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

Submitted To

Federal Aviation Administration
GPS Product Team
AND 730
1284 Maryland Avenue SW
Washington, DC 20024

Report #38
July 31, 2002
Reporting Period: 1 April – 30 June 2002

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 #38, includes data collected from 1 April through 30 June 2002. The next quarterly report will be issued 31 October 2002.

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 99.583% or better.

Availability was verified by reviewing the “Notice: Advisory to Navstar Users” (NANU) reports issued between 1 April and 31 June 2002 and by calculating the satellite availability from the data obtained from the fourteen sites. A total of twenty-one outages were reported in the NANU’s. Seventeen of the outages were scheduled and four were unscheduled. The quarterly availabilities for Prescott was 99.9991% and for Anchorage was 99.998%; while 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 23.066 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 0.93353 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 9.340 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 April and 31 June 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

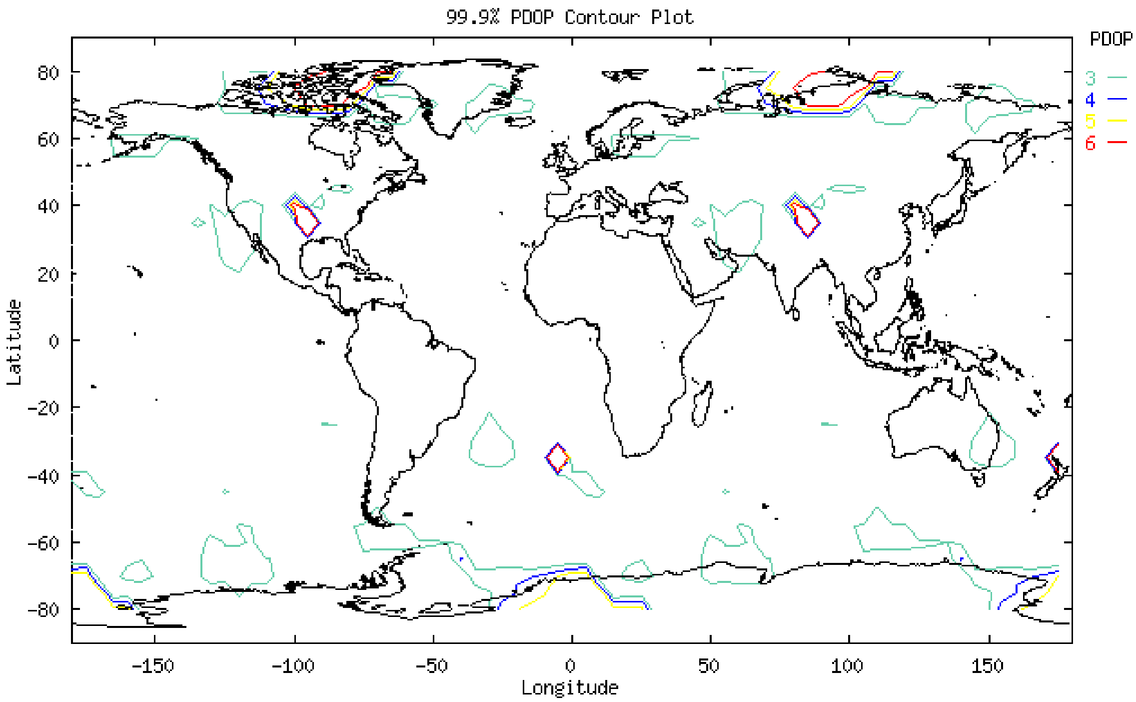
Almanacs for GPS weeks 97-109 used for this coverage portion of the report were obtained from the Coast Guard web site (www.navcen.uscg.mil). Using these almanacs, an SPS coverage area program developed by ACT-360 was used to calculate the PDOP at every 5^{o} point between longitudes of 180W to 180E 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 3.19503 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%)
136	3.172	99.998	99.583
137	3.190	99.998	99.583
138	3.204	99.998	99.375
139	3.678	99.994	99.236
140	3.187	99.997	99.236
141	3.180	99.997	99.236
142	3.167	99.997	99.375
143	3.168	99.997	99.375
144	3.212	99.997	99.375
145	3.239	99.998	99.514
146	3.353	99.999	99.583
147	3.722	99.997	99.306
148	3.311	99.999	99.514

