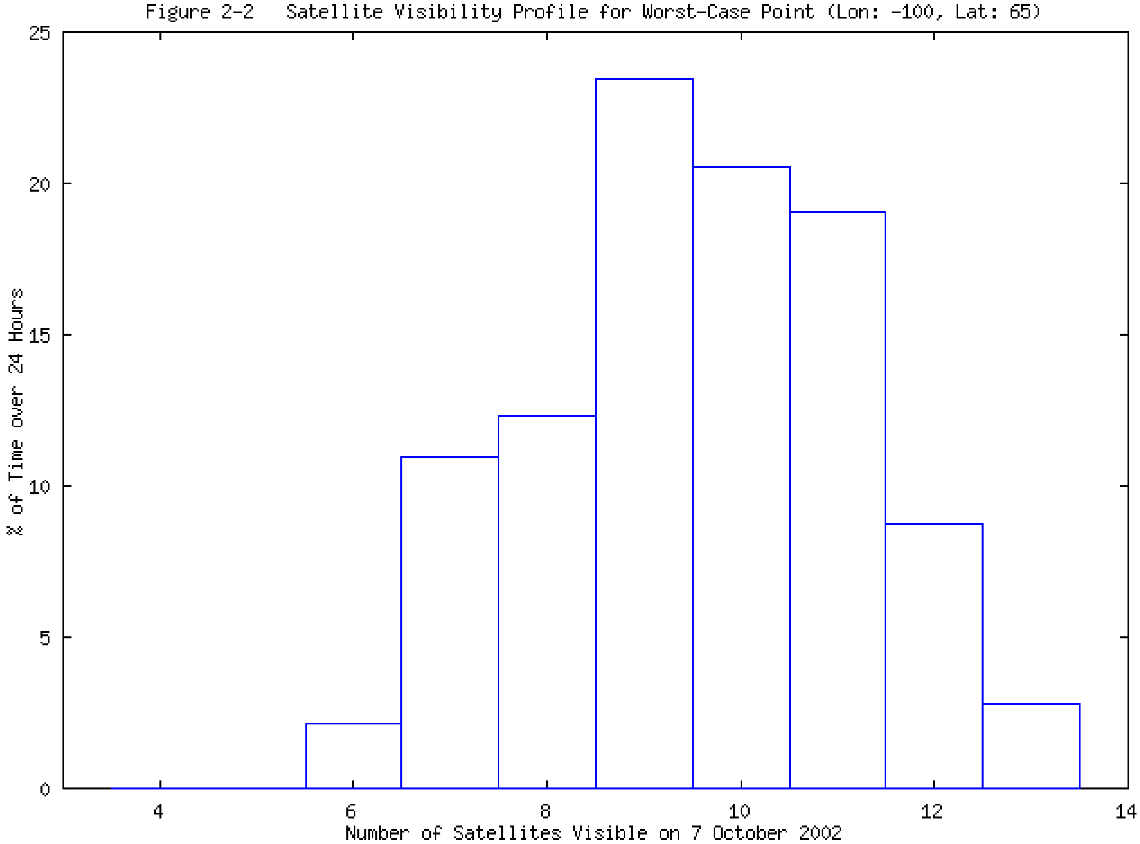
GPS Week	Global 99.9% PDOP Value*	Global Average* (Spec: ≥ 99.9%)	Worst-Case Point (Spec: ≥ 96.9%)
163	4.206	99.948	98.542
164	4.076	99.955	98.681
165	3.950	99.964	98.611
166	3.920	99.965	98.542
167	3.918	99.964	98.542
168	3.988	99.961	98.403
169	3.872	99.964	98.403
170	3.865	99.964	98.333
171	3.838	99.966	98.403
172	3.947	99.965	98.542
173	3.971	99.966	98.681
174	3.978	99.968	98.681
175	4.045	99.967	98.750

Figure 2-1 SPS Coverage (24-Hour Period: 7 October 2002)



Developed by FAA William J. Hughes Technical Center

Figure 2-2 Satellite Visibility Profile for Worst-Case Point (Lon: -100, Lat: 65)



3.0 Service Availability Performance

Service Availability: *Given coverage, the percentage of time over a specified time interval that a sufficient number of satellites are transmitting a usable ranging signal within view of any point on or near the Earth.*

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 2002, there were a total of twenty-one reported outages. Seventeen of these outages were maintenance activities and were reported in advance. Four 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
127	2	S	11-Oct	4:35	11-Oct	8:05		3.50	3.50
129	17	S	7-Oct	1:10	15-Oct	16:26		207.27	207.27
132	2	S	15-Oct	4:16	20-Oct	16:21		132.08	132.08
134	22	S	25-Oct	17:53	26-Oct	2:18		8.42	8.42
135	22	S	28-Oct	16:17	28-Oct	20:35		4.30	4.30
138	8	S	12-Nov	15:54	12-Nov	20:24		4.50	4.50
139 *	22	S	5-Nov	17:56	18-Nov	14:03		N/A	N/A
140*	22	S	5-Nov	17:56	18-Nov	14:03		308.12	308.12
142	25	S	26-Nov	3:02	26-Nov	14:43		11.68	11.68
146	23	S	3-Dec	18:27	4-Dec	5:26		10.98	10.98
147	1	S	6-Dec	7:31	6-Dec	13:29		5.97	5.97
151	4	S	16-Dec	15:27	17-Dec	1:59		10.53	10.53
152	7	S	18-Dec	19:15	18-Dec	22:19		3.07	3.07
153	4	S	19-Dec	21:20	20-Dec	0:33		3.22	3.22
156	1	S	25-Dec	0:56	25-Dec	5:32		4.60	4.60
157	29	S	25-Dec	3:22	30-Dec	19:35		136.22	136.22
Total Actual Unscheduled and Scheduled Downtime and Total Actual Downtime							**0.00**	**854.46**	**854.46**
Type:	S = Scheduled		U = Unscheduled						

* NANU’s 139 and 140 were identical NANU’s with the exception of NANU number and reference NANU number. NANU 139 was mistakenly put out with the incorrect reference NANU, thus 140 was Put out immediately afterward to correct the mistake.

	Table 3-2 NANUs Forecasted to Affect Satellite Availability							
NANU #	PRN	Type	Start Date	Start Time	End Date	End Time	Total	Comments
124	17	F	7-Oct	1:10	N/A	N/A	N/A	See NANU 129
125	22	F	17-Oct	18:00	18-Oct	6:00	12	See NANU 130
126	2	F	11-Oct	4:35	N/A	N/A	N/A	See NANU 127
128	2	F	15-Oct	4:16	N/A	N/A	N/A	See NANU 132
131	22	F	25-Oct	17:30	26-Oct	5:30	12	See NANU 134
133	22	F	28-Oct	16:00	29-Oct	4:00	12	See NANU 135
136	22	F	5-Nov	17:56	N/A	N/A	N/A	See NANU 140
137	8	F	12-Nov	15:30	13-Nov	3:30	12	See NANU 138
141	25	F	26-Nov	2:45	26-Nov	14:45	12	See NANU 142
143	23	F	3-Dec	18:15	4-Dec	18:15	24	See NANU 146
144	1	F	6-Dec	7:15	6-Dec	19:15	12	See NANU 147
145	22	F	3-Dec	14:02	N/A	N/A	N/A	
148	4	F	16-Dec	15:30	17-Dec	3:30	12	See NANU 151
149	7	F	18-Dec	19:00	18-Dec	7:00	12	See NANU 152
150	4	F	19-Dec	21:00	20-Dec	9:00	12	See NANU 153
154	1	F	25-Dec	0:56	N/A	N/A	N/A	See NANU 156
155	29	F	25-Dec	3:22	N/A	N/A	N/A	See NANU 157
					Total Forecast Downtime		132	

	Table 3-3 NANUs Canceled				
NANU#	PRN	Type	Start Date	Start Time	Comments
130	22	C	17-Oct	18:00	See NANU 125

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 October - 31 Dec. 2002**	**1 October, 1999- 31 Dec. 2002**
Total Forecast Downtime (hrs):	132	3608.25
Total Actual Downtime (hrs):	854.46	5997.81
Total Actual Scheduled Downtime (hrs):	854.46	3073.80
Total Actual Unscheduled Downtime (hrs):	0	2924.01
Total Satellite Observed MTTR (hrs):	53.40	25.31
Scheduled Satellite Observed MTTR (hrs):	53.40	16.18
Unscheduled Satellite Observed MTTR (hrs):	N/A	62.21
# Total Satellite Outages:	16	237
# Scheduled Satellite Outages:	16	190
# Unscheduled Satellite Outages:	0	47
Percent Operational -- Scheduled Downtime:	98.57	99.61
Percent Operational -- All Downtime:	99.89	99.24

3.2 Service Availability

Service Availability Standard	Conditions and Constraints
≥ 99.85% global average	• Conditioned on coverage standard • Standard based on a typical 24 hour interval, averaged over the globe • Typical 24 hour interval defined using averaging period of 30 days
≥ 99.16% single point average	• Conditioned on coverage standard • Standard based on a typical 24 hour interval, for the worst-case point on the globe • Typical 24 hour interval defined using averaging period of 30 days
≥ 95.87% global average on worst-case day	• Conditioned on coverage standard • Standard represents a worst-case 24 hour interval, averaged over the globe
≥ 83.92% at worst-case point on worst-case day	• Conditioned on coverage standard • Standard based on a worst-case 24 hour interval, for the worst-case point on the globe

To verify availability, the data collected from receivers at the nine NSTB/WAAS sites was reduced to calculate DOP information and reported in Tables 3-5 to 3-7. The data was collected at one-second intervals between 1 October and 31 December 2002.

Table 3-5 PDOP Statistics

NSTB/WAAS Site	Min PDOP	Max PDOP	VDOP at Max PDOP	Mean PDOP	99.99% PDOP	99.99% VDOP	Number of Samples
Atlantic City	1.238	5.998	2.873	1.882	5.552	4.670	7938032
Columbus	1.198	7.482	6.202	1.901	4.722	3.842	7640775
Denver	1.197	5.931	5.134	1.924	4.793	3.825	7569153
Grand Forks	1.211	7.763	5.903	1.872	4.602	3.997	7930766
Green Bay	1.231	6.000	4.358	1.851	5.891	4.347	4268132
Greenwood	1.292	5.668	5.071	1.883	5.406	5.198	7886984
Prescott	1.433	7.295	6.917	2.291	5.996	5.756	7816639
Billings	1.170	4.580	3.835	1.873	4.453	3.816	7671685
Anchorage	1.178	9.768	8.852	1.860	4.586	4.020	7467806
Chicago	1.182	5.998	5.491	1.853	5.508	5.293	7670184
Kansas City	1.221	5.998	5.207	1.883	5.387	5.040	7664309
Salt Lake City	1.158	4.917	4.018	1.896	4.681	4.198	7672879
Miami	1.172	26.573	23.283	1.854	4.035	3.662	7667654
Atlanta	1.253	5.999	5.352	1.879	5.283	5.044	7662276

Tables 3-6 and 3-7 show the statistics related to maximum PDOP and PDOP greater than six, respectively. Table 3-6 shows the PDOP statistics for the worst-case point on the worst-case day.
NOTE: Global in this report refers to the fourteen sites used. Although future reports will have all additional sites, a true global availability cannot be determined since there aren't reference stations around the world.

