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

Submitted To

Federal Aviation Administration
GPS Product Team
AND 730
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Washington, DC 20024

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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 #39, includes data collected from 1 July through 30 June 2002. The next quarterly report will be issued 31 January 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 98.542% or better.

Availability was verified by reviewing the “Notice: Advisory to Navstar Users” (NANU) reports issued between 1 July and 30 September 2002 and by calculating the satellite availability from the data obtained from the fourteen sites. A total of twelve outages were reported in the NANU’s. Eleven of the outages were scheduled and one was unscheduled. The quarterly availabilities Prescott, Anchorage, Atlantic City, Columbus, Denver, Grand Forks, Green Bay, Greenwood, Billings, Chicago, Atlanta, Kansas City, Salt Lake City and Miami were all 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 31.490 meters on Satellite PRN 20. The SPS specification states that the range error should never exceed 150 meters. The maximum range rate error recorded was 0.77825 Meters/second on Satellite PRN 20. The SPS specification states that the range rate error should never exceed 2 meters/second. The maximum range acceleration error recorded was 7.780 Millimeters/second^2 on Satellite PRN 20. 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 July and 30 September 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° 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 3.98159 or better 99.9% 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%)
149	3.63180	99.999	99.514
150	3.83358	99.974	98.958
151	3.28815	99.999	99.514
152	3.28885	99.999	99.444
153	3.33970	99.999	99.444
154	3.27763	99.999	99.444
155	3.31718	99.998	99.444
156	3.30894	99.998	99.375
157	3.26133	99.998	99.444
158	3.89466	99.974	98.125
159	3.25246	99.997	99.444
160	3.25282	99.997	99.444
161	3.23154	99.996	99.514
162	3.98159	99.961	98.542

Figure 2-1 SPS Coverage (24-Hour Period: 29 September 2002)

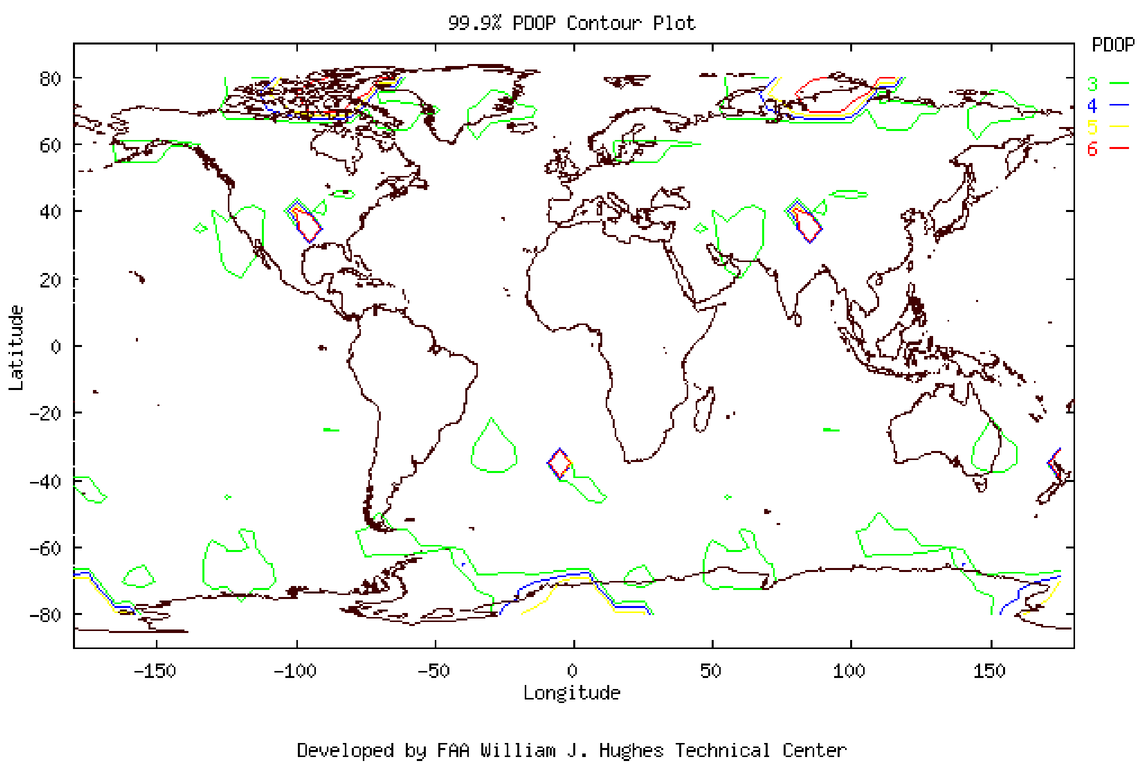
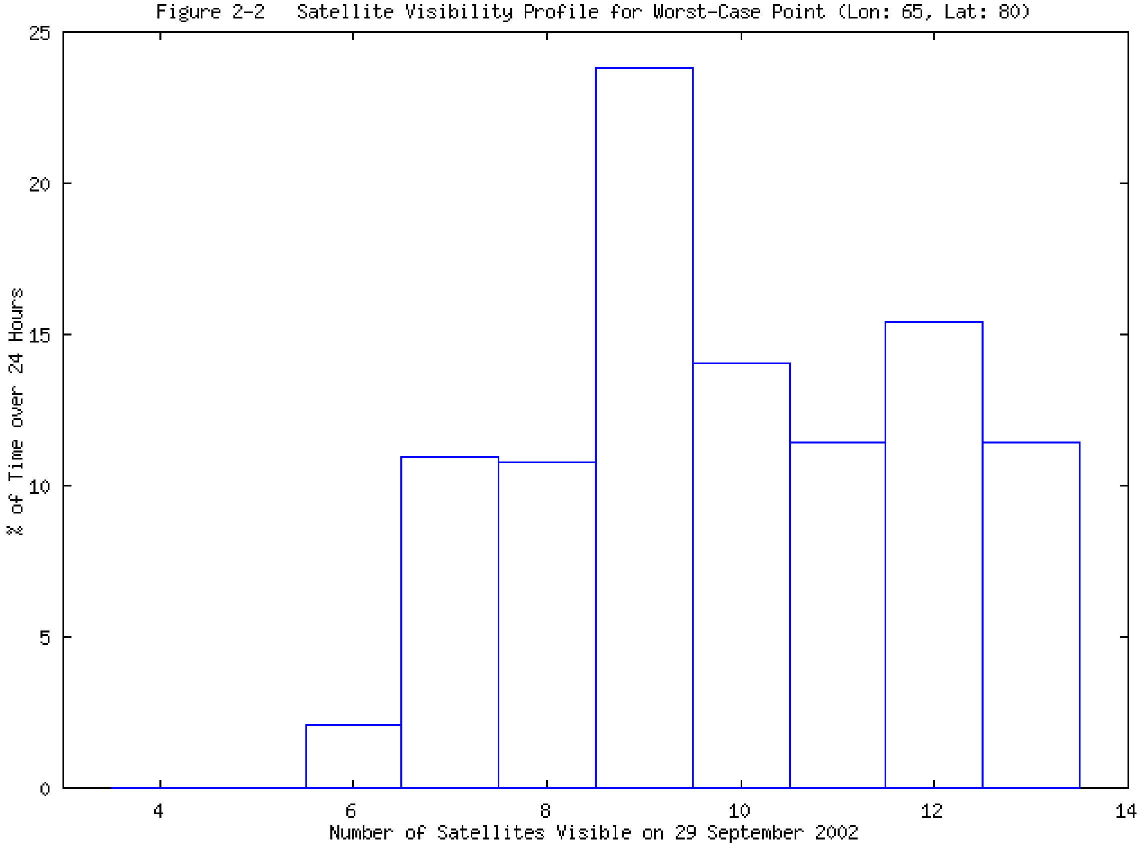


Figure 2-2 Satellite Visibility Profile for Worst-Case Point (Lon: 65, Lat: 80)



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 July through 30 September 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
2099	26	S	1-Jul	14:40	1-Jul	21:06		6.43	6.43
2101	27	S	1-Jul	0:00	5-Jul	16:04		112.07	112.07
2103	30	U	10-Jul	9:17	10-Jul	15:13	5.93		5.93
2106	9	S	18-Jul	16:48	19-Jul	0:37		7.82	7.82
2109	22	S	23-Jul	22:45	24-Jul	1:25		2.67	2.67
2110	17	S	28-Jul	9:43	29-Jul	21:35		35.87	35.87
2112	15	S	12-Aug	18:49	17-Aug	19:16		120.45	120.45
2116	24	S	30-Aug	8:00	30-Aug	18:14		10.23	10.23
2118	20	S	3-Sep	12:33	3-Sep	20:04		7.52	7.52
2119	6	S	6-Sep	6:37	6-Sep	10:37		4.00	4.00
2120	27	S	9-Sep	19:32	9-Sep	21:40		2.13	2.13
2122	22	S	18-Sep	11:23	18-Sep	13:00		1.62	1.62
Total Actual Unscheduled and Scheduled Downtime and Total Actual Downtime							**5.93**	**310.81**	**316.74**
Type:	S = Scheduled		U = Unscheduled						