Figure 2-1 SPS Coverage (24-Hour Period: 22 April 2002)



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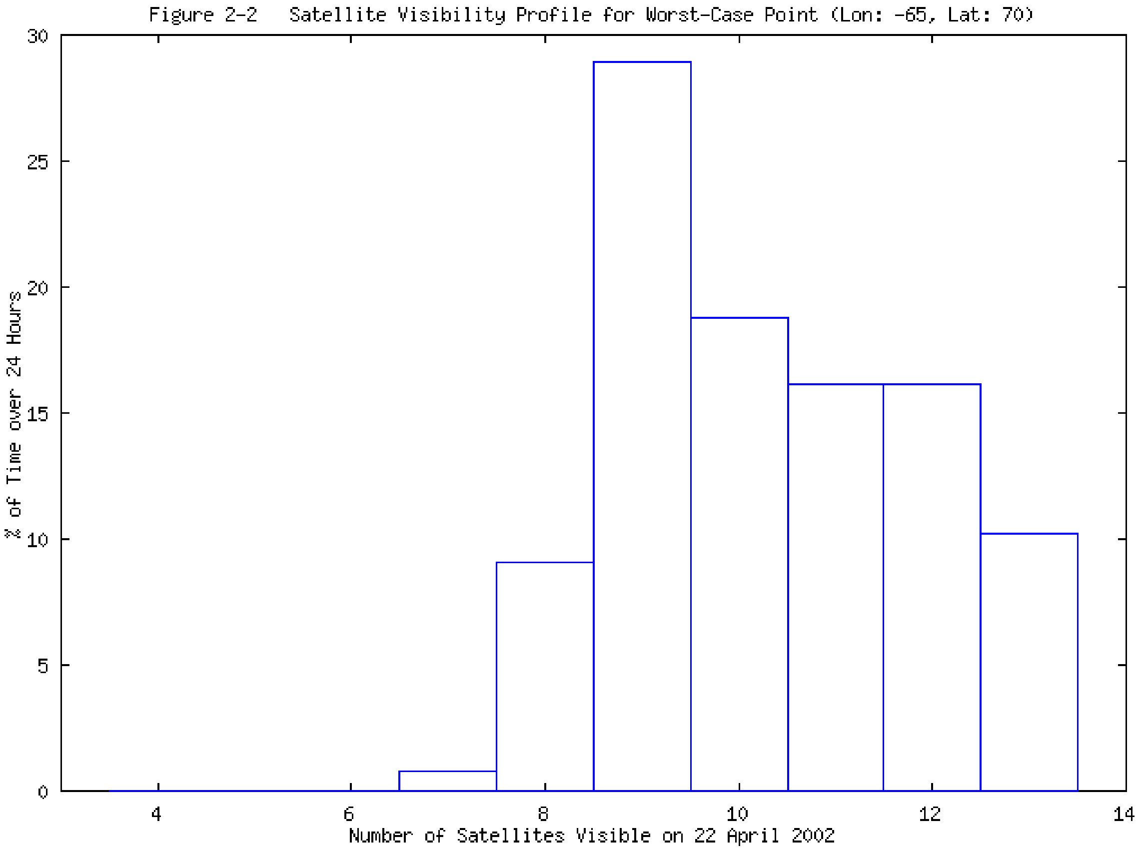


Figure 2-2 Satellite Visibility Profile for Worst-Case Point (Lon: -65, Lat: 70)
% of Time over 24 Hours
Number of Satellites Visible on 22 April 2002
0
5
10
15
20
25
30
4
6
8
10
12
14