Whenever the PDOP goes above six and an SPS requirement is not met, an investigation is performed to determine what caused the PDOP to go above six. The following is a list of programs/procedures used during times of high PDOP:

- Notice of Advisory to Navstar Users (NANU's) messages are used to verify that satellite outages did occur. (See Section 3.1 for more details about NANU's for this quarter.)

- A satellite outage detection program developed by ACT-360 verifies satellite outages that are not verified through a NANU. For example, a satellite outage can occur for just a few seconds during an upload. This satellite detection program monitors all the receivers and keeps track of what satellites the receiver should be tracking versus what satellites the receiver is actually tracking. At least six receivers need to be tracking the satellite prior to the outage and no receiver can be tracking the satellite for the program to detect an outage. This program is also being enhanced so that false locks and late ephemeris problems can also be detected. This program will also output flags from the receivers so that problems with the receiver or TRS software, if any, can be tracked more easily.

- Data from co-located receivers is analyzed for times that the PDOP goes above six. This helps in determining whether the problem is due to the environment.

The instance of worst performance where the PDOP went above six is reported in Table 3-6. The column labeled "NANU/SOD" reports whether the outage was detected via a NANU or the Satellite Outage Detection (SOD) program along with the Satellite PRN number that had the outage.

Table 3-6 Maximum PDOP Statistics

Site	GPS Week/ Day	Max PDOP	Number of Seconds of Whole Day PDOP > 6	NANU/SOD, Satellite PRN Number	Number of Samples	Availability on days when PDOP > 6
Prescott	W169 D1	7.295	257	None	86328	99.702%
Worst-Case Point on Worst-Case Day = 99.702% (SPS Spec. ≥ 83.92%)						

Global Average on Worst-Case Day = 99.979% (SPS Spec. ≥ 95.87%)

Table 3-7 PDOP > 6 Statistics

NSTB/WAAS Site	Total Number of Seconds of PDOP Monitoring	Total Seconds with PDOP > 6	Overall % Availability
Atlantic City	7938032	0	100
Columbus	7640775	2	99.99997
Denver	7569153	0	100
Grand Forks	7930766	1	99.99998
Green Bay	4268132	0	100
Greenwood	7886984	0	100
Prescott	7816639	508	99.99350
Billings	7671685	0	100
Anchorage	7467806	241	99.99677
Chicago	7670184	0	100
Kansas City	7664309	0	100
Salt Lake City	7672879	0	100
Miami	7667654	2	99.99997
Atlanta	7662276	0	100
Worst Single Point Average = 99.9935% (SPS Spec. ≥ 99.16%)			

Global Average over Reporting Period = 99.999% (SPS Spec. > 99.85%)

4.0 Service Reliability Standard

Service Reliability: *Given coverage and service availability, the percentage of time over a specified time interval that the instantaneous predictable horizontal error is maintained within a specified threshold at any point on or near the Earth.*

Service Reliability Standard	Conditions and Constraints
≥ 99.97% global average	• Conditioned on coverage and service availability standards • 500 meter NTE predictable horizontal error reliability threshold • Standard based on a measurement interval of one year; average of daily values over the globe • Standard predicated on a maximum of 18 hours of major service failure behavior over the sample interval
≥ 99.79% single point average	• Conditioned on coverage and service availability standards • 500 meter Not-to-Exceed (NTE) predictable horizontal error reliability threshold • Standard based on a measurement interval of one year; average of daily values from the worst-case point on the globe • Standard based on a maximum of 18 hours of major service failure behavior over the sample interval

Table 4-1 has the 99.99% horizontal errors reported by a receiver at each of the fourteen NSTB/WAAS sites. This will be evaluated against the SPS specification at the end of the year.

Table 4-1 Service Reliability Based on Horizontal Error

NSTB/WAAS Site	Number of Samples This Quarter	Maximum Horizontal Error (Meters)
Atlantic City	7938032	30.6
Columbus	7640775	14.5
Denver	7569153	13.8
Grand Forks	7930766	19.0
Green Bay	4268132	25.6
Greenwood	7886984	16.6
Prescott	7816639	14.8
Billings	7671685	13.9
Anchorage	7467806	13.7
Chicago	7670184	19.1
Kansas City	7664309	14.8
Salt Lake City	7672879	13.2
Miami	7667654	21.2

Atlanta	7662276	18.1

5.0 Accuracy Characteristics

Accuracy: *Given coverage, service availability and service reliability, the percentage of time over a specified time interval that the difference between the measured and expected user position or time is within a specified threshold at any point on or near the Earth.*

Accuracy Standard	Conditions and Constraints
Predictable Accuracy ≤ 100 meters horizontal error 95% of time ≤ 156 meters vertical error 95% of time ≤ 300 meters horizontal error 99.99% of time ≤ 500 meters vertical error 99.99% of time	• Conditioned on coverage, service availability and service reliability standards • Standard based on a measurement interval of 24 hours, for any point on the globe
Repeatable Accuracy ≤ 141 meters horizontal error 95% of time ≤ 221 meters vertical error 95% of time	• Conditioned on coverage, service availability and service reliability standards • Standard based on a measurement interval of 24 hours, for any point on the globe
Relative Accuracy ≤ 1.0 meters horizontal error 95% of time ≤ 1.5 meters vertical error 95% of time	• Conditioned on coverage, service availability and service reliability standards • Standard based on a measurement interval of 24 hours, for any point on the globe • Standard presumes that the receivers base their position solutions on the same satellites, with position solutions computed at approximately the same time
Time Transfer Accuracy ≤ 340 nanoseconds time transfer error 95% of time	• Conditioned on coverage, service availability and service reliability standards • Standard based upon SPS receiver time as computed using the output of the position solution • Standard based on a measurement interval of 24 hours, for any point on the globe • Standard is defined with respect to Universal Coordinated Time, as it is maintained by the United States Naval Observatory
Range Domain Accuracy ≤ 150 meters NTE range error ≤ 2 meters/second NTE range rate error ≤ 8 millimeters/second^2 range acceleration error 95% of time ≤ 19 millimeters/second^2 NTE range acceleration error	• Conditioned on satellite indicating healthy status • Standard based on a measurement interval of 24 hours, for any point on the globe • Standard restricted to range domain errors allocated to space/control segments • Standards are not constellation values -- each satellite is required to meet the standards • Assessment requires minimum of four hours of data over the

	24 hour period for a satellite in order to evaluate that satellite against the standard

5.1 Position Accuracies

The data used for this section was collected for every second between 1 October through 31 December 2002 at the NSTB and WAAS selected locations.

Table 5-1 provides the 95% and 99.99% horizontal and vertical error accuracies for the quarter.

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

NSTB Site	95% Horizontal (Meters)	95% Vertical (Meters)	99.99% Horizontal (Meters)	99.99% Vertical (Meters)
Atlantic City	5.034	12.116	22.118	32.607
Columbus	4.961	12.140	11.142	23.088
Denver	4.893	12.818	11.471	24.041
Grand Forks	5.270	10.620	17.896	21.528
Green Bay	5.399	12.251	11.882	23.667
Greenwood	4.876	14.032	12.953	25.926
Prescott	4.854	13.265	13.692	22.694
Billings	5.555	10.591	12.884	20.981
Anchorage	4.927	9.577	9.300	35.406
Chicago	5.120	11.932	18.301	26.030
Kansas City	5.071	12.665	13.216	24.050
Salt Lake City	5.031	12.132	12.232	20.022
Miami	5.180	15.932	14.979	30.548
Atlanta	4.915	13.716	13.561	24.848

Figures 5-1 and 5-2 are the combined histograms of the vertical and horizontal errors for all fourteen NSTB and WAAS sites from 1 October to 31 December 2002.

Figure 5-1 Combined Vertical Error Histogram

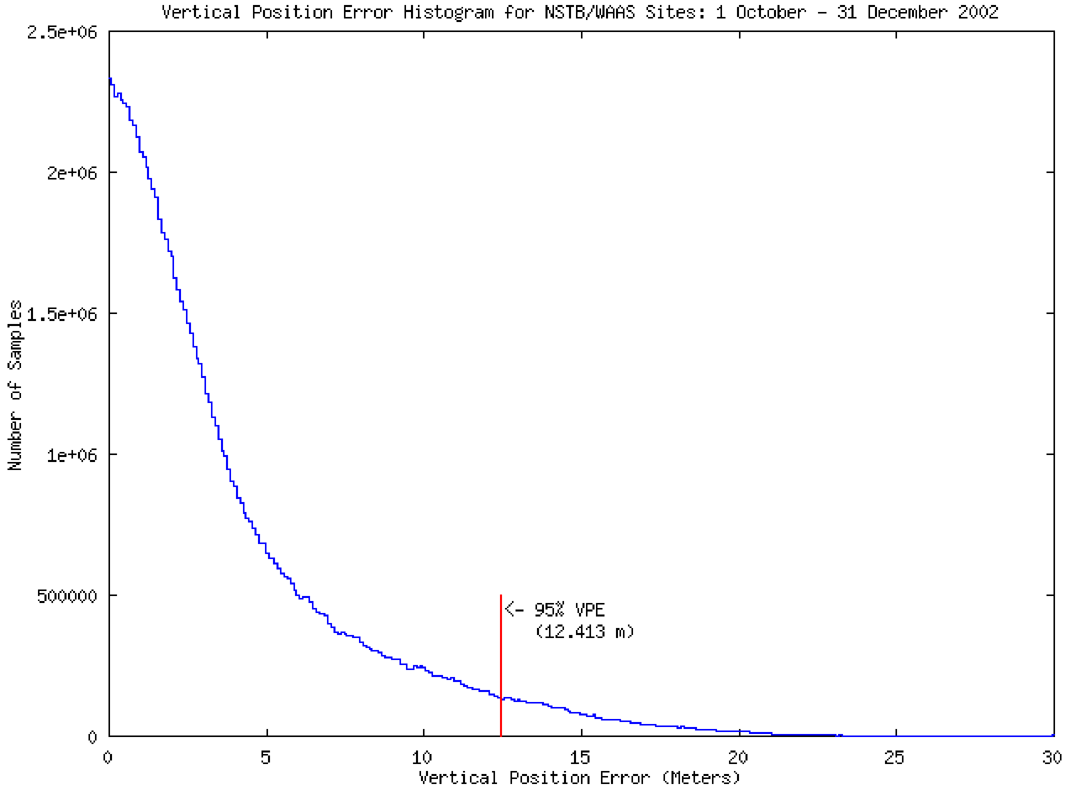
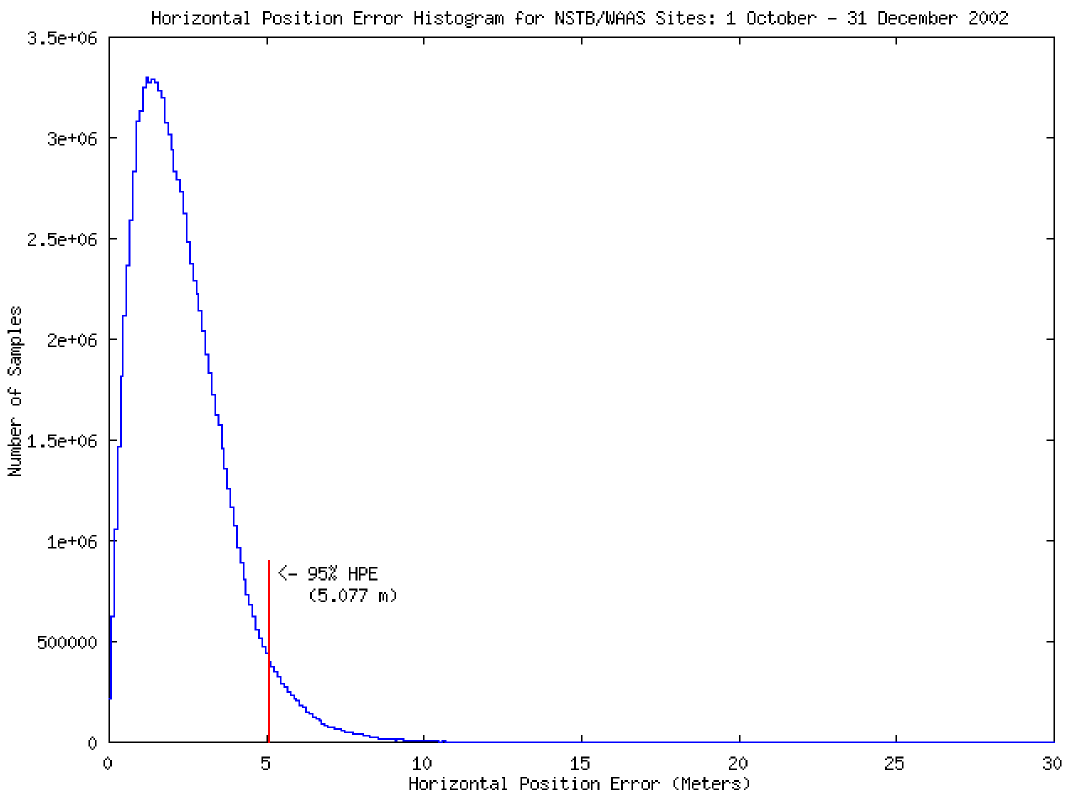