		Table 3-2 NANUs Forecasted to Affect Satellite Availability						
NANU #	PRN	Type	Start Date	Start Time	End Date	End Time	Total	Comments
2097	27	F	26-Jun	23:08	N/A	N/A	N/A	See NANU 2101
2095	26	F	1-Jul	14:00	2-Jul	2:00	12	See NANU 2099
2100	30	F	10-Jul	9:00	10-Jul	21:00	12	See NANU 2103
2102	9	F	18-Jul	16:00	19-Jul	4:00	12	See NANU 2106
2104	22	F	23-Jul	22:00	24-Jul	10:00	12	See NANU 2109
2108	17	F	28-Jul	4:40	1-Aug	4:40	96	See NANU 2110
2111	15	F	12-Aug	18:49	N/A	N/A	N/A	See NANU 2112
2113	24	F	30-Aug	7:45	30-Aug	19:45	12	See NANU 2116
2114	20	F	3-Sep	12:15	4-Sep	0:15	12	See NANU 2118
2115	6	F	6-Sep	6:00	6-Sep	18:00	12	See NANU 2119
2117	27	F	9-Sep	19:00	10-Sep	7:00	12	See NANU 2120
2121	22	F	18-Sep	11:00	18-Sep	23:00	12	See NANU 2122
2123	21	F	25-Sep	18:30	N/A	N/A	N/A	N/A
					Total Forecast Downtime		204	

	Table 3-3 NANUs Canceled				
NANU#	PRN	Type	Start Date	Start Time	Comments

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 July - 30 Sept, 2002**	**1 October, 1999- 30 June, 2002**
Total Forecast Downtime (hrs):	204.00	3476.25
Total Actual Downtime (hrs):	316.74	5143.35
Total Actual Scheduled Downtime (hrs):	310.81	2219.34
Total Actual Unscheduled Downtime (hrs):	5.93	2924.01
Total Satellite Observed MTTR (hrs):	26.40	23.27
Scheduled Satellite Observed MTTR (hrs):	28.26	12.75
Unscheduled Satellite Observed MTTR (hrs):	5.93	62.21
# Total Satellite Outages:	12	221
# Scheduled Satellite Outages:	11	174
# Unscheduled Satellite Outages:	1	47
Percent Operational -- Scheduled Downtime:	99.50	99.70
Percent Operational -- All Downtime:	99.96	99.30

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 July and 30 September 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	1.237	5.026	4.599	1.839	3.944	3.587	7823455
Columbus	1.198	5.160	4.468	1.799	4.253	3.337	7822733
Denver	1.194	6.000	5.359	1.817	5.128	4.505	6914997
Grand Forks	1.189	6.000	5.745	1.774	4.460	4.100	7770693
Green Bay	1.155	5.035	3.706	1.790	4.325	3.786	7748719
Greenwood	1.266	5.836	5.457	1.808	4.738	4.310	7812965
Prescott	1.388	5.998	4.940	2.168	5.764	5.494	7597385
Billings	1.168	4.709	4.093	1.770	4.014	3.713	7797989
Anchorage	1.166	5.749	5.160	1.795	4.777	4.358	7796601
Chicago	1.171	4.439	3.976	1.774	4.352	3.889	7801238
Kansas City	1.235	5.199	4.561	1.771	4.280	3.225	7803724
Salt Lake City	1.166	4.466	4.277	1.796	4.247	4.035	7800205
Miami	1.134	4.032	3.492	1.794	3.468	3.205	7796842
Atlanta	1.254	4.696	4.238	1.820	4.678	4.225	7807428

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
Worst-Case Point on Worst-Case Day = 100% (SPS Spec. ≥ 83.92%)						

Global Average on Worst-Case Day = 100% (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	7823455	0	100%
Columbus	7822733	0	100%
Denver	6914997	0	100%
Grand Forks	7770693	0	100%
Green Bay	7748719	0	100%
Greenwood	7812965	0	100%
Prescott	7597385	0	100%
Billings	7797989	0	100%
Anchorage	7796601	0	100%
Chicago	7801238	0	100%
Kansas City	7803724	0	100%
Salt Lake City	7800205	0	100%
Miami	7796842	0	100%
Atlanta	7807428	0	100%
Worst Single Point Average = 100% (SPS Spec. ≥ 99.16%)			

Global Average over Reporting Period = 100% (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	7823455	23.90
Columbus	7822733	24.60
Denver	6914997	24.80
Grand Forks	7770693	23.30
Green Bay	7748719	22.40
Greenwood	7812965	29.80
Prescott	7597385	24.20
Billings	7797989	19.70
Anchorage	7796601	19.30
Chicago	7801238	23.30
Kansas City	7803724	23.40
Salt Lake City	7800205	19.60
Miami	7796842	36.80

Atlanta	7807428	27.40

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 July through 30 September 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	4.558	8.292	13.501	19.354
Columbus	4.998	7.869	13.548	22.519
Denver	5.263	8.624	13.253	23.078
Grand Forks	4.584	7.004	14.765	16.603
Green Bay	4.618	7.442	12.861	18.477
Greenwood	5.323	9.860	12.087	27.657
Prescott	5.307	9.381	11.538	22.784
Billings	5.132	7.355	12.564	18.268
Anchorage	3.991	6.558	9.299	13.670
Chicago	4.830	7.743	13.661	19.520
Kansas City	5.176	8.046	13.130	22.297
Salt Lake City	5.340	8.269	13.184	18.684
Miami	5.748	12.535	15.926	34.721
Atlanta	5.279	9.731	13.388	26.173

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 July to 30 September 2002.

Figure 5-1 Combined Vertical Error Histogram

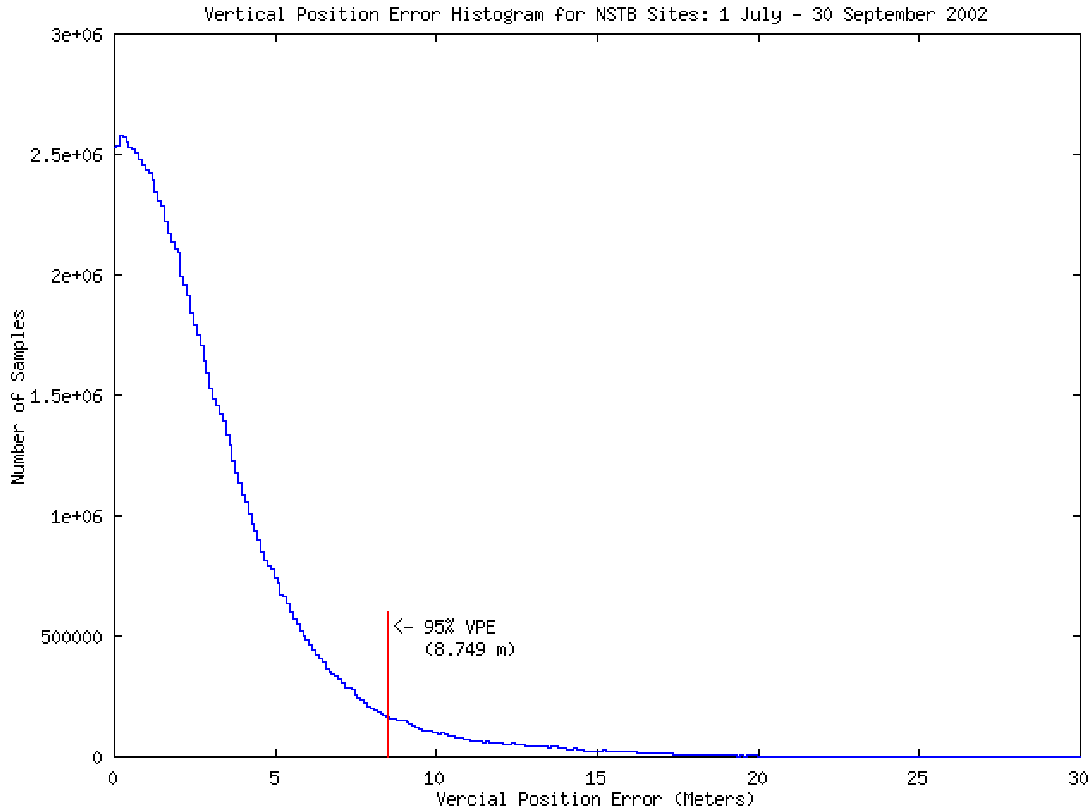
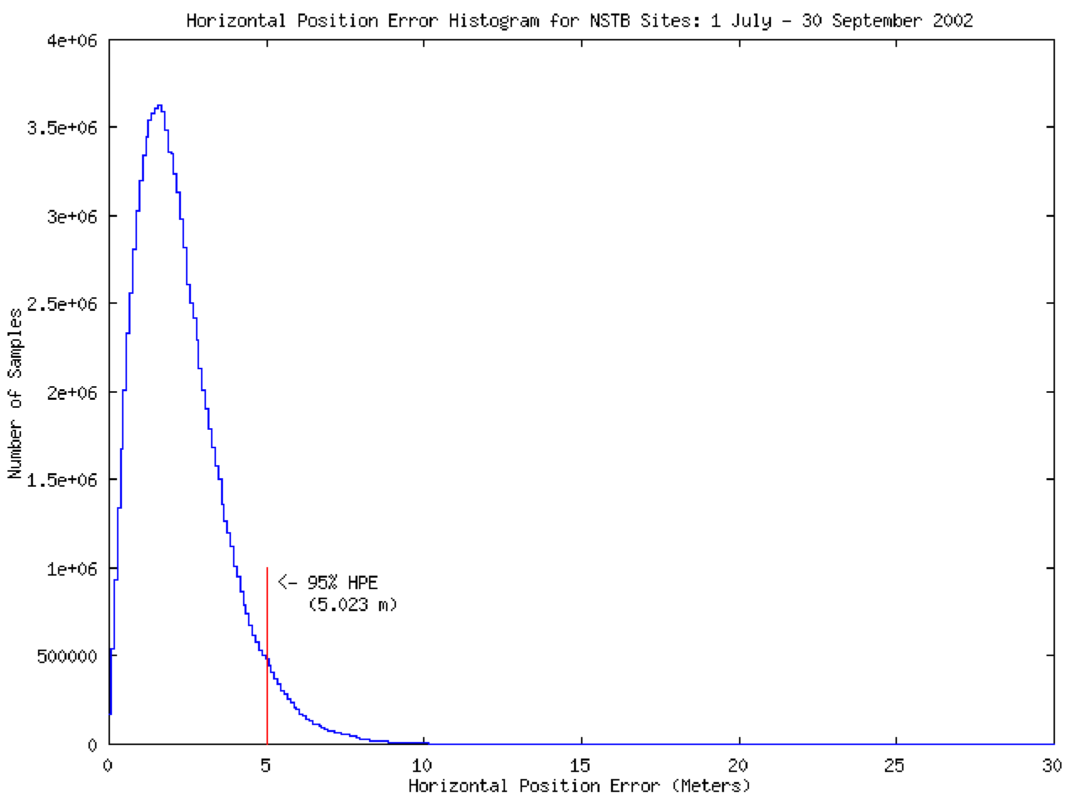