***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 April through 31 June 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
2049	2	S	4-Apr	6:15	4-Apr	7:57		1.70	1.70
2051	30	S	5-Apr	16:06	6-Apr	1:45		9.65	9.65
2052	15	U	8-Apr	3:13	N/A	N/A			
2053	15	U	8-Apr	3:13	8-Apr	7:47	4.57		4.57
2054	17	S	8-Apr	17:50	9-Apr	3:20		9.50	9.50
2056	2	S	10-Apr	7:59	10-Apr	16:32		8.55	8.55
2061	31	S	15-Apr	14:31	23-Apr	20:18		197.78	197.78
2062	18	S	23-Apr	21:59	24-Apr	1:28		3.48	3.48
2063	31	U	25-Apr	8:03	N/A	N/A			
2065	31	U	25-Apr	8:03	26-Apr	14:05	30.03		30.03
2067	14	S	30-Apr	20:38	1-May	3:33		6.92	6.92
2069	10	S	6-May	19:00	7-May	6:25		11.42	11.42
2071	18	S	17-May	18:53	17-May	21:52		2.98	2.98
2079	21	S	31-May	22:02	1-Jun	7:56		9.90	9.90
2082	23	S	5-Jun	16:16	7-Jun	15:25		47.15	47.15
2083	29	S	7-Jun	16:17	7-Jun	22:31		6.23	6.23
2084	27	S	9-Jun	0:41	9-Jun	6:49		6.13	6.13
2085	2	U	10-Jun	11:33	N/A	N/A			
2086	2	U	10-Jun	11:33	10-Jun	12:27	0.90		0.90
2089	27	S	10-Jun	15:16	20-Jun	14:02		238.77	238.77
2092	13	S	21-Jun	3:15	21-Jun	14:14		10.98	10.98
2096	31	S	26-Jun	5:00	26-Jun	12:50		7.83	7.83
2097	27	U	26-Jun	23:08	N/A	N/A			
2098	29	S	27-Jun	17:48	28-Jun	4:36		10.80	10.80
2101	27	U	26-Jun	23:08	1-Jul	0:00	96.87		96.87
Total Actual Unscheduled and Scheduled Downtime and Total Actual Downtime							**132.37**	**589.77**	**722.14**
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
2044	2	F	4-Apr	6:00	4-Apr	18:00	12	See NANU 2049
2045	30	F	5-Apr	15:45	6-Apr	3:45	12	See NANU 2051
2048	2	F	10-Apr	7:30	11-Apr	7:30	24	See NANU 2056
2050	17	F	8-Apr	17:30	11-Apr	17:30	72	See NANU 2054
2055	31	F	15-Apr	14:15	25-Apr	14:15	240	See NANU 2061
2057	18	F	23-Apr	20:15	24-Apr	8:15	12	See NANU 2062
2058	29	F	26-Apr	11:50	26-Apr	23:50	12	See NANU 2064
2059	14	F	30-Apr	20:30	1-May	8:30	12	See NANU 2067
2060	27	F	2-May	5:45	2-May	17:45	12	See NANU 2068
2066	10	F	6-May	18:45	7-May	6:45	12	See NANu 2069
2070	18	F	17-May	18:00	18-May	6:00	12	See NANU 2071
2072	23	F	3-Jun	16:00	5-Jun	16:00	48	See NANU 2075
2073	21	F	31-May	21:45	1-Jun	9:45	12	See NANU 2079
2074	27	F	7-Jun	0:30	7-Jun	12:30	12	See NANU 2076
2075	23	F	5-Jun	16:00	7-Jun	16:00	48	See NANU 2082
2077	29	F	7-Jun	16:00	8-Jun	4:00	12	See NANU 2083
2080	27	F	9-Jun	0:30	9-Jun	12:30	12	See NANU 2084
2081	27	F	10-Jun	14:30	20-Jun	14:30	240	See NANU 2089
2087	13	F	21-Jun	1:30	21-Jun	13:30	12	See NANU 2092
2088	26	F	24-Jun	17:45	25-Jun	5:45	12	See NANU 2094
2090	31	F	26-Jun	4:45	26-Jun	16:45	12	See NANU 2096
2091	13	F	21-Jun	13:30	N/A	N/A		See NANU 2087
2093	29	F	27-Jun	17:30	28-Jun	17:30	24	See NANU 2098
						Total Forecast Downtime	864	