Figure 5-2 Combined Horizontal Error Histogram



5.2 Repeatable Accuracy

Table 5-2 provides the repeatability statistics, which met all of the evaluated requirements stated in the SPS.

Table 5-2 Repeatability Statistics

NSTB Site	95% Horizontal (m)	95% Vertical (m)
Atlantic City	1.484	4.491
Columbus	1.742	3.795
Denver	1.883	5.294
Grand Forks	1.698	4.274
Green Bay	1.730	4.340
Greenwood	1.928	4.733
Prescott	2.145	5.833
Billings	1.836	3.882
Anchorage	1.539	4.192
Chicago	1.521	3.621
Kansas City	1.699	3.748
Salt Lake City	1.731	4.910
Miami	1.883	5.723
Atlanta	1.899	4.518

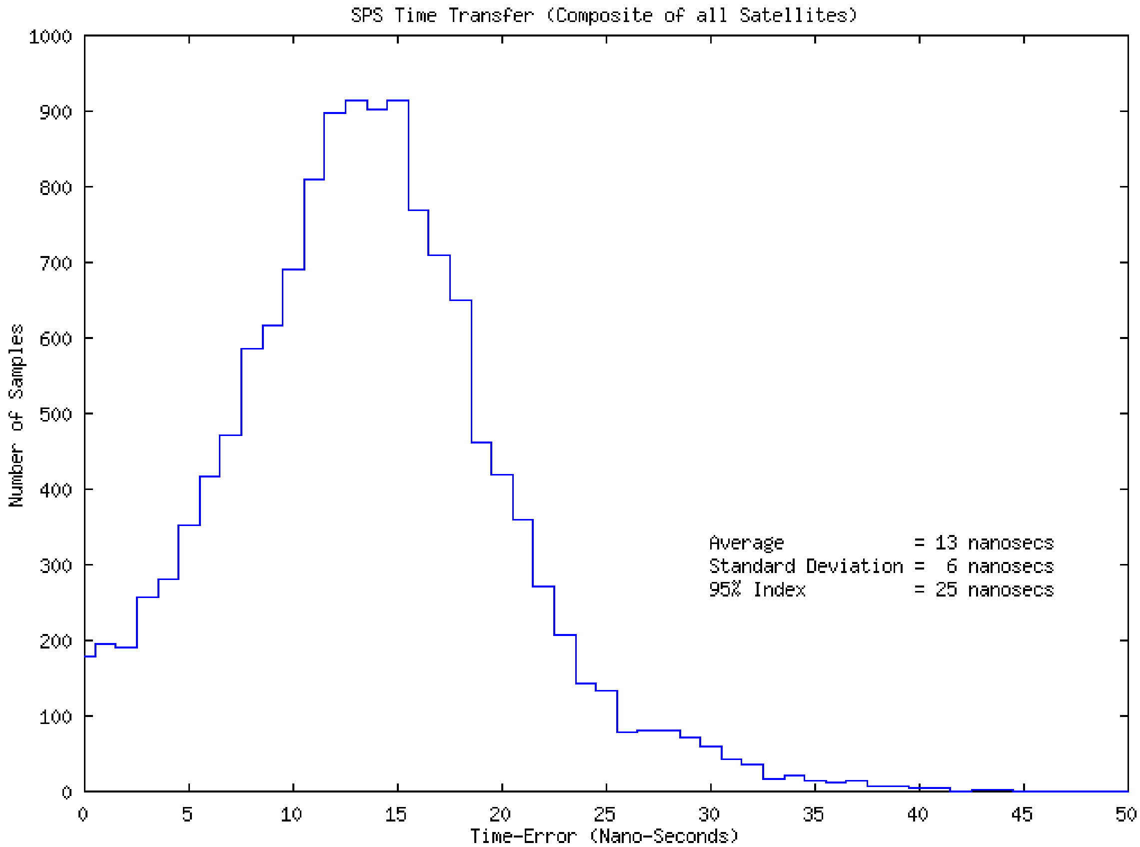
5.3 Relative Accuracy

To be included in future reports.

5.4 Time Transfer Accuracy

The GPS time error data between 1 October and 31 December 2002 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



5.5 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 2002. The Millennium at Anderson was used to collect range measurement. Future PAN reports will contain statistics from all WAAS sites.

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 5-3 Range Error Statistics (meters)

PRN	Range Error Mean	Range Error RMS	1 s	95% Range Error	Max Range Error (SPS Spec. ≤ 150 m)	Samples
1	-2.284	5.718	5.241	11.096	24.805	2139548
2	-2.739	6.472	5.864	13.113	24.767	2084997
3	-3.189	6.831	6.041	13.637	29.187	1746064
4	-0.393	2.706	2.678	5.167	26.234	2108575
5	0.014	3.272	3.272	6.424	25.978	2441713
6	-0.623	3.175	3.114	6.401	29.046	2401965
7	-0.156	3.633	3.630	7.179	27.566	2201384
8	-0.590	5.094	5.059	9.812	24.382	2112067
9	-0.254	3.043	3.032	6.287	18.679	2174789
10	0.601	2.386	2.309	4.518	27.874	2026293
11	-2.055	4.987	4.544	9.501	30.037	2100438
13	-2.270	5.020	4.477	10.995	25.847	2399022
14	-1.235	4.420	4.244	9.903	27.520	2202263
15	-0.448	3.138	3.105	6.422	26.628	2013482
17	0.170	2.428	2.422	5.079	12.090	1630419
18	-0.224	3.019	3.010	6.645	17.173	2086974
20	-1.634	4.225	3.896	8.783	29.956	2535457
22	-4.348	7.816	6.495	16.218	28.919	1102756
23	0.574	2.774	2.714	5.391	18.712	2221566
24	0.350	2.354	2.327	4.447	29.348	2255460
25	-2.503	5.824	5.259	13.159	30.122	2244417
26	-0.041	1.903	1.902	3.609	16.736	1767047
27	-2.093	6.240	5.878	11.751	24.904	1800244
28	-0.239	4.605	4.599	8.946	26.956	2024328
29	0.240	1.908	1.892	3.696	16.565	1676933
30	-0.836	3.728	3.633	8.432	30.021	2446687
31	-2.236	6.432	6.031	11.844	26.586	1871071

Table 5-4 Range Rate Error Statistics (meters/second)

PRN	Range Rate Error Mean	Range Rate Error RMS	Range Rate Error 1s	95% Range Rate Error	Max Range Rate Error (SPS Spec. ≤ 2 m)	Samples
1	0.00028	0.01154	0.01154	0.00830	0.45958	2139548
2	-0.00022	0.01114	0.01114	0.00990	0.69861	2084997
3	-0.00047	0.01190	0.01189	0.01068	0.90839	1746064
4	-0.00020	0.00346	0.00345	0.00375	0.42297	2108575
5	-0.00021	0.00619	0.00618	0.00480	0.76629	2441713
6	-0.00015	0.00871	0.00871	0.00465	0.73910	2401965
7	-0.00012	0.00598	0.00598	0.00509	0.59306	2201384
8	0.00001	0.00922	0.00922	0.00791	0.81714	2112067
9	-0.00003	0.00504	0.00504	0.00432	0.60412	2174789
10	-0.00012	0.00242	0.00242	0.00321	0.17078	2026293
11	-0.00009	0.01041	0.01041	0.00942	0.87349	2100438
13	0.00006	0.01006	0.01006	0.00713	0.44629	2399022
14	-0.00007	0.00759	0.00759	0.00566	0.87208	2202263
15	0.00008	0.00889	0.00889	0.00525	0.94089	2013482
17	0.00004	0.00308	0.00308	0.00398	0.27211	1630419
18	0.00016	0.00460	0.00460	0.00422	0.59020	2086974
20	0.00006	0.01097	0.01097	0.00738	0.48869	2535457
22	-0.00041	0.01250	0.01249	0.01076	0.83602	1102756
23	-0.00010	0.00261	0.00261	0.00333	0.20816	2221566
24	-0.00012	0.00285	0.00284	0.00331	0.60188	2255460
25	-0.00008	0.00983	0.00982	0.00797	0.78918	2244417
26	-0.00013	0.00215	0.00215	0.00323	0.19206	1767047
27	0.00012	0.01080	0.01080	0.01038	0.90659	1800244
28	-0.00007	0.01146	0.01146	0.00726	0.54532	2024328
29	-0.00007	0.00205	0.00205	0.00309	0.23086	1676933
30	-0.00009	0.00681	0.00681	0.00501	0.73549	2446687
31	-0.00031	0.01110	0.01110	0.01085	0.85653	1871071