Figure 5-2 Combined Horizontal Error Histogram



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	1.438	3.338
Columbus	1.289	3.453
Denver	1.341	3.273
Grand Forks	1.255	3.115
Green Bay	1.300	3.048
Greenwood	1.459	3.576
Prescott	1.685	3.970
Billings	1.244	3.218
Anchorage	1.162	3.394
Chicago	1.194	2.870
Kansas City	1.273	3.033
Salt Lake City	1.385	3.212
Miami	1.198	3.568
Atlanta	1.299	3.434

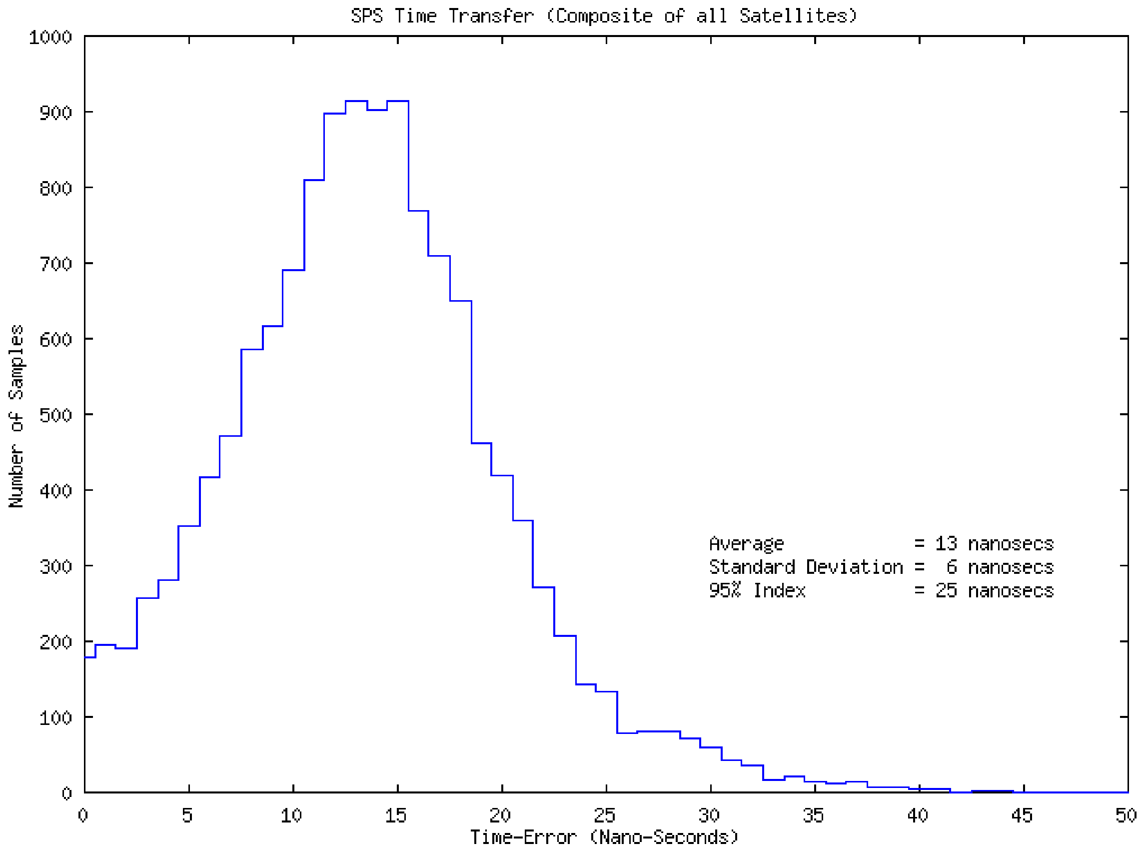
5.3 Relative Accuracy

To be included in future reports.

5.4 Time Transfer Accuracy

The GPS time error data between 1 July and 30 September 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 July and 30 September 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	-0.672	3.26	3.563	7.444	31.474	2211665
2	-0.675	4.329	4.276	8.788	20.352	2231837
3	-1.390	3.825	3.563	7.285	19.669	1753752
4	-0.322	2.180	2.156	4.210	11.260	2157666
5	-0.256	2.935	2.924	5.813	24.776	2500683
6	-0.955	3.192	3.046	6.324	23.317	2454134
7	0.100	2.425	2.423	4.704	11.605	2258388
8	0.156	2.715	2.711	5.281	18.587	2179431
9	-0.677	3.868	3.808	7.711	19.236	2201661
10	0.487	2.612	2.566	5.369	10.628	2064289
11	-0.368	2.414	2.386	4.744	21.781	2117393
13	-0.383	2.749	2.722	5.620	18.768	2427504
14	-0.864	4.313	4.226	9.184	19.993	2214001
15	-0.705	4.074	4.012	7.845	17.040	1677975
17	-1.044	3.646	3.493	7.379	18.281	1779909
18	-0.939	3.944	3.831	7.925	17.795	2122025
20	-0.326	3.324	3.308	6.787	31.490	2525681
21	-0.199	4.183	4.179	8.662	19.347	1861527
22	-1.104	4.575	4.439	9.518	24.883	2028145
23	-0.595	3.111	3.053	6.211	15.297	2259487
24	0.216	2.604	2.595	5.164	10.311	2242218
25	-0.913	4.742	4.653	9.975	23.149	2262354
26	-0.798	3.068	2.962	6.354	15.233	1776047
27	-0.757	2.754	2.648	5.569	21.500	1717720
28	-0.132	2.507	2.504	4.974	11.818	2019962
29	-0.303	3.001	2.985	5.958	18.034	1820315
30	-1.296	3.649	3.411	7.861	31.104	2437289
31	-0.068	3.063	3.062	6.107	23.710	1910847