	Table 3-3 NANUs Canceled				
NANU#	PRN	Type	Start Date	Start Time	Comments
2064	29	C	26-Apr	11:50	See NANU 2058
2068	27	C	2-May	5:45	See NANU 2060
2076	27	C	7-Jun	0:30	See NANU 2074
2094	26	C	24-Jun	17:45	See NANU 2088

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 April - 30 June, 2002**	**1 October, 1999- 30 June, 2002**
Total Forecast Downtime (hrs):	864.00	3272.25
Total Actual Downtime (hrs):	722.14	4826.61
Total Actual Scheduled Downtime (hrs):	589.77	1908.53
Total Actual Unscheduled Downtime (hrs):	132.37	2918.08
Total Satellite Observed MTTR (hrs):	34.39	23.09
Scheduled Satellite Observed MTTR (hrs):	34.69	11.71
Unscheduled Satellite Observed MTTR (hrs):	33.09	63.44
# Total Satellite Outages:	21	209
# Scheduled Satellite Outages:	17	163
# Unscheduled Satellite Outages:	4	46
Percent Operational -- Scheduled Downtime:	99.04	99.72
Percent Operational -- All Downtime:	99.89	99.28

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 April and 31 June 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	1.204	6.000	2.447	1.853	5.812	5.298	7728199
Columbus	1.191	6.000	5.172	1.820	5.910	5.298	7655045
Denver	1.196	6.000	5.232	1.830	5.923	5.371	6507416
Grand Forks	1.170	6.000	1.577	1.802	5.858	5.029	7355685
Green Bay	1.147	6.000	5.258	1.809	5.898	5.280	7189410
Greenwood	1.218	6.000	5.679	1.843	5.825	5.193	7733336
Prescott	1.415	7.088	5.060	2.196	5.997	5.409	7682253
Billings	1.106	6.000	5.485	1.785	5.902	5.208	7039577
Anchorage	1.188	6.689	6.019	1.824	5.893	5.386	7217745
Chicago	1.165	6.000	5.223	1.801	5.897	5.309	7055098
Kansas City	1.245	6.000	5.836	1.788	5.851	5.332	7176763
Salt Lake City	1.166	6.000	5.630	1.817	5.918	5.359	7200343
Miami	1.135	6.000	4.611	1.809	5.882	4.949	7063927
Atlanta	1.234	6.000	5.675	1.854	5.891	5.234	7053627

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 nine sites used. Although future reports will have all WAAS 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	1164_3	7.088	702		85152	99.200
Anchorage	1164_3	6.689	164		86098	99.800
Worst-Case Point on Worst-Case Day = 99.200% (SPS Spec. ≥ 83.92%)						

Global Average on Worst-Case Day = 99.929% (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	7728199	0	100
Columbus	7655045	0	100
Denver	6507416	0	100
Grand Forks	7355685	0	100
Green Bay	7189410	0	100
Greenwood	7733336	0	100
Prescott	7682253	702	99.991
Billings	7039577	0	100
Anchorage	7217745	164	99.998
Chicago	7055098	0	100
Kansas City	7176763	0	100
Salt Lake City	7200343	0	100
Miami	7063927	0	100
Atlanta	7053627	0	100
Worst Single Point Average = 99.991% (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	7728199	18.20
Columbus	7655045	17.80
Denver	6507416	20.70
Grand Forks	7355685	17.80
Green Bay	7189410	24.70
Greenwood	7733336	18.20
Prescott	7682253	20.00
Billings	7039577	18.60
Anchorage	7217745	13.40
Chicago	7055098	19.50
Kansas City	7176763	17.10
Salt Lake City	7200343	19.80
Miami	7063927	14.80
Atlanta	7053627	18.60

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 April through 31 June 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	6.107	7.903	13.789	17.736
Columbus	6.370	7.426	12.485	17.880
Denver	6.427	8.052	16.736	20.946
Grand Forks	5.784	6.936	11.444	13.526
Green Bay	5.791	6.882	14.405	15.028
Greenwood	6.885	8.395	16.828	17.967
Prescott	6.947	8.870	15.865	20.888
Billings	6.347	7.198	13.014	15.741
Anchorage	4.946	7.150	10.275	16.817
Chicago	6.331	7.171	12.820	15.720
Kansas City	6.560	7.463	14.226	17.767
Salt Lake City	6.797	7.897	15.845	21.043
Miami	7.238	9.573	14.215	21.749
Atlanta	6.915	8.433	16.825	19.955

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 April to 31 June 2002.