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

PRN	Range Acceleration Error Mean	Range Acceleration Error RMS	Range Acceleration 1 s	% ≤ 0.008 (SPS Spec. 95% of Time)	Max Range Acceleration Error (SPS Spec. ≤ 0.019 m/s2)	Samples
1	0	0.00010	0.00010	99.999	0.00890	2139548
2	0	0.00010	0.00010	100	0.00697	2084997
3	0	0.00010	0.00010	99.999	0.00808	1746064
4	0	0.00003	0.00003	100	0.00424	2108575
5	0	0.00005	0.00005	100	0.00765	2441713
6	0	0.00008	0.00008	100	0.00740	2401965
7	0	0.00005	0.00005	100	0.00733	2201384
8	0	0.00008	0.00008	99.999	0.00818	2112067
9	0	0.00004	0.00004	100	0.00603	2174789
10	0	0.00002	0.00002	100	0.00171	2026293
11	0	0.00009	0.00009	99.999	0.00876	2100438
13	0	0.00009	0.00009	100	0.00624	2399022
14	0	0.00007	0.00007	99.999	0.00875	2202263
15	0	0.00008	0.00008	99.999	0.00842	2013482
17	0	0.00002	0.00002	100	0.00274	1630419
18	0	0.00004	0.00004	100	0.00594	2086974
20	0	0.00010	0.00010	99.999	0.00839	2535457
22	0	0.00011	0.00011	99.999	0.00841	1102756
23	0	0.00002	0.00002	100	0.00208	2221566
24	0	0.00002	0.00002	100	0.00279	2255460
25	0	0.00009	0.00009	100	0.00791	2244417
26	0	0.00002	0.00002	100	0.00192	1767047
27	0	0.00009	0.00009	99.999	0.00806	1800244
28	0	0.00007	0.00007	99.999	0.00863	2024328
29	0	0.00002	0.00002	100	0.00230	1676933
30	0	0.00006	0.00006	100	0.00736	2446687
31	0	0.00010	0.00010	99.999	0.00855	1871071

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. None of the range errors for any of the satellites exceeded the 150-meter SPS requirement. The highest maximum range error occurred on satellite 25 with an error of 30.122 meters. Satellite 17 had the lowest maximum range error of 12.090 meters.