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	-0.00001	0.00862	0.00862	0.00497	0.58481	2211665
2	-0.00021	0.01126	0.01125	0.00555	0.49204	2231837
3	-0.00025	0.01163	0.01163	0.00500	0.72611	1753752
4	-0.00002	0.00195	0.00195	0.00311	0.19371	2157666
5	-0.00014	0.00750	0.00750	0.00489	0.72112	2500683
6	0.00004	0.00807	0.00807	0.00468	0.65079	2454134
7	0.00010	0.00201	0.00201	0.00330	0.25293	2258388
8	-0.00019	0.00791	0.00791	0.00399	0.37522	2179431
9	-0.00019	0.00631	0.00631	0.00521	0.49787	2201661
10	0.00001	0.00385	0.00385	0.00374	0.34869	2064289
11	0.00015	0.00713	0.00713	0.00490	0.70614	2117393
13	-0.00007	0.00865	0.00865	0.00455	0.61655	2427504
14	-0.00011	0.00731	0.00731	0.00621	0.75353	2214001
15	0.00024	0.00635	0.00634	0.00565	0.53302	1677975
17	0.00019	0.00584	0.00584	0.00555	0.62687	1779909
18	0.00008	0.00592	0.00592	0.00546	0.62384	2122025
20	-0.00004	0.00773	0.00773	0.00518	0.77825	2525681
21	0.00012	0.00732	0.00731	0.00672	0.45292	1861527
22	-0.00029	0.01281	0.01281	0.00591	0.41054	2028145
23	-0.00005	0.00487	0.00487	0.00424	0.42323	2259487
24	0.00006	0.00339	0.00339	0.00335	0.34321	2242218
25	-0.00014	0.00740	0.00740	0.00624	0.70273	2262354
26	-0.00028	0.00506	0.00505	0.00420	0.46674	1776047
27	0.00002	0.00863	0.00863	0.00420	0.61939	1717720
28	-0.00002	0.00316	0.00316	0.00365	0.20532	2019962
29	-0.00020	0.00456	0.00456	0.00392	0.42731	1820315
30	-0.00009	0.00730	0.00730	0.00503	0.76524	2437289
31	-0.00019	0.00936	0.00936	0.00458	0.54148	1910847

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	0.00005	0.00005	100%	0.00583	2211665
2	0	0.00005	0.00005	100%	0.00502	2231837
3	0	0.00006	0.00006	100%	0.00723	1753752
4	0	0.00001	0.00001	100%	0.00193	2157666
5	0	0.00007	0.00007	100%	0.00723	2500683
6	0	0.00007	0.00007	100%	0.00652	2454134
7	0	0.00001	0.00001	100%	0.00253	2258388
8	0	0.00003	0.00003	100%	0.00389	2179431
9	0	0.00006	0.00006	100%	0.00499	2201661
10	0	0.00003	0.00003	100%	0.00348	2064289
11	0	0.00006	0.00006	100%	0.00691	2117393
13	0	0.00005	0.00005	100%	0.00615	2427504
14	0	0.00006	0.00006	100%	0.00578	2214001
15	0	0.00006	0.00006	100%	0.00531	1677975
17	0	0.00005	0.00005	100%	0.00634	1779909
18	0	0.00005	0.00005	100%	0.00627	2122025
20	0	0.00007	0.00007	100%	0.00778	2525681
21	0	0.00006	0.00006	100%	0.00455	1861527
22	0	0.00005	0.00005	100%	0.00637	2028145
23	0	0.00004	0.00004	100%	0.00423	2259487
24	0	0.00003	0.00003	100%	0.00343	2242218
25	0	0.00006	0.00006	100%	0.00639	2262354
26	0	0.00004	0.00004	100%	0.00467	1776047
27	0	0.00004	0.00004	100%	0.00621	1717720
28	0	0.00002	0.00002	100%	0.00207	2019962
29	0	0.00004	0.00004	100%	0.00430	1820315
30	0	0.00006	0.00006	100%	0.00767	2437289
31	0	0.00004	0.00004	100%	0.00543	1910847

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 20 with an error of 31.490 meters. Satellite 24 had the lowest maximum range error of 10.311 meters.