Figure 5-1 Combined Vertical Error Histogram

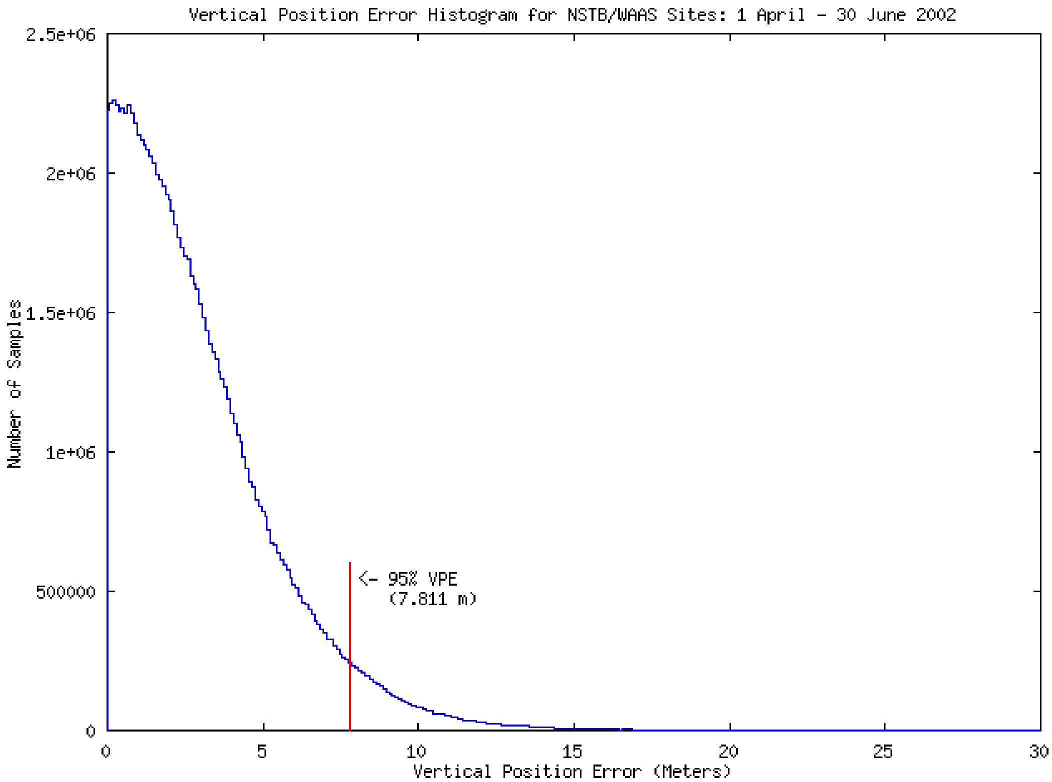
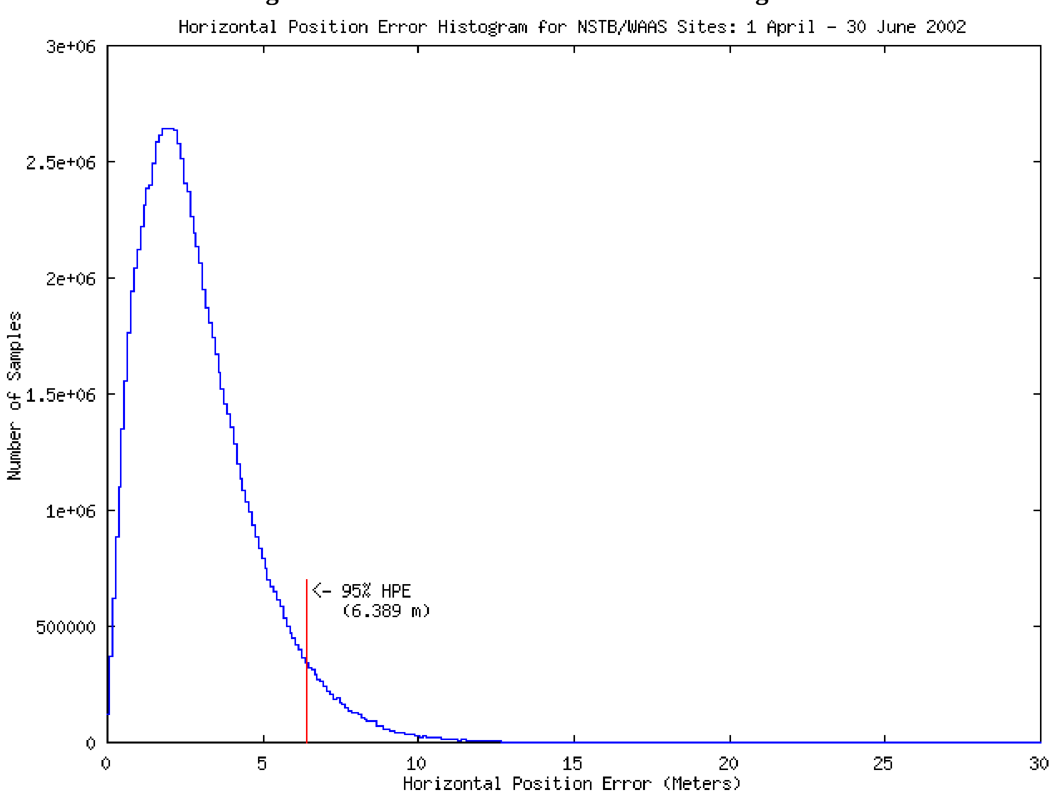