Figure 5-4 Distribution of Daily Max Range Errors

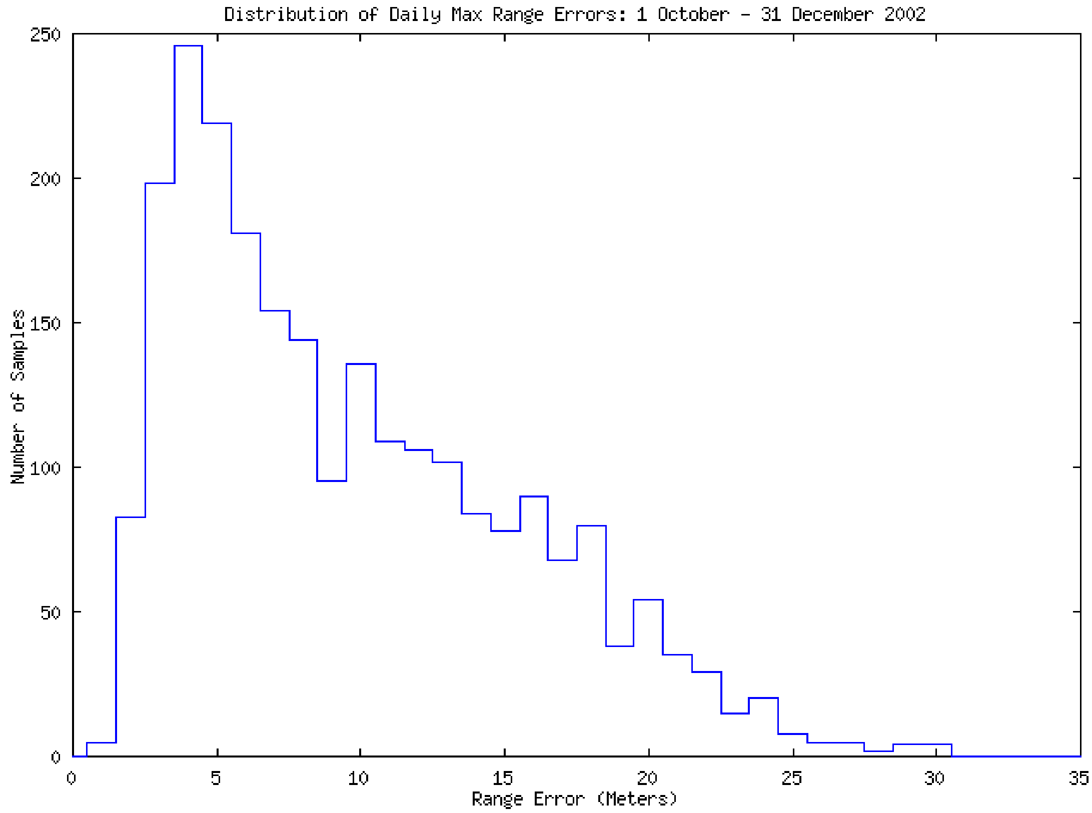


Figure 5-5: Distribution of Daily Max Range Rate Errors

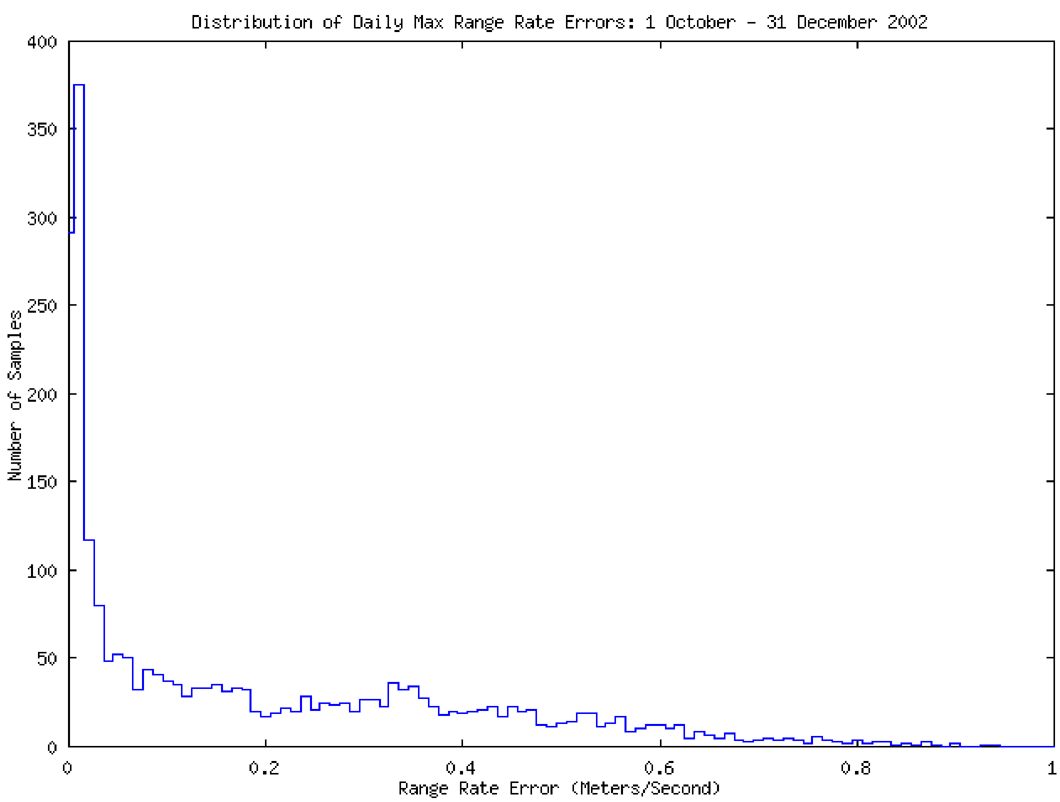


Figure 5-6: Distribution of Daily Max Acceleration Rate Errors

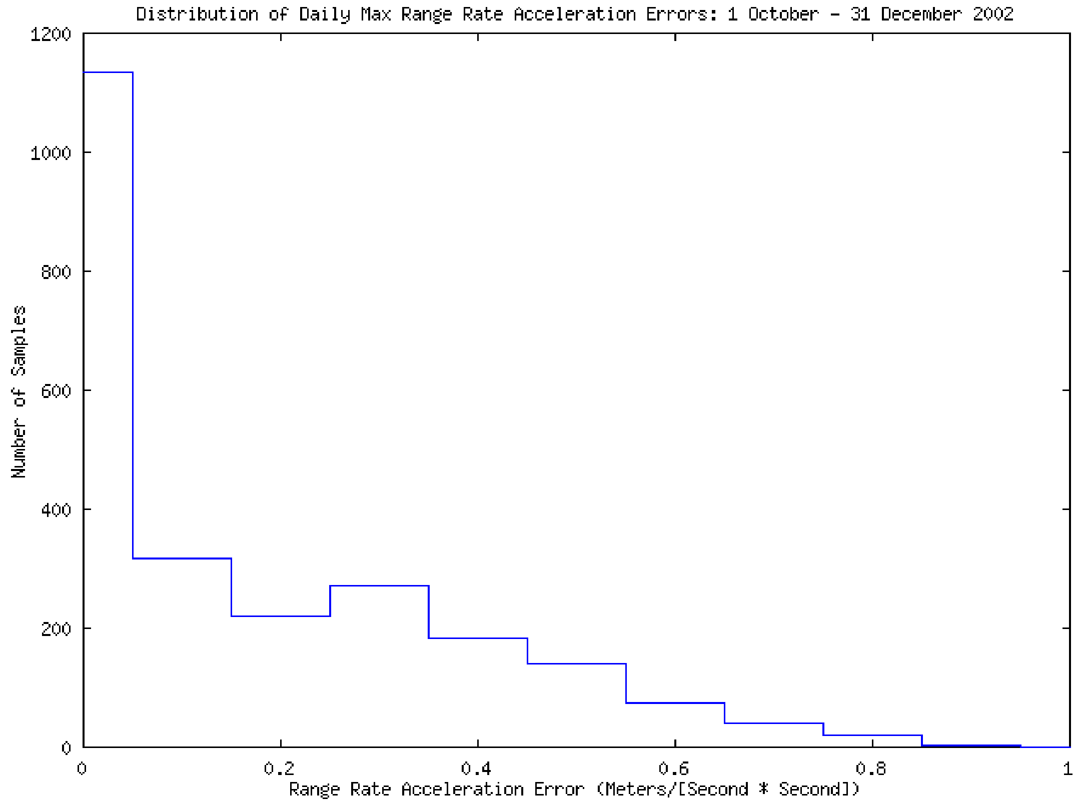
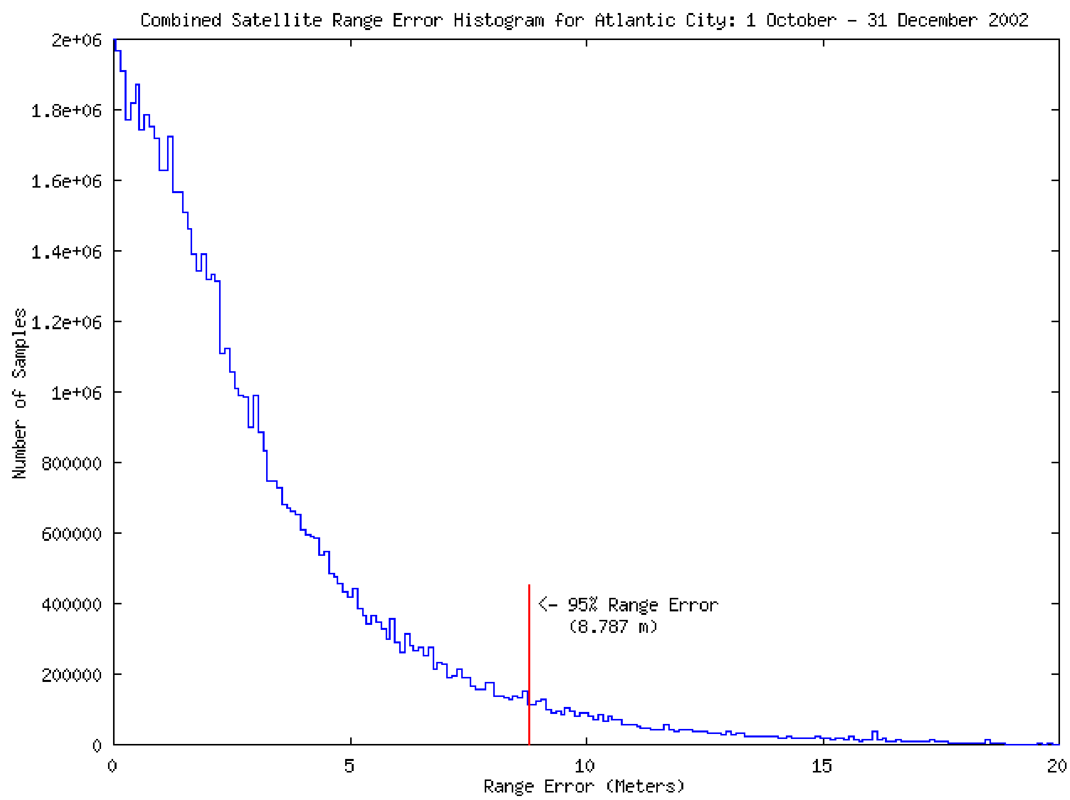


Figure 5-7: Range Error Histogram



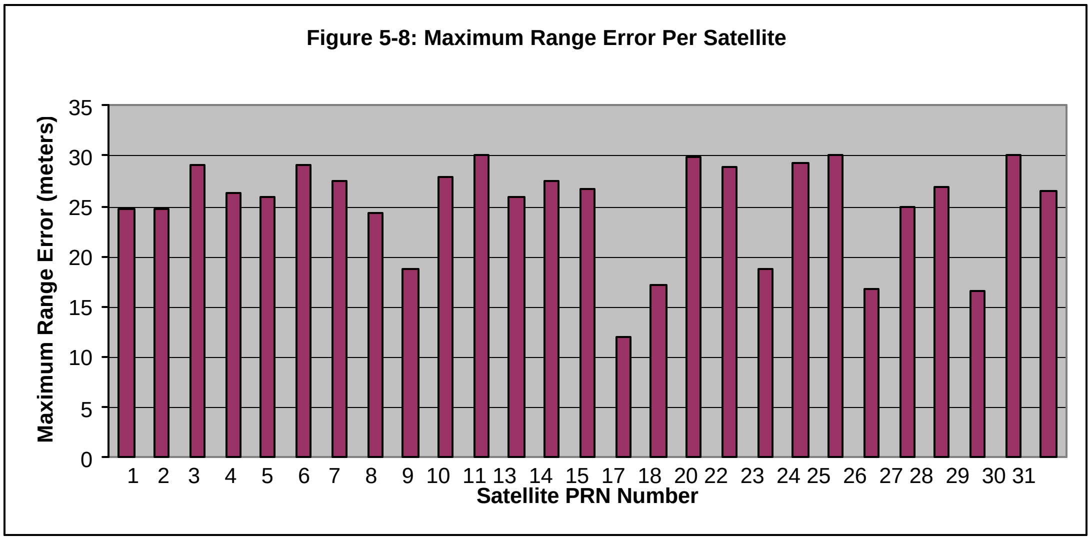


Figure 5-8: Maximum Range Error Per Satellite
Maximum Range Error (meters)
0
5
10
15
20
25
30
35
1 2 3 4 5 6 7 8 9 10 11 13 14 15 17 18 20 22 23 24 25 26 27 28 29 30 31
Satellite PRN Number

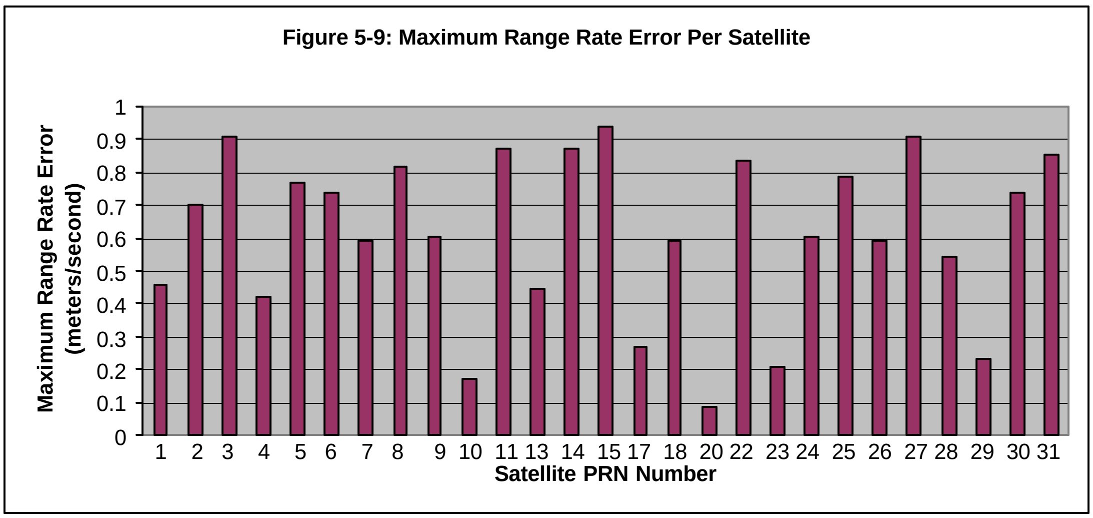


Figure 5-9: Maximum Range Rate Error Per Satellite
Maximum Range Rate Error (meters/second)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
1 2 3 4 5 6 7 8 9 10 11 13 14 15 17 18 20 22 23 24 25 26 27 28 29 30 31
Satellite PRN Number

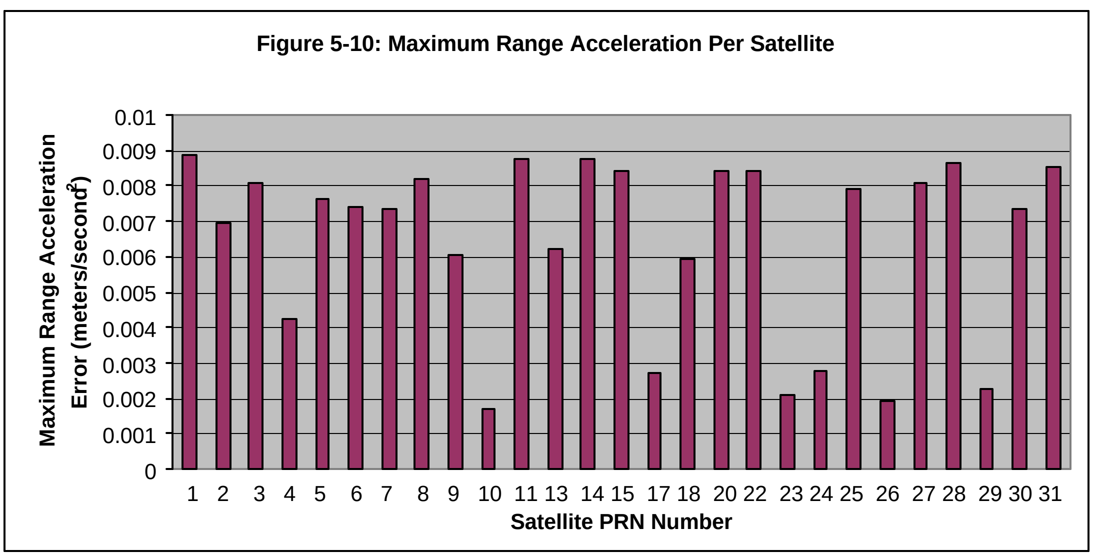


Figure 5-10: Maximum Range Acceleration Per Satellite
Maximum Range Acceleration Error (meters/second²)
0
0.001
0.002
0.003
0.004
0.005
0.006
0.007
0.008
0.009
0.01
1 2 3 4 5 6 7 8 9 10 11 13 14 15 17 18 20 22 23 24 25 26 27 28 29 30 31
Satellite PRN Number