Figure 5-4 Distribution of Daily Max Range Errors

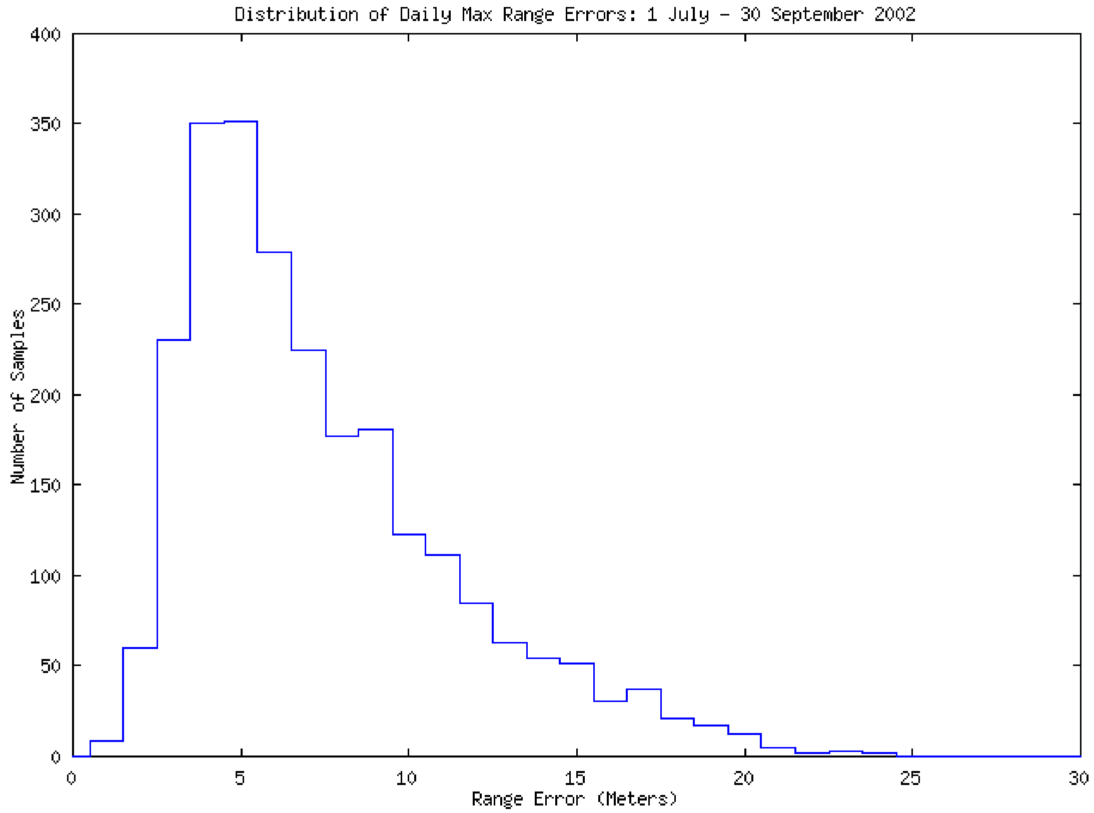


Figure 5-5: Distribution of Daily Max Range Rate Errors

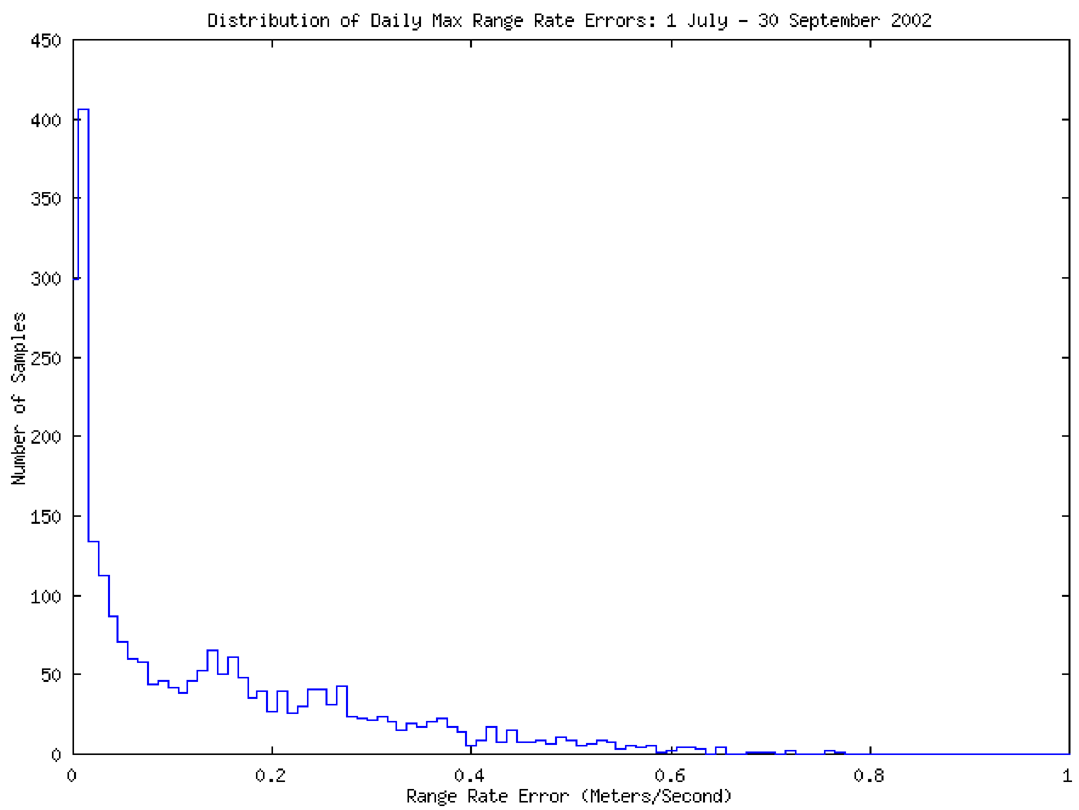


Figure 5-6: Distribution of Daily Max Acceleration Rate Errors

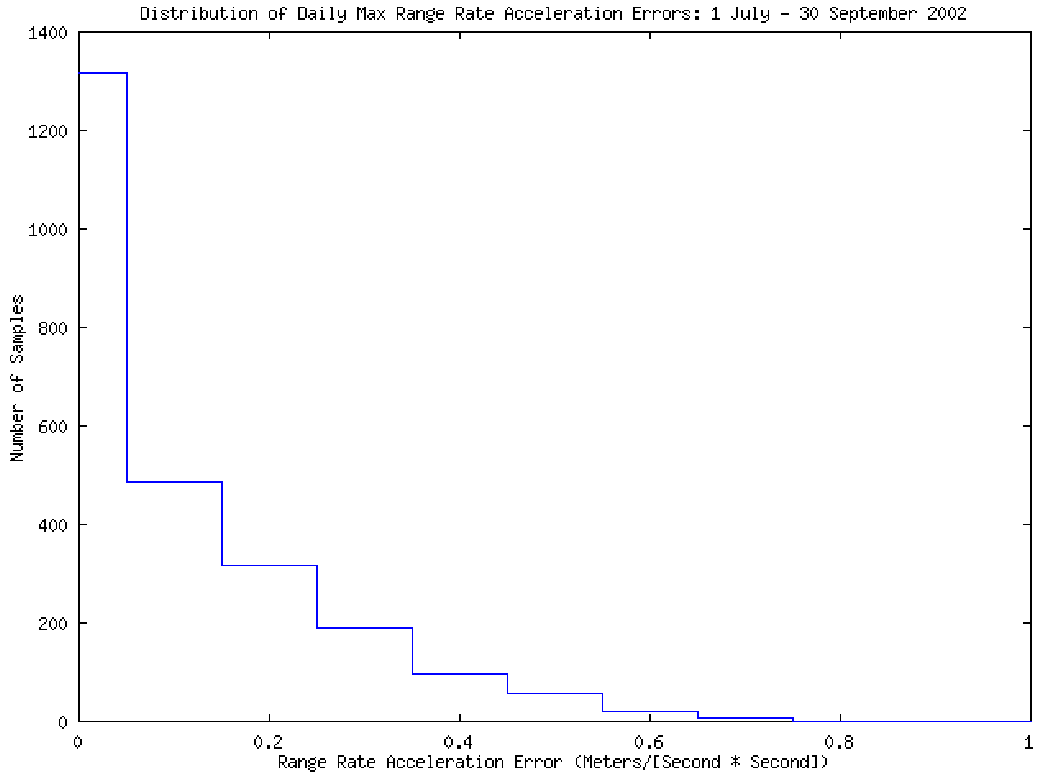


Figure 5-7: Range Error Histogram

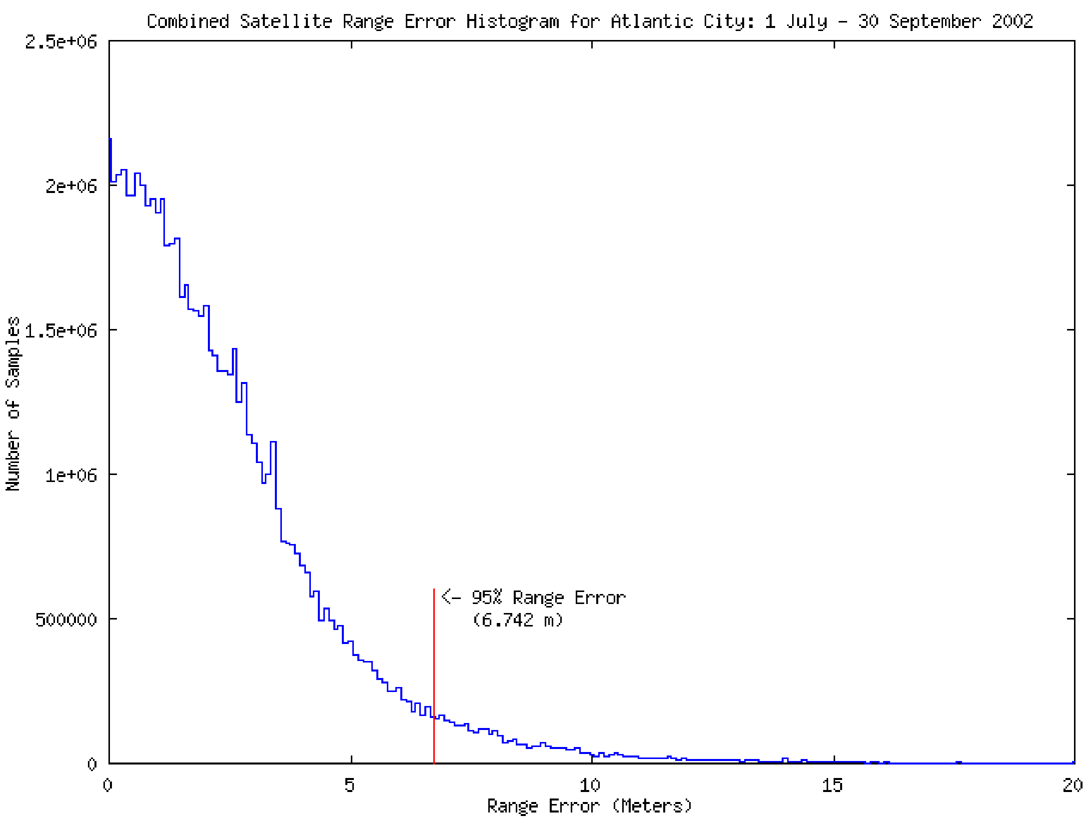


Figure 5-8: Maximum Range Error Per Satellite

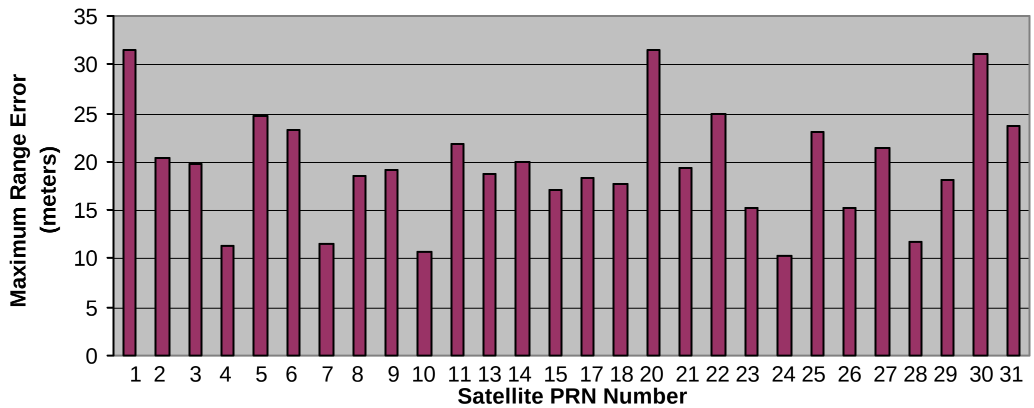


Figure 5-9: Maximum Range Rate Error Per Satellite

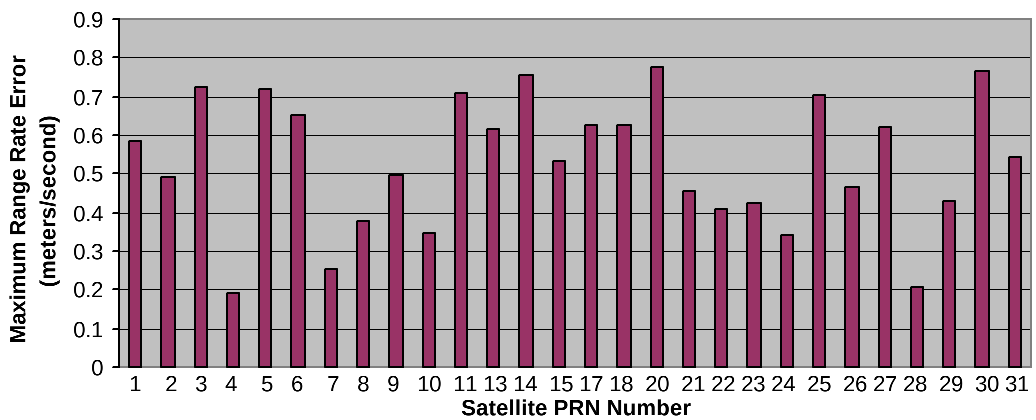
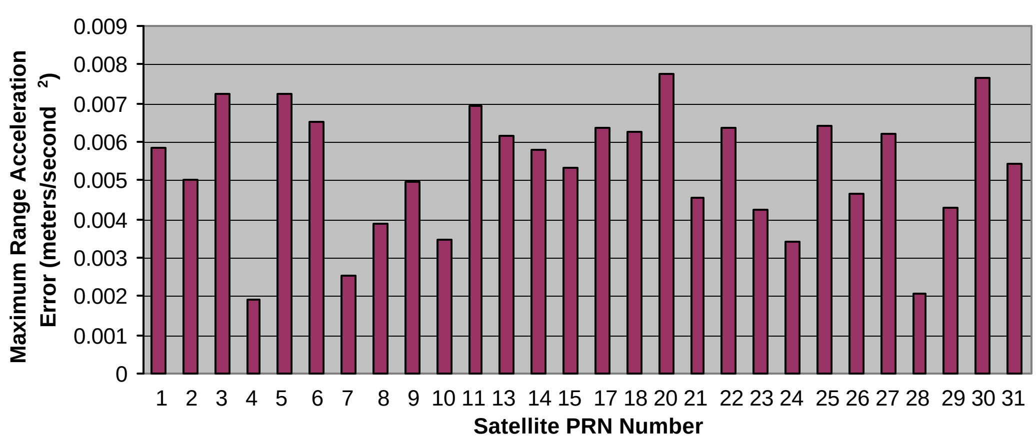