Figure 5-2 Combined Horizontal Error Histogram



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	1.688	4.138
Columbus	1.890	4.219
Denver	1.903	4.421
Grand Forks	1.844	3.594
Green Bay	1.740	3.659
Greenwood	1.771	4.406
Prescott	1.874	5.119
Billings	1.786	4.075
Anchorage	1.255	4.167
Chicago	2.302	3.181
Kansas City	1.855	3.605
Salt Lake City	1.681	4.138
Miami	2.516	5.592
Atlanta	2.177	4.383

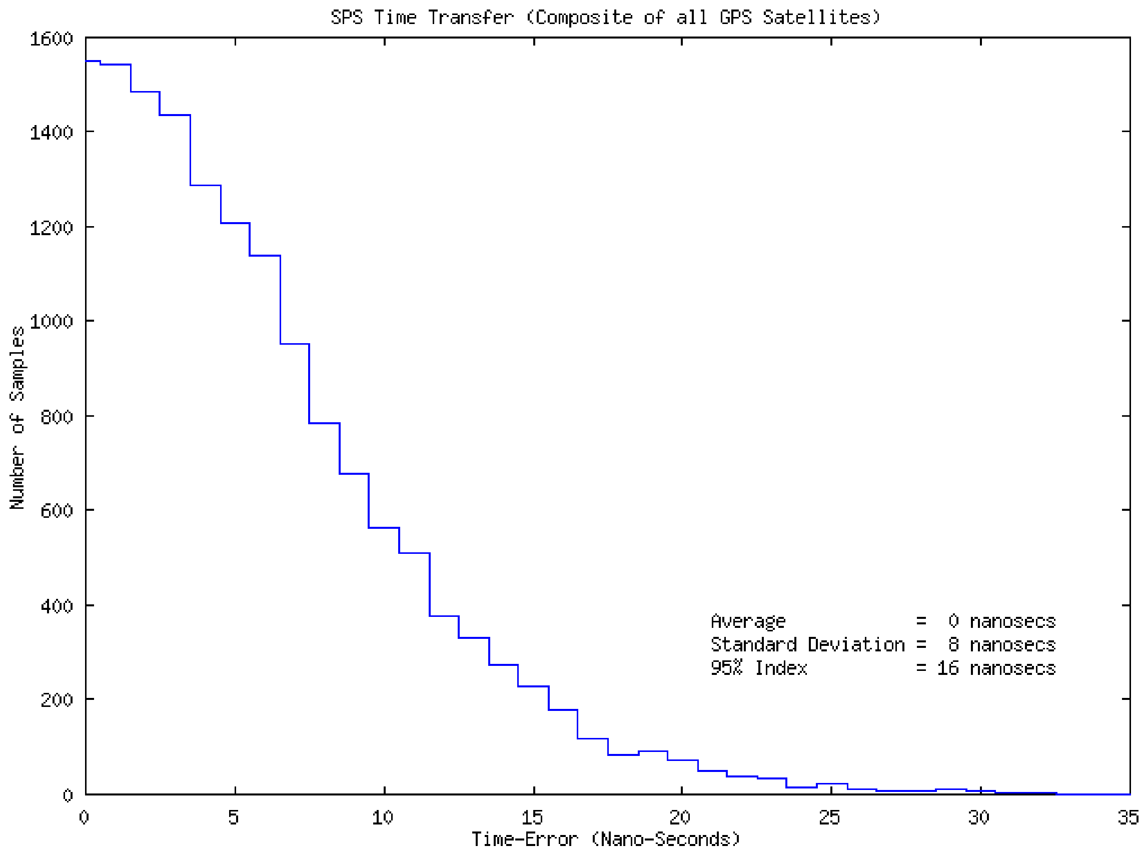
5.3 Relative Accuracy

To be included in future reports.

5.4 Time Transfer Accuracy

The GPS time error data between 1 April and 31 June 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 April and 31 June 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	1s	95% Range Error	Max Range Error (SPS Spec. ≤ 150 m)	Samples
1	-1.387	2.851	2.491	5.615	17.830	2180921
2	-0.192	2.834	2.827	5.555	11.038	2063777
3	-1.345	2.947	2.622	5.919	14.544	1802068
4	-0.583	3.320	3.268	6.750	15.887	2111006
5	-0.075	3.243	3.242	6.294	20.693	2492217