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 1-3 October 2002

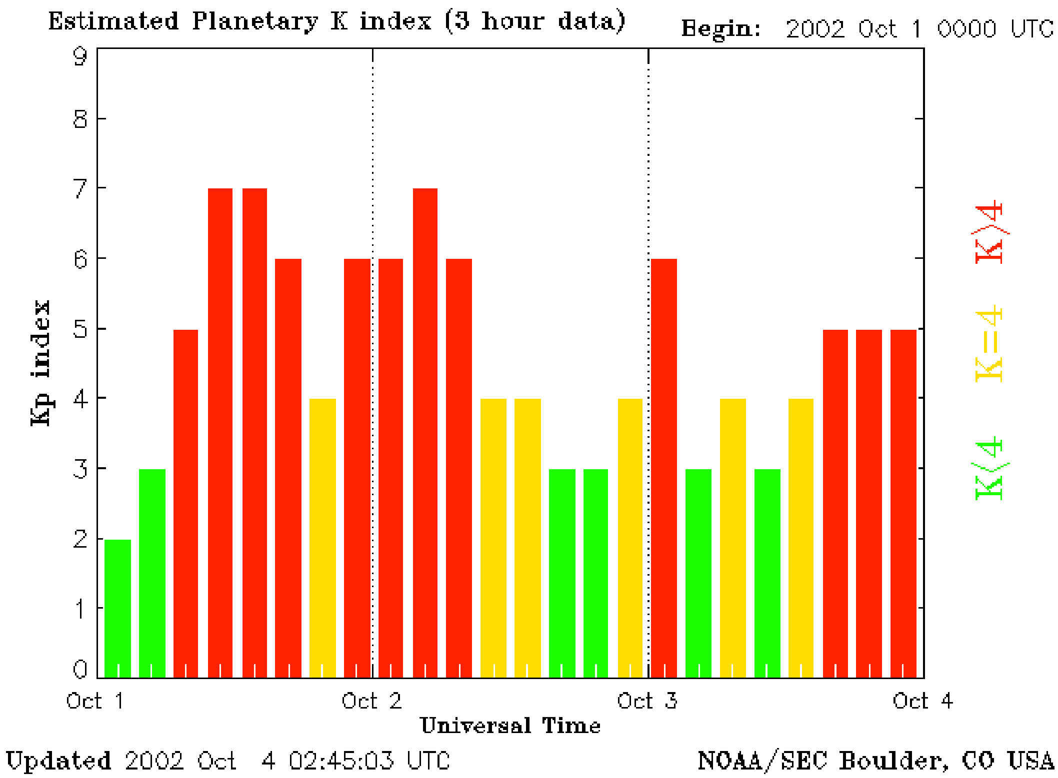


Figure 6-2 K-Index for 4-6 October 2002

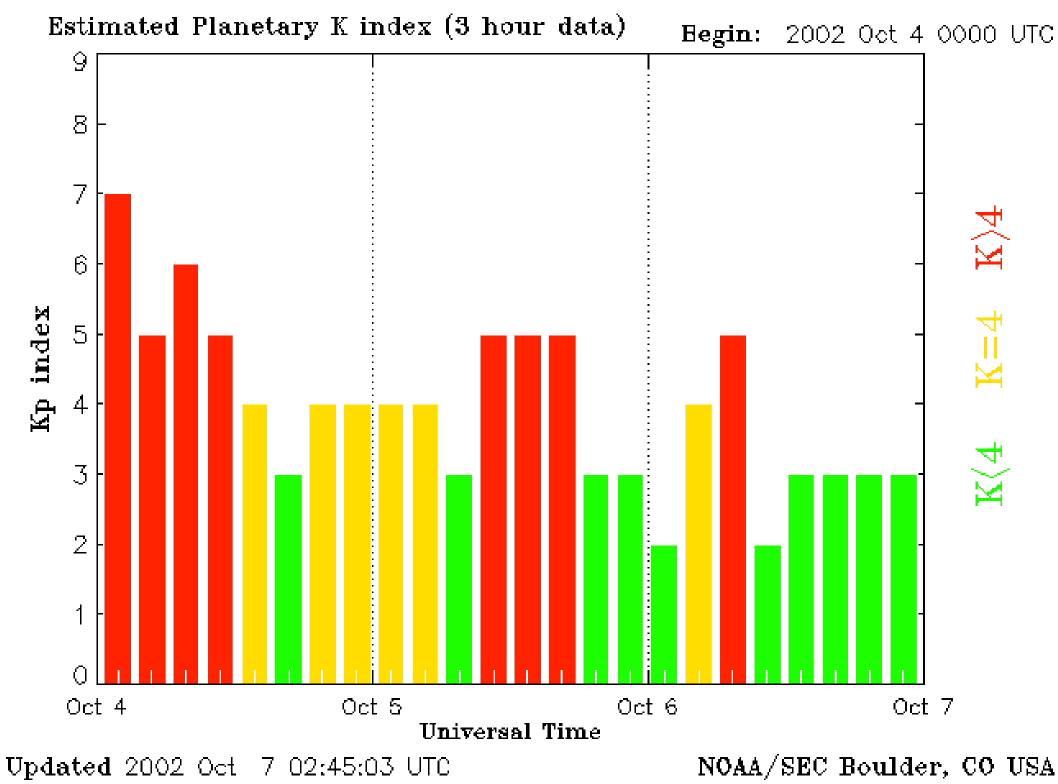
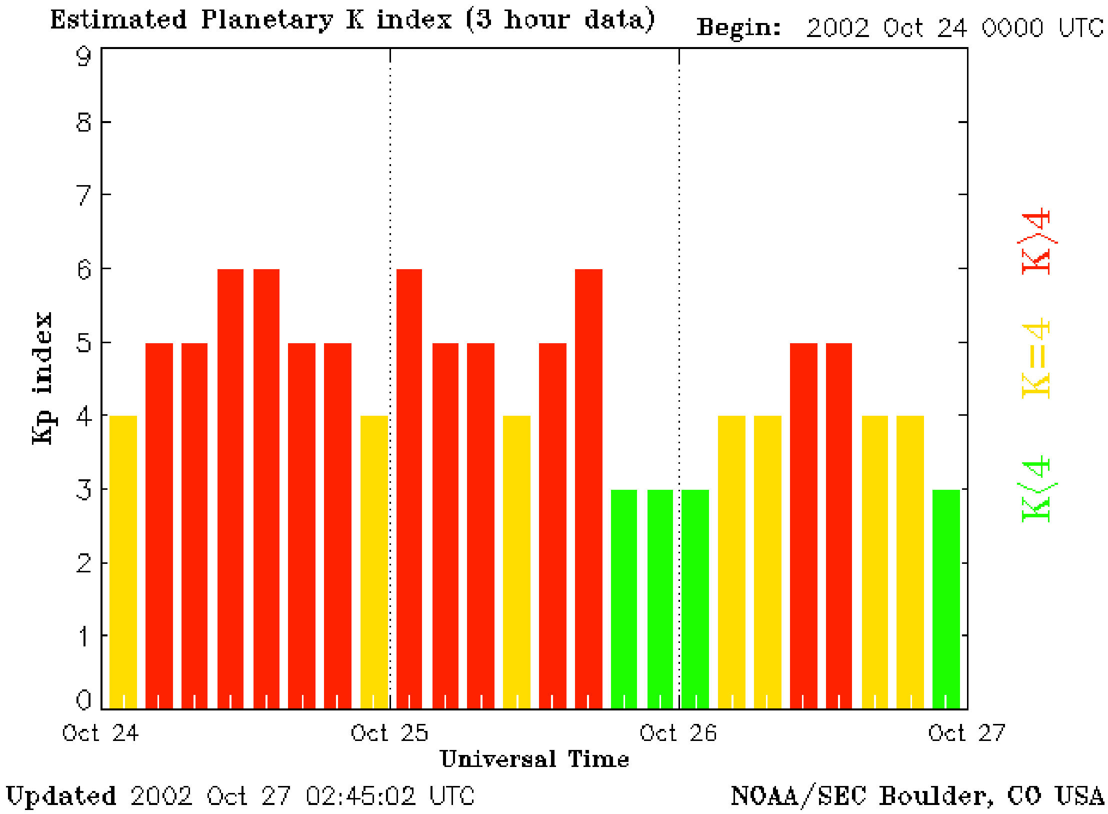


Figure 6-3 K-Index for 24– 26 October 2002



Tables 6-1 and 6-2 below show the PDOP and position accuracy information, respectively, for the days corresponding to Figure 6-1. The GPS SPS performance met the availability requirements during all storms that occurred during this quarter.

Table 6-1 PDOP Statistics for 1 October 2002

NSTB/WAAS Site	Min PDOP	Max PDOP	Mean PDOP	99.99% PDOP	99.99% VDOP
Atlantic City	1.238	4.073	1.850	4.066	3.096
Columbus	1.293	4.277	1.848	4.277	3.358
Denver	1.224	4.290	1.844	4.288	3.330
Grand Forks	1.257	5.689	1.894	5.681	5.130
Green Bay	1.295	4.912	1.866	4.890	3.625
Greenwood	1.317	4.560	1.827	4.559	4.286
Prescott	1.434	5.600	2.187	5.565	4.857
Billings	1.179	2.806	1.704	2.806	2.504
Anchorage	1.233	3.483	1.761	3.483	3.086
Chicago	1.275	3.091	1.731	3.088	2.852
Kansas City	1.254	2.588	1.747	2.588	2.282
Salt Lake City	1.166	3.005	1.721	3.004	2.510
Miami	1.176	3.188	1.781	3.188	2.911
Atlanta	1.254	4.154	1.804	4.152	3.820

Table 6-2 Horizontal & Vertical Accuracy Statistics for 1 October 2002

NSTB Site	95% Horizontal (Meters)	95% Vertical (Meters)	99.99% Horizontal (Meters)	99.99% Vertical (Meters)
Atlantic City	5.100	7.691	8.314	14.653
Columbus	4.259	8.232	6.964	12.089
Denver	4.625	9.209	8.769	12.558
Grand Forks	3.216	7.484	5.049	10.858
Green Bay	3.636	8.694	5.837	14.217
Greenwood	7.085	8.368	12.230	14.010
Prescott	7.094	8.792	9.901	14.113
Billings	4.101	7.016	5.833	10.332
Anchorage	3.598	7.331	4.273	8.096
Chicago	3.891	8.901	5.178	12.766
Kansas City	4.226	7.576	5.124	8.720
Salt Lake City	3.876	6.511	5.517	10.469
Miami	4.924	5.425	7.462	8.006
Atlanta	3.983	6.810	5.837	16.246

APPENDICES A – D

Conditions and Constraints	*Coverage Standard*	*Measured Performance*
• Probability of 4 or more satellites in view over any 24 hour interval, averaged over the globe • 4 satellites must provide PDOP of 6 or less • 5° mask angle with no obscura • Standard is predicated on 24 operational satellites, as the constellation is defined in the almanac	≥ 99.9% global average	99.948%
• Probability of 4 or more satellites in view over any 24 hour interval, for the worst-case point on the globe • 4 satellites must provide PDOP of 6 or less • 5° mask angle with no obscura • Standard is predicated on 24 operational satellites, as the constellation is defined in the almanac	≥ 96.9% at worst-case point	98.333% Availability 99.9% PDOP was 4.206
Conditions and Constraints	***Satellite Availability Standard***	***Measured Performance***
• Conditioned on coverage standard • Standard based on a typical 24 hour interval, averaged over the globe • Typical 24 hour interval defined using averaging period of 30 days	≥ 99.85% global average	99.999%
• Conditioned on coverage standard • Standard based on a typical 24 hour interval, for the worst-case point on the globe • Typical 24 hour interval defined using averaging period of 30 days	≥ 99.16% single point average	99.9935%
• Conditioned on coverage standard • Standard represents a worst-case 24 hour interval, averaged over the globe	≥ 95.87% global average on worst-case day	99.979%
• Conditioned on coverage standard • Standard based on a worst-case 24 hour interval, for the worst-case point on the globe	≥ 83.92% at worst-case point on worst-case day	99.702%
Conditions and Constraints	***Service Reliability Standard***	***Measured Performance***
• Conditioned on coverage and service availability standards • 500 meter NTE predictable horizontal error reliability threshold • Standard based on a measurement interval of one year; average of daily values over the globe • Standard predicated on a maximum of 18 hours of major service failure behavior over the sample interval	≥ 99.97% global average	100%