Figure 5-10: Maximum Range Acceleration Per Satellite



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 7-9 September 2002

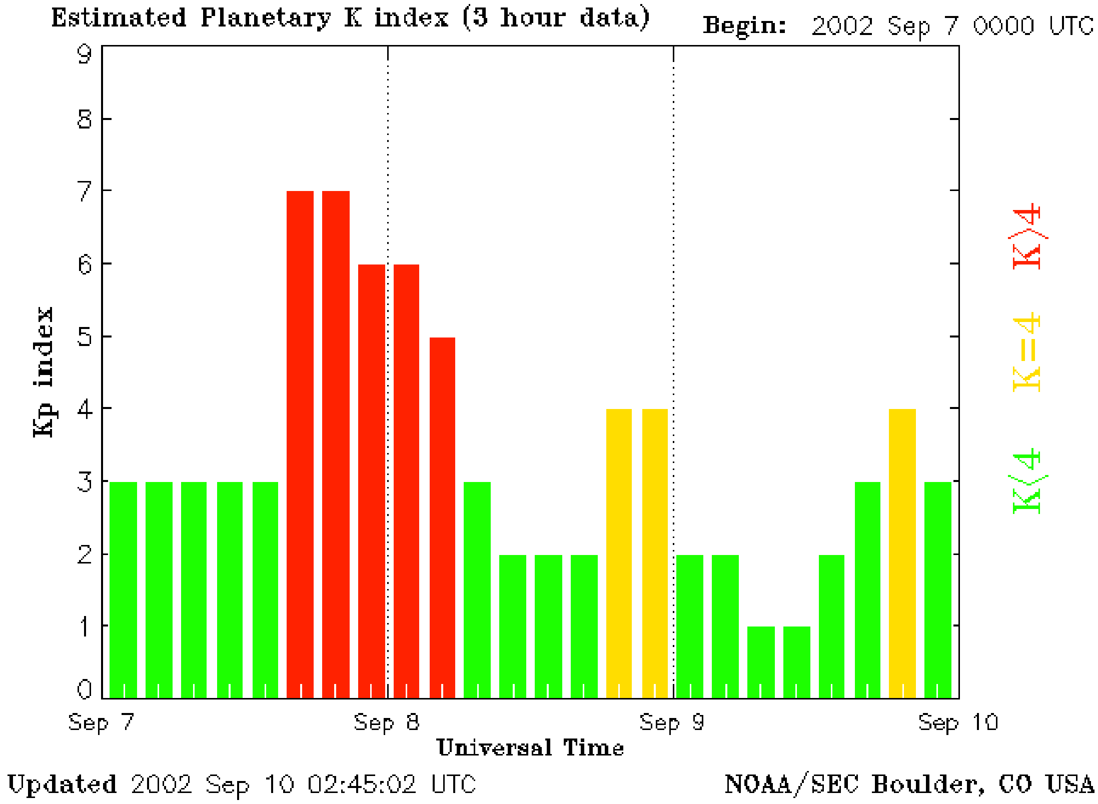


Figure 6-2 K-Index for 20-22 August 2002

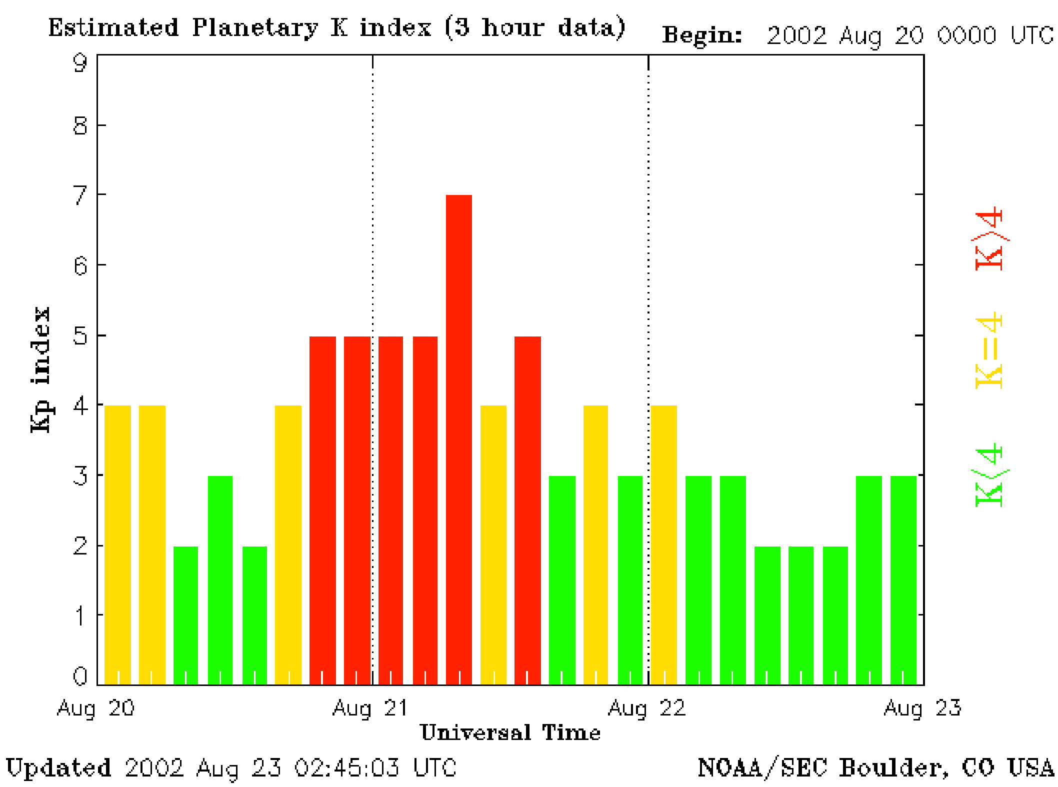
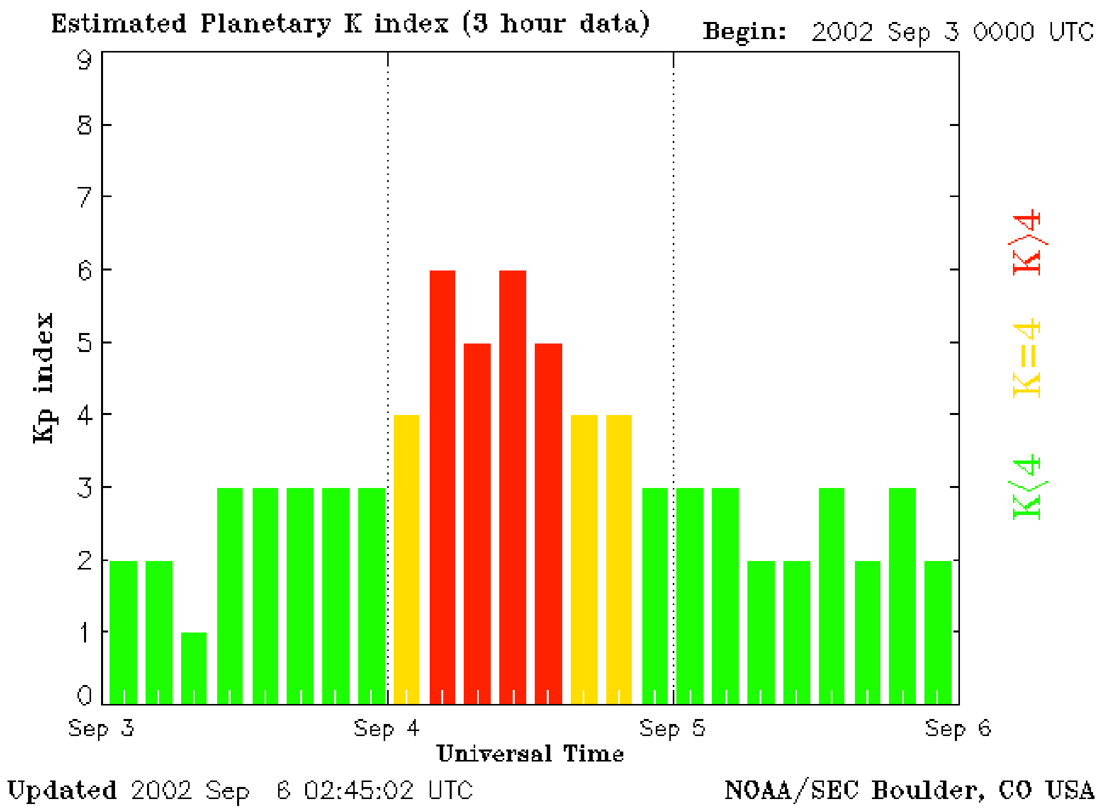