6	-0.180	3.341	3.336	6.475	15.792	2367831
7	0.058	3.928	3.927	7.834	15.562	2221368
8	-1.245	3.901	3.697	7.788	15.802	2150633
9	-0.821	3.604	3.509	6.963	13.820	2212602
10	0.276	3.758	3.748	7.574	21.869	2022362
11	-0.973	3.156	3.002	6.589	14.873	2092686
13	-1.725	3.131	2.613	6.278	17.346	2361757
14	-0.477	2.965	2.927	5.810	12.182	2180707
15	-0.111	3.486	3.485	7.229	17.578	1841035
17	-0.626	3.541	3.485	7.243	17.507	1805144
18	-0.384	3.256	3.233	6.859	12.766	2099876
20	-0.268	2.706	2.693	5.381	23.066	2477693
21	-0.583	3.660	3.613	7.392	15.312	1944539
22	-0.350	2.697	2.674	5.368	9.534	1964942
23	0.330	3.708	3.693	7.331	16.842	2156814
24	-0.120	3.525	3.523	6.986	15.505	2214371
25	-0.609	2.937	2.873	5.793	15.009	2218300
26	-0.677	3.733	3.671	7.575	16.763	1770394
27	-1.646	4.117	3.774	8.163	13.296	1491647
28	-0.187	3.968	3.964	8.310	16.675	1982582
29	-0.340	3.719	3.704	7.246	16.497	1945756
30	-1.166	2.994	2.757	5.811	20.393	2416227
31	-0.323	2.997	2.979	5.822	11.811	1633558