• Conditioned on coverage and service availability standards • 500 meter Not-to-Exceed (NTE) predictable horizontal error reliability threshold • Standard based on a measurement interval of one year; average of daily values from the worst-case point on the globe • Standard based on a maximum of 18 hours of major service failure behavior over the sample interval	≥ 99.79% single point average	100%
Conditions and Constraints	***Accuracy Standard***	***Measured Performance***
• Conditioned on coverage, service availability and service reliability standards • Standard based on a measurement interval of 24 hours, for any point on the globe	Predictable Accuracy ≤ 100 m horz. error 95% of time ≤ 156 m vert. error 95% of time ≤ 300 m horz. error 99.99% of time ≤ 500 m vert. error 99.99% of time	≤5.555m HE 95% ≤22.118m HE 99.99% ≤15.932m VE 95% ≤35.406m VE 99.99%
• Conditioned on coverage, service availability and service reliability standards • Standard based on a measurement interval of 24 hours, for any point on the globe	Repeatable Accuracy ≤ 141 m horz. error 95% of time ≤ 221 m vert. error 95% of time	≤2.145m HE 95% ≤5.833m VE 95%
• Conditioned on coverage, service availability and service reliability standards • Standard based on a measurement interval of 24 hours, for any point on the globe • Standard presumes that the receivers base their position solutions on the same satellites, with position solutions computed at approximately the same time	Relative Accuracy ≤ 1.0 m horz. error 95% of time ≤ 1.5 m vert. error 95% of time	Future Reports
• Conditioned on coverage, service availability and service reliability standards • Standard based upon SPS receiver time as computed using the output of the position solution • Standard based on a measurement interval of 24 hours, for any point on the globe • Standard is defined with respect to Universal Coordinated Time, as it is maintained by the United States Naval Observatory	Time Transfer Accuracy ≤ 340 nanoseconds time transfer error 95% of time	≤25 ns 95% of the time
• Conditioned on satellite indicating healthy status • Standard based on a measurement interval of 24 hours, for any point on the globe • Standard restricted to range domain errors allocated to space/control segments • Standards are not constellation values -- each	Range Domain Accuracy ≤ 150 m NTE range error ≤ 2 m/s NTE range rate error ≤ 19 mm/s^2 NTE range	30.122m NTE Range Error 0.94089m/s NTE Rate Error 8.90mm/s^2 NTE Accl. Error

satellite is required to meet the standards • Assessment requires minimum of four hours of data over the 24 hour period for a satellite in order to evaluate that satellite against the standard	acceleration error ≤ 8 mm/s^2 range acceleration error 95% of time	$\leq$8mm/s^2 99.999% of the time