Figure 6-3 K-Index for 3 – 5 September 2002



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 7 September 2002

NSTB/WAAS Site	Min PDOP	Max PDOP	Mean PDOP	99.99% PDOP	99.99% VDOP
Atlantic City	1.238	3.319	1.795	3.318	2.856
Columbus	1.246	3.624	1.766	3.620	3.189
Denver	1.196	5.915	1.795	5.618	5.243
Grand Forks	1.261	3.900	1.766	3.894	3.229
Green Bay	1.160	4.750	1.750	4.743	4.352
Greenwood	1.277	4.109	1.770	4.105	3.757
Prescott	1.395	5.663	2.073	5.662	5.400
Billings	1.177	2.923	1.735	2.921	2.556
Anchorage	1.223	4.940	1.773	4.937	4.698
Chicago	1.271	3.082	1.721	3.076	2.843
Kansas City	1.240	2.798	1.735	2.795	2.255
Salt Lake City	1.169	2.990	1.759	2.976	2.570
Miami	1.138	3.240	1.744	3.240	2.957
Atlanta	1.256	4.109	1.789	4.107	3.773

Table 6-2 Horizontal & Vertical Accuracy Statistics for 7 September 2002

NSTB Site	95% Horizontal (Meters)	95% Vertical (Meters)	99.99% Horizontal (Meters)	99.99% Vertical (Meters)
Atlantic City	7.951	9.842	12.766	16.322
Columbus	9.261	10.556	13.851	17.984
Denver	8.933	11.088	13.300	18.253
Grand Forks	13.013	6.179	16.174	8.145
Green Bay	9.593	6.669	13.978	11.906
Greenwood	8.576	15.583	14.003	29.060
Prescott	8.417	10.422	11.051	14.144
Billings	10.339	8.284	14.117	12.645
Anchorage	3.039	6.094	8.223	19.173
Chicago	8.755	7.699	15.126	14.834
Kansas City	9.294	11.638	14.655	18.445
Salt Lake City	10.037	11.529	13.900	14.407
Miami	9.801	18.418	16.623	32.556
Atlanta	8.747	12.243	14.532	23.956

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	99.961%
• 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	98.542% Availability 99.9% PDOP was 3.98159
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	100%
• 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	100%
• Conditioned on coverage standard • Standard represents a worst-case 24 hour interval, averaged over the globe	≥ 95.87% global average on worst-case day	100%
• 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	100%
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	≤5.748m HE 95% ≤12.535m HE 99.99% ≤15.926m VE 95% ≤34.721m 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	≤1.685m HE 95% ≤3.970m 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	31.490m NTE Range Error 0.77825m/s NTE Rate Error 7.780mm/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^2 100% 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
#

Date	Middle Latitude - Fredericksburg - A	K-indices	High Latitude ---- College ---- A	K-indices	Estimated --- Planetary --- A	K-indices
2002 07 01	13	2 3 2 3 4 3 3 1	25	3 3 3 5 5 5 2 2	15	3 4 2 4 3 4 3 2
2002 07 02	4	2 1 1 0 2 0 2 2	4	3 2 2 1 0 0 1 0	9	3 3 2 1 2 2 3 3
2002 07 03	3	1 1 1 1 1 0 2 1	-1	2 1 1 3 2 2 1-1	7	3 2 2 2 2 2 3 2
2002 07 04	4	1 0 1 0 1 1 2 3	-1	-1-1-1-1-1-1-1-1	7	3 2 1 1 2 2 2 3
2002 07 05	9	2 1 2 3 1 2 3 3	-1	-1-1-1-1-1-1-1-1	13	3 2 3 3 3 3 4 3
2002 07 06	18	4 3 3 4 3 3 3 3	-1	-1-1-1-1-1-1-1-1	23	4 4 4 4 3 4 4 3
2002 07 07	10	2 1 2 2 3 3 3 2	-1	-1-1-1-1-1-1-1-1	11	3 3 3 2 3 3 3 2
2002 07 08	6	2 1 0 2 2 1 2 4	8	2 2 0 3 3 2 1 2	10	3 2 1 3 3 2 2 3
2002 07 09	9	2 2 2 2 2 3 2 3	20	2 3 3 5 3 5 2 2	16	4 3 3 3 2 4 3 3
2002 07 10	7	1 2 3 2 2 1 2 2	18	5 2 3 5 3 1 1 2	11	3 3 3 3 2 2 3 3
2002 07 11	8	2 1 2 2 2 2 2 3	10	2 1 1 4 4 1 1 2	9	2 2 2 2 2 2 3 3
2002 07 12	12	2 3 3 3 3 3 2 2	31	2 2 4 5 5 6 3 3	20	3 3 3 5 5 4 3 2
2002 07 13	5	2 1 1 1 2 2 1 1	15	3 2 2 2 3 3 1 5	8	3 3 2 2 2 2 3 2
2002 07 14	1	0 0 0 0 1 1 0 0	0	0 0 0 0 0 1 1 0	6	2 2 1 1 2 2 3 1
2002 07 15	5	0 0 1 1 1 2 3 2	2	0 0 1 0 1 0 1 1	8	2 2 1 1 2 3 4 2
2002 07 16	9	2 2 1 2 2 2 3 3	10	2 3 1 3 3 2 3 2	11	2 3 2 2 2 2 4 4
2002 07 17	15	3 3 3 2 2 4 3 3	20	2 3 5 4 3 4 3 2	18	3 3 4 3 3 4 4 3
2002 07 18	4	3 1 1 2 1 0 0 0	4	2 2 1 3 1 0 0 0	8	3 3 2 3 2 2 2 1
2002 07 19	9	1 0 0 3 2 3 2 4	8	1 1 0 3 3 2 2 3	12	2 2 1 3 2 3 2 4
2002 07 20	13	4 3 2 2 1 2 2 4	23	4 5 4 4 3 2 3 3	18	4 4 3 2 2 3 3 4
2002 07 21	17	5 4 3 1 3 2 2 3	33	4 4 5 2 4 6 5 1	19	4 4 4 2 3 3 3 1
2002 07 22	12	2 2 4 3 2 2 3 3	35	2 4 6 4 5 4 3 5	20	3 3 4 5 4 3 3 3
2002 07 23	11	3 1 3 2 2 2 3 4	17	3 3 4 4 3 3 2 3	18	4 3 3 3 2 3 4 4
2002 07 24	8	2 3 2 2 2 2 2 1	8	2 3 2 3 2 1 2 1	12	3 3 3 2 3 3 3 2
2002 07 25	9	1 2 2 2 3 2 3 2	9	2 2 2 3 3 2 2 2	13	3 3 2 3 3 3 4 3
2002 07 26	10	3 2 2 2 2 2 3 3	23	4 3 3 6 2 3 3 2	17	4 3 3 4 3 3 4 3
2002 07 27	11	3 2 2 3 3 2 3 2	20	3 3 3 5 4 4 2 2	19	4 3 3 4 4 3 4 3
2002 07 28	9	3 3 1 2 2 2 2 2	14	4 4 2 3 3 2 2 1	12	4 3 2 3 3 3 3 2
2002 07 29	9	1 2 2 1 4 3 2 2	9	2 3 2 2 4 2 1 1	11	2 3 2 2 4 3 3 2
2002 07 30	5	1 1 1 1 1 2 2 2	4	1 2 0 0 0 2 2 2	8	2 2 1 2 2 3 3 3
2002 07 31	6	1 1 1 2 3 2 1 1	18	2 1 1 0 5 6 1 1	9	3 2 1 2 3 3 3 2
2002 08 01	27	0 3 3 3 4 3 3 5	32	2 3 4 4 6 6 2 3	26	2 4 4 4 5 4 3 5
2002 08 02	28	5 5 4 1 4 2 3 5	33	6 5 3 2 4 4 3 5	37	6 6 4 2 3 4 4 5
2002 08 03	11	4 2 3 2 2 1 3 2	20	4 3 5 4 3 3 2 2	20	5 4 4 3 3 3 4 3
2002 08 04	12	4 4 3 2 2 1 2 1	29	6 4 5 4 2 1 4 3	16	4 5 4 3 2 2 3 1
2002 08 05	4	1 2 1 0 1 1 1 2	4	1 2 1 1 0 1 1 2	8	2 2 2 1 2 2 3 3
2002 08 06	4	2 2 1 1 2 1 0 1	4	2 2 1 2 2 0 1 0	9	3 3 1 2 2 3 3 1