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

PRN	Range Rate Error Mean	Range Rate Error RMS	Range Rate Error 1σ	95% Range Rate Error	Max Range Rate Error (SPS Spec. ≤ 2 m)	Samples
1	-0.00005	0.00360	0.00360	0.00383	0.64237	2180921
2	-0.00002	0.00303	0.00303	0.00375	0.21589	2063777
3	-0.00010	0.00534	0.00534	0.00392	0.59536	1802068
4	-0.00008	0.00264	0.00264	0.00402	0.30407	2111006
5	0.00008	0.00725	0.00725	0.00440	0.72164	2492217
6	0.00023	0.00741	0.00741	0.00410	0.72927	2367831
7	0.00023	0.00280	0.00279	0.00474	0.38281	2221368
8	0.00011	0.00308	0.00308	0.00506	0.25734	2150633
9	-0.00021	0.00446	0.00446	0.00425	0.55093	2212602
10	-0.00024	0.00432	0.00432	0.00404	0.68891	2022362
11	0.00011	0.00709	0.00709	0.00591	0.57999	2092686
13	-0.00031	0.00580	0.00579	0.00427	0.62975	2361757
14	-0.00005	0.00212	0.00212	0.00384	0.12429	2180707
15	0.00012	0.00331	0.00331	0.00426	0.27264	1841035
17	0.00008	0.00328	0.00328	0.00394	0.31489	1805144
18	-0.0003	0.00204	0.00204	0.00393	0.10376	2099876
20	-0.00023	0.00712	0.00712	0.00431	0.93353	2477693
21	0.00007	0.00351	0.00351	0.00463	0.32947	1944539
22	-0.00003	0.00283	0.00283	0.00366	0.22018	1964942
23	-0.00023	0.00287	0.00286	0.00408	0.44499	2156814
24	-0.00004	0.00279	0.00279	0.00386	0.36170	2214371
25	-0.00003	0.00287	0.00287	0.00386	0.19258	2218300
26	-0.00052	0.00464	0.00461	0.00445	0.43999	1770394
27	0.00017	0.00347	0.00347	0.00522	0.29720	1491647
28	0.00023	0.00314	0.00313	0.00523	0.36883	1982582
29	-0.00031	0.00271	0.00269	0.00401	0.28511	1945756
30	0.00011	0.00612	0.00611	0.00434	0.62688	2416227
31	-0.00011	0.00352	0.00352	0.00466	0.39336	1633558

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

PRN	Range Acceleration Error Mean	Range Acceleration Error RMS	Range Acceleration 1σ	% ≤ 0.008 (SPS Spec. 95% of Time)	Max Range Acceleration Error (SPS Spec. ≤ 0.019 m/s2)	Samples
1	0	0.00003	0.00003	100	0.00644	2180921
2	0	0.00002	0.00002	100	0.00216	2063777
3	0	0.00005	0.00005	100	0.00594	1802068
4	0	0.00002	0.00002	100	0.00306	2111006
5	0	0.00007	0.00007	100	0.00721	2492217
6	0	0.00007	0.00007	100	0.00730	2367831
7	0	0.00002	0.00002	100	0.00387	2221368
8	0	0.00002	0.00002	100	0.00258	2150633
9	0	0.00004	0.00004	100	0.00550	2212602
10	0	0.00004	0.00004	100	0.00689	2022362
11	0	0.00006	0.00006	100	0.00581	2092686
13	0	0.00005	0.00005	100	0.00629	2361757
14	0	0.00001	0.00001	100	0.00125	2180707
15	0	0.00003	0.00003	100	0.00276	1841035
17	0	0.00002	0.00002	100	0.00317	1805144
18	0	0.00001	0.00001	100	0.00103	2099876
20	0	0.00007	0.00007	99.999	0.00934	2477693
21	0	0.00003	0.00003	100	0.00330	1944539
22	0	0.00002	0.00002	100	0.00219	1964942
23	0	0.00002	0.00002	100	0.00441	2156814
24	0	0.00002	0.00002	100	0.00360	2214371
25	0	0.00002	0.00002	100	0.00192	2218300
26	0	0.00004	0.00004	100	0.00437	1770394
27	0	0.00003	0.00003	100	0.00297	1491647
28	0	0.00002	0.00002	100	0.00368	1982582
29	0	0.00002	0.00002	100	0.00288	1945756
30	0	0.00006	0.00006	100	0.00629	2416227
31	0	0.00003	0.00003	100	0.00391	1633558

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 23.066 meters. Satellite 22 had the lowest maximum range error of 9.534 meters.

Figure 5-4 Distribution of Daily Max Range Errors