Appendix B Geomagnetic Data

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

                 Middle Latitude        High Latitude          Estimated
               - Fredericksburg -     ---- College ----      --- Planetary ---
   Date         A     K-indices        A     K-indices        A     K-indices
2002 10 01     30   2 2 4 4 5 4 3 6   58   1 2 6 6 7 6 5 4   60   2 3 5 7 7 6 4 6
2002 10 02     31   6 6 5 2 2 2 2 3   47   4 7 6 3 6 3 2 3   44   6 7 6 4 4 3 3 4
2002 10 03     22   6 2 3 2 2 3 4 3   55   5 2 4 4 6 6 7 4   33   6 3 4 3 4 5 5 5
2002 10 04     43   7 4 6 4 3 3 4 3   55   4 4 7 7 4 5 4 2   48   7 5 6 5 4 3 4 4
2002 10 05     12   3 4 2 2 3 3 2 1   45   3 4 4 6 6 6 4 4   29   4 4 3 5 5 5 3 3
2002 10 06      9   2 3 3 2 1 1 2 3   23   2 3 6 4 2 3 3 3   19   2 4 5 2 3 3 3 3
2002 10 07     21   2 5 4 3 4 3 3 3   64   3 5 7 4 7 6 5 3   39   3 5 6 4 5 4 4 4
2002 10 08     19   2 6 2 3 3 3 2 1   40   4 6 5 6 5 3 3 1   34   4 6 4 5 4 4 3 3
2002 10 09      9   0 2 4 2 2 2 2 2   30   1 3 6 5 5 4 3 2   22   2 4 5 5 4 4 3 3
2002 10 10     10   1 3 4 3 2 1 1 2   34   1 4 6 6 5 4 1 1   23   3 3 5 5 4 2 2 3
2002 10 11      5   1 2 2 2 2 1 1 1   18   1 2 4 5 5 2 1 1    8   2 2 2 3 3 2 2 2
2002 10 12      6   1 1 1 3 2 2 1 1   11   1 1 2 4 4 3 1 0   11   2 3 2 4 3 3 3 2
2002 10 13      4   1 1 2 1 1 1 1 1    9   1 1 3 3 4 0 1 1   10   2 3 3 3 3 3 2 2
2002 10 14     13   2 3 4 3 3 2 3 2   27   1 3 4 4 6 5 2 2   26   3 4 4 4 6 4 3 2
2002 10 15     13   2 3 2 3 2 4 3 2   23   3 3 3 4 4 5 4 2   15   3 3 2 4 3 4 4 2
2002 10 16      9   3 0 1 1 2 2 4 2   18   3 1 0 2 2 3 6 3   14   3 2 1 2 3 4 5 3
2002 10 17      8   3 2 1 1 3 2 2 2   15   4 3 2 2 4 3 2 2   11   4 3 2 2 3 3 3 3
2002 10 18      9   2 3 2 1 3 2 2 2   13   3 3 3 1 3 4 2 2   13   3 3 2 1 3 4 3 2
2002 10 19      9   2 2 2 2 2 2 3 3   11   2 3 2 2 3 2 3 3   11   3 3 2 2 2 3 3 3
2002 10 20      8   1 3 1 1 3 1 3 2   10   2 3 0 3 4 2 1 2   10   2 3 1 2 3 3 3 3
2002 10 21      7   1 3 2 2 2 2 1 1    6   1 2 3 2 2 2 1 1   11   2 3 3 2 3 3 3 3
2002 10 22     10   3 1 1 3 2 3 3 1   13   1 2 1 5 4 2 2 0   12   3 2 1 4 3 3 3 3
2002 10 23      6   1 0 1 1 3 2 2 2   14   0 1 2 4 5 3 2 2   10   2 2 2 2 3 3 3 3
2002 10 24     22   3 4 4 4 4 3 4 3   76   3 6 5 6 7 7 6 4   47   4 5 5 6 6 5 5 4
2002 10 25     22   5 4 4 3 4 2 3 3   69   5 4 7 7 7 4 3 3   40   6 5 5 4 5 6 3 3
2002 10 26     16   3 4 4 3 3 2 3 2   48   3 3 5 7 6 5 4 3   27   3 4 4 5 5 4 4 3
2002 10 27     13   1 3 3 2 3 2 3 4   43   3 4 6 4 6 5 5 3   22   2 4 4 3 4 4 4 4
2002 10 28     10   3 3 2 2 2 1 3 2   24   4 4 3 5 4 3 3 3   17   4 4 3 3 3 3 3 3
2002 10 29     10   3 3 2 2 2 1 3 2   24   4 4 3 5 4 3 3 3   16   4 3 3 4 3 3 2 3
2002 10 30     11   3 3 3 2 2 2 3 2   25   2 3 6 5 2 3 3 3   19   2 3 5 4 3 3 3 3
2002 10 31     13   3 3 3 3 3 3 2 2   28   3 3 4 5 5 5 3 2   18   4 3 3 3 4 4 3 3
2002 11 01      5   2 1 1 1 1 1 1 3    9   2 1 1 4 3 1 2 1   10   2 3 2 3 3 3 3 2
2002 11 02     13   3 2 3 3 3 2 3 3   42   3 2 5 6 4 6 5 4   21   3 2 4 5 4 4 4 3
2002 11 03     15   3 3 3 3 3 3 3 3   47   3 4 6 6 5 6 4 3   27   4 4 4 4 4 4 3 4
2002 11 04     11   3 3 2 3 2 2 2 3   33   3 3 5 5 5 5 3 4   21   4 4 4 4 4 4 3 4
2002 11 05     15   2 4 3 3 3 3 2 3   43   4 4 6 6 5 5 3 3   19   3 4 4 4 4 3 3 3
2002 11 06     12   3 2 3 2 3 2 3 3   38   3 3 5 6 6 4 4 3   19   4 3 3 4 4 4 4 3
```

2002	11	07	10	4	3	2	2	2	2	2	1	21	3	2	3	5	5	3	3	1	14	4	3	3	3	3	3	3	3
2002	11	08	3	1	1	0	1	1	1	2	0	6	1	1	3	3	3	0	0	0	8	2	2	2	2	3	2	3	2
2002	11	09	3	0	0	1	0	1	1	2	2	2	0	0	0	2	0	0	2	1	9	2	2	1	2	2	3	3	3
2002	11	10	12	2	4	4	1	2	2	1	2	11	2	4	4	2	2	2	1	1	15	3	4	5	2	3	3	2	2
2002	11	11	10	2	2	3	3	3	2	2	2	15	1	1	3	4	5	3	1	1	12	2	2	3	3	4	3	2	3
2002	11	12	9	1	2	2	2	3	2	2	3	23	1	2	3	5	6	2	2	3	14	2	2	3	3	4	3	3	4
2002	11	13	16	4	3	5	2	3	1	1	2	16	3	3	2	3	5	3	2	1	12	4	3	2	2	3	3	3	2
2002	11	14	5	2	1	1	1	2	2	2	1	5	2	2	0	0	3	2	2	0	9	3	2	2	2	3	3	2	3
2002	11	15	8	2	1	3	3	2	1	2	2	11	1	1	3	4	3	2	2	2	11	3	2	3	3	3	3	3	3
2002	11	16	3	1	1	0	0	1	1	1	2	4	2	1	0	1	2	1	1	2	8	3	2	1	2	3	3	2	3
2002	11	17	5	3	2	1	0	1	2	0	1	4	3	2	1	0	0	1	1	1	8	3	2	1	1	3	3	2	2
2002	11	18	11	2	1	1	1	2	1	2	2	18	2	2	4	4	4	3	3	3	12	3	2	3	2	3	3	3	3
2002	11	19	12	2	3	3	2	2	1	3	4	29	5	5	6	3	2	1	3	3	14	3	3	3	2	3	3	3	4
2002	11	20	13	3	2	1	2	1	3	4	4	30	3	1	1	4	3	6	6	3	17	3	3	1	3	2	4	4	4
2002	11	21	22	3	4	5	4	3	3	3	3	64	2	4	7	7	6	6	4	3	50	3	5	7	6	5	4	4	4
2002	11	22	17	5	3	2	3	3	3	2	3	37	4	2	5	6	5	5	4	3	24	5	4	3	4	4	4	3	3
2002	11	23	10	3	4	2	2	2	2	1	1	32	3	5	6	5	4	4	2	2	19	4	5	4	3	3	3	3	2
2002	11	24	8	2	3	2	2	2	2	2	2	27	2	2	2	5	6	5	3	2	16	3	4	3	3	4	4	3	3
2002	11	25	-1	-1	3	2	2	2	3	2	2	-1	-1	3	4	6	5	5	3	2	17	2	3	3	4	4	3	3	3
2002	11	26	6	1	1	1	1	1	1	1	4	15	2	2	1	4	4	3	2	4	14	3	3	2	2	3	3	2	5
2002	11	27	13	3	4	3	3	3	1	2	2	32	4	4	6	5	4	3	3	3	21	4	4	4	4	4	3	3	3
2002	11	28	10	3	3	3	1	2	2	3	1	26	3	3	4	5	5	4	3	3	15	3	4	3	3	3	3	3	2
2002	11	29	9	2	1	3	1	2	3	3	2	22	2	2	4	3	5	4	4	3	14	3	3	4	2	3	4	3	3
2002	11	30	14	2	4	4	3	2	3	2	2	-1	-1	-1	-1	-1	-1	-1	-1	-1	16	3	4	4	3	3	3	3	3
2002	12	01	16	3	3	2	3	3	4	3	3	-1	-1	-1	-1	-1	-1	-1	-1	-1	16	4	3	3	4	4	3	3	3
2002	12	02	9	2	3	2	2	2	3	2	2	-1	-1	-1	-1	-1	-1	-1	-1	-1	11	2	3	3	3	3	3	3	2
2002	12	03	7	3	2	1	2	2	1	2	1	17	2	3	2	4	5	3	2	2	11	3	3	2	3	3	3	3	2
2002	12	04	7	1	1	2	1	2	3	3	1	16	1	1	3	3	4	4	4	2	12	2	2	3	3	3	4	3	2
2002	12	05	5	2	1	2	1	2	1	1	1	7	1	1	3	3	2	2	1	0	9	3	3	2	3	2	3	2	2
2002	12	06	6	0	2	2	2	1	2	2	2	4	0	0	2	2	2	2	1	1	10	2	2	2	2	3	3	3	3
2002	12	07	8	2	2	2	2	3	2	2	2	27	3	3	3	5	6	3	3	3	16	3	3	3	4	3	3	3	3
2002	12	08	8	1	3	1	1	3	3	2	1	15	2	4	1	1	3	5	3	1	12	2	4	2	2	3	4	3	2
2002	12	09	3	2	0	0	0	1	2	1	1	4	2	0	0	1	2	2	1	1	8	3	2	1	2	2	3	2	2
2002	12	10	4	2	1	1	1	0	1	2	1	3	1	1	0	2	0	1	1	1	7	2	2	1	2	2	3	2	2
2002	12	11	5	0	1	2	1	3	1	2	1	1	0	0	1	1	0	1	0	0	6	2	2	1	2	2	3	2	2
2002	12	12	6	1	2	1	2	2	2	2	2	1	0	0	0	1	0	1	0	0	7	2	2	1	2	2	3	2	2
2002	12	13	2	1	1	0	0	1	1	1	1	1	1	0	0	0	0	1	0	0	7	2	2	1	2	2	3	2	2
2002	12	14	9	1	1	1	2	2	3	3	3	14	1	1	1	4	3	4	4	2	11	2	2	2	2	3	3	3	3
2002	12	15	5	3	1	1	1	2	1	1	0	9	2	2	2	2	4	2	1	1	9	3	2	2	2	3	3	3	2
2002	12	16	3	0	1	2	1	1	1	1	1	2	0	1	2	1	1	0	0	0	8	2	2	2	2	3	3	2	2
2002	12	17	2	1	0	0	0	0	1	1	1	2	3	1	0	0	0	0	0	0	6	2	2	1	2	2	3	2	2
2002	12	18	2	1	1	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	6	2	2	0	1	2	3	2	1
2002	12	19	15	2	3	3	3	4	3	3	2	39	1	2	4	6	5	6	5	3	21	3	3	4	5	4	4	4	2
2002	12	20	12	3	4	1	1	2	2	3	3	18	2	4	2	3	4	3	4	3	16	3	4	2	3	3	3	3	4
2002	12	21	12	3	5	2	1	2	2	1	1	14	3	4	3	3	3	3	1	1	18	4	5	3	2	3	3	2	2
2002	12	22	9	1	1	0	2	3	2	4	2	9	2	1	2	3	4	1	2	1	12	2	2	2	3	3	3	4	2
2002	12	23	12	2	1	3	3	2	3	3	3	40	2	2	4	7	6	3	4	3	26	3	3	4	5	5	3	4	3
2002	12	24	14	2	1	3	2	4	4	3	2	37	3	1	3	6	6	6	3	2	18	3	2	3	3	4	4	3	3
2002	12	25	10	2	2	2	2	2	2	4	2	28	2	2	4	5	6	4	4	1	14	3	3	3	3	4	3	3	3
2002	12	26	8	1	1	1	2	2	2	2	4	27	0	0	3	6	5	5	3	2	15	2	2	2	4	4	4	3	4
2002	12	27	22	3	5	3	4	3	4	3	3	52	4	5	4	6	6	6	5	4	37	4	6	4	5	5	4	4	3
2002	12	28	12	3	3	3	3	3	2	2	1	41	3	3	6	6	6	4	4	1	19	4	4	4	4	3	4	3	2
2002	12	29	8	3	1	2	2	2	2	2	2	23	1	2	3	6	5	3	3	1	13	3	2	3	3	3	3	3	3
2002	12	30	9	4	2	2	1	2	2	2	1	21	1	1	4	5	5	3	3	2	15	4	3	3	3	3	4	3	3
2002	12	31	7	4	1	1	2	2	1	1	1	9	2	1	3	4	3	0	0	1	11	3	3	2	3	3	3	2	2

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:

GPS did not fail SPS specification in any instances during this quarter.

The terms and definitions discussed below are taken from the Standard Positioning Service Performance Specification (SPS) (June 2, 1995). An understanding of these terms and definitions is a necessary prerequisite to full understanding of the Signal Specification.

General Terms and Definitions

Block I and Block II Satellites. The Block I is a GPS concept validation satellite; it does not have all of the design features and capabilities of the production model GPS satellite, the Block II. The FOC 24 satellite constellation is defined to consist entirely of Block II/IIA satellites. For the purposes of this Signal Specification, the Block II satellite and a slightly modified version of the Block II known as the Block IIA provide an identical service.

Dilution of Precision (DOP). The magnifying effect on GPS position error induced by mapping GPS ranging errors into position through the position solution. 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.

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

Major Service Failure. A condition over a time interval during which one or more SPS performance standards are not met and the civil community was not warned in advance.

Minimum SPS Receiver Capabilities. Minimum standards for signal reception and processing capabilities that are incorporated into the design of an SPS receiver. This ensures consistent performance with the SPS performance standards.

Navigation Data. Data provided to the SPS receiver via each satellite's ranging signal, containing 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.

Navigation Message. Message structure designed to carry navigation data.

Operational Satellite. A GPS satellite that is capable of, but may or may not be, transmitting a usable ranging signal. For the purposes of the SPS, any satellite contained within the transmitted navigation message almanac is considered to be an operational satellite.

Position Solution. The use of ranging signal measurements and navigation data from at least four satellites to solve for three position coordinates and a time offset.

Selective Availability. Protection technique employed by the DOD to deny full system accuracy to unauthorized users.

Service Disruption. A condition over a time interval during which one or more SPS performance standards are not supported, but the civil community was warned in advance.

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

SPS Performance Standard. A quantifiable minimum level for a specified aspect of GPS SPS performance.

Standard Positioning Service (SPS). Three-dimensional position and time determination capability provided to a user equipped with a minimum capability GPS SPS receiver in accordance with GPS national policy and the performance specifications.

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

SPS Signal, or SPS Ranging Signal. An electromagnetic signal originating from an operational satellite. The SPS ranging signal consists of a Pseudo Random Noise (PRN) Coarse/Acquisition (C/A) code, a timing reference and sufficient data to support the position solution generation process.

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

Performance Parameter Definitions

The definitions provided below establish the basis for correct interpretation of the GPS SPS performance standards. The GPS performance parameters contained in the SPS are defined differently than other radio navigation systems in the Federal Radio Navigation Plan. For a more comprehensive treatment of these definitions and their implications on system use, refer to Annex B of the SPS.

Coverage. The percentage of time over a specified time interval that a sufficient number of satellites are above a specified mask angle and provide an acceptable position solution geometry at any point on or near the Earth. The term "near the Earth" means on or within approximately 200 kilometers of the Earth's surface.

Positioning Accuracy. Given reliable service, the percentage of time over a specified time interval that the difference between the measured and expected user position or time is within a specified tolerance at any point on or near the Earth. This general accuracy definition is further refined through the more specific definitions of four different aspects of positioning accuracy:

- **Predictable Accuracy.** Given reliable service, the percentage of time over a specified time interval that the difference between a position measurement and a surveyed benchmark is within a specified tolerance at any point on or near the Earth.

- **Repeatable Accuracy.** Given reliable service, the percentage of time over a specified time interval that the difference between a position measurement taken at one time and a position measurement taken at another time at the same location is within a specified tolerance at any point on or near the Earth.

- **Relative Accuracy.** Given reliable service, the percentage of time over a specified time interval that the difference between two receivers' position estimates taken at the same time is within a specified tolerance at any point on or near the Earth.

- **Time Transfer Accuracy.** Given reliable service, the percentage of time over a specified time interval that the difference between a Universal Coordinated Time (commonly referred to as UTC) time estimate from the position solution and UTC as it is managed by the United States Naval Observatory (USNO) is within a specified tolerance.

Range Domain Accuracy. Range domain accuracy deals with the performance of each satellite's SPS ranging signal. Range domain accuracy is defined in terms of three different aspects:

- **Range Error.** Given reliable service, the percentage of time over a specified time interval that the difference between an SPS ranging signal measurement and the "true" range between the satellite and an SPS user is within a specified tolerance at any point on or near the Earth.

- **Range Rate Error.** Given reliable service, the percentage of time over a specified time interval that the instantaneous rate-of-change of range error is within a specified tolerance at any point on or near the Earth.

- **Range Acceleration Error.** Given reliable service, the percentage of time over a specified time interval that the instantaneous rate-of-change of range rate error is within a specified tolerance at any point on or near the Earth.

Service Availability. Given coverage, the percentage of time over a specified time interval that a sufficient number of satellites are transmitting a usable ranging signal within view of any point on or near the Earth.

Service Reliability. Given service availability, the percentage of time over a specified time interval that the instantaneous predictable horizontal error is maintained within a specified reliability threshold at any point on or near the Earth. Note that service reliability does not take into consideration the reliability characteristics of the SPS receiver or possible signal interference. Service reliability may be used to measure the total number of major failure hours experienced by the satellite constellation over a specified time interval.