2002 08 07	4	2 2 1 1 1 1 1 1	4	2 1 2 1 1 1 1 1	8	2 3 2 2 2 2 3 2
2002 08 08	5	1 1 0 1 2 1 2 3	5	1 2 0 0 3 1 2 2	10	2 3 1 2 3 3 3 3
2002 08 09	9	1 1 2 2 3 2 3 3	20	1 1 2 2 6 4 3 3	15	2 2 2 2 4 3 4 4
2002 08 10	13	4 4 1 2 3 2 2 2	24	5 5 3 3 5 2 2 2	16	4 5 2 2 3 3 3 3
2002 08 11	13	2 1 2 3 3 3 4 3	31	1 2 2 6 6 5 3 2	15	2 3 2 4 4 3 3 3
2002 08 12	9	2 3 2 2 3 2 2 2	24	3 4 4 5 5 3 2 1	15	3 3 3 4 3 3 3 3
2002 08 13	9	4 3 2 2 1 1 1 2	12	3 3 3 4 2 1 2 1	13	4 4 3 3 3 2 3 2
2002 08 14	10	1 2 3 2 3 2 2 3	26	2 2 3 5 6 4 3 2	15	3 3 3 3 4 3 3 3
2002 08 15	18	2 2 3 4 2 2 5 4	32	4 3 3 6 5 4 4 3	19	3 3 3 4 3 4 5 5
2002 08 16	8	3 2 3 2 2 2 1 1	37	3 4 7 5 5 3 1 1	17	4 3 5 3 3 3 3 2
2002 08 17	8	1 3 3 2 2 1 2 1	19	1 3 6 4 3 2 2 1	13	2 3 4 3 2 2 3 3
2002 08 18	15	3 3 1 1 1 1 4 5	18	4 4 2 2 4 1 4 3	18	4 3 2 3 3 2 4 5
2002 08 19	20	3 3 5 3 3 2 3 4	50	4 5 7 5 5 4 3 5	27	4 4 5 4 4 3 4 4
2002 08 20	16	4 4 1 2 1 2 4 4	28	4 4 5 5 2 3 4 4	23	4 4 2 3 2 4 5 5
2002 08 21	19	4 3 5 2 3 2 3 3	50	3 6 7 6 5 3 2 3	41	5 5 7 4 5 3 4 3
2002 08 22	8	3 2 3 1 1 2 2 1	8	4 3 2 2 0 1 1 1	11	4 3 3 2 2 2 3 3
2002 08 23	6	1 1 1 2 2 1 3 2	7	1 2 3 2 1 1 2 2	11	2 3 2 2 3 3 3 3
2002 08 24	3	2 0 0 1 1 1 1 1	4	2 1 2 2 2 0 0 0	11	3 2 2 2 3 3 3 3
2002 08 25	4	0 1 2 1 1 1 1 2	7	4 1 2 2 1 1 0 1	9	2 2 2 2 2 3 3 3
2002 08 26	11	2 2 2 3 3 3 3 2	30	2 3 2 3 3 7 3 4	18	3 3 2 3 4 5 3 3
2002 08 27	14	2 4 2 3 2 4 3 2	15	3 4 3 1 4 3 2 2	15	3 4 3 3 3 3 3 3
2002 08 28	7	2 1 1 1 2 2 2 3	8	3 2 2 2 2 1 2 2	10	3 3 2 2 2 3 3 3
2002 08 29	6	0 0 1 1 3 3 2 2	12	2 1 1 2 4 5 1 1	10	3 2 1 2 3 3 3 2
2002 08 30	7	1 2 3 1 3 1 2 1	17	1 4 4 3 4 4 2 1	10	1 3 3 2 3 2 3 2
2002 08 31	7	1 1 3 3 2 1 1 2	21	2 1 2 6 5 3 1 2	13	2 2 3 3 4 2 3 3
2002 09 01	13	4 2 3 2 2 3 2 3	11	3 3 3 3 2 1 2 2	13	4 3 3 2 2 3 3 4
2002 09 02	5	2 2 1 2 2 1 1 1	23	3 4 2 6 5 1 0 0	14	3 3 2 4 3 3 3 2
2002 09 03	5	0 1 1 2 1 1 3 2	3	1 1 0 1 1 0 2 2	10	2 2 1 3 3 3 3 3
2002 09 04	23	3 4 4 5 4 3 3 2	56	4 6 5 7 6 5 4 2	42	4 6 5 6 5 4 4 3
2002 09 05	-1	2 3 1 2-1-1 2 2	21	3 2 3 5 4 3 1 5	10	3 3 2 2 3 2 3 2
2002 09 06	5	1 2 2 2 2 1 1 1	20	2 2 5 4 3 5 2 1	10	2 3 3 3 3 2 3 2
2002 09 07	16	2 3 2 2 2 4 4 4	66	1 3 3 3 5 8 7 5	45	3 3 3 3 3 7 7 6
2002 09 08	19	6 4 2 1 1 1 3 3	19	5 5 3 0 1 2 3 3	26	6 5 3 2 2 2 4 4
2002 09 09	7	1 1 0 1 2 2 3 3	13	2 1 0 1 2 2 5 4	10	2 2 1 1 2 3 4 3
2002 09 10	14	3 2 1 3 4 3 3 3	43	3 2 3 5 7 6 4 3	24	3 2 3 4 5 4 4 4
2002 09 11	16	1 2 3 5 2 3 3 3	43	2 2 6 6 4 6 5 3	28	2 3 5 6 4 4 4 4
2002 09 12	9	2 3 2 2 3 2 2 1	34	3 3 6 5 6 3 3 1	17	4 3 4 3 4 3 3 2
2002 09 13	9	3 3 3 2 2 1 2 1	21	2 4 4 6 3 1 2 1	16	3 3 4 4 3 2 3 2
2002 09 14	7	3 2 2 2 2 1 1 1	14	2 2 4 5 3 1 1 0	11	3 3 2 4 3 2 3 2
2002 09 15	5	1 1 2 1 2 1 2 1	9	1 1 3 3 3 2 2 1	8	2 2 3 3 2 2 3 2
2002 09 16	5	1 0 2 2 2 2 1 1	7	1 0 2 3 3 2 2 0	8	2 2 2 2 3 2 3 1
2002 09 17	11	2 3 3 3 2 2 2 3	20	1 2 4 5 5 3 2 2	13	2 3 3 3 4 3 3 3
2002 09 18	13	3 2 2 3 4 3 2 2	17	3 3 2 4 5 3 2 1	14	4 3 2 3 4 3 3 3
2002 09 19	11	2 1 2 3 3 4 1 2	22	2 2 2 3 5 6 1 2	13	3 2 1 2 4 4 3 3
2002 09 20	3	2 2 1 0 0 0 0 1	2	1 2 1 1 0 1 0 0	6	3 2 1 1 2 2 3 2
2002 09 21	5	1 1 1 2 2 2 1 1	6	1 0 1 3 3 2 0 1	9	2 2 2 3 3 3 2 2
2002 09 22	4	1 0 2 1 2 2 1 1	6	1 1 1 1 3 3 1 1	9	2 2 3 2 3 3 3 2
2002 09 23	0	1 0 0 0 0 0 0 0	1	1 0 0 0 0 1 0 0	5	2 2 1 2 2 2 2 1
2002 09 24	3	0 0 0 1 2 0 2 1	2	0 0 0 2 2 0 1 0	6	2 2 1 2 2 2 3 2
2002 09 25	1	0 0 0 0 0 0 1 1	2	0 0 0 1 1 1 1 1	6	2 2 1 1 2 2 3 2
2002 09 26	3	1 1 1 1 0 1 1 2	3	1 0 0 2 2 0 1 2	8	2 2 1 2 2 3 3 3
2002 09 27	4	2 1 0 1 1 1 1 2	4	2 1 0 3 1 0 1 1	8	3 2 1 2 2 2 3 2
2002 09 28	5	2 2 1 1 0 1 2 2	1	1 0 0 0 0 0 0 1	8	1 3 1 2 2 2 3 3
2002 09 29	3	0 1 1 1 2 1 1 1	0	0 1 0 0 0 1 0 0	6	2 2 1 1 2 3 3 1
2002 09 30	21	1 3 3 4 4 3 3 5	33	1 3 4 4 6 4 2 6	26	3 3 4 4 6 4 3 4

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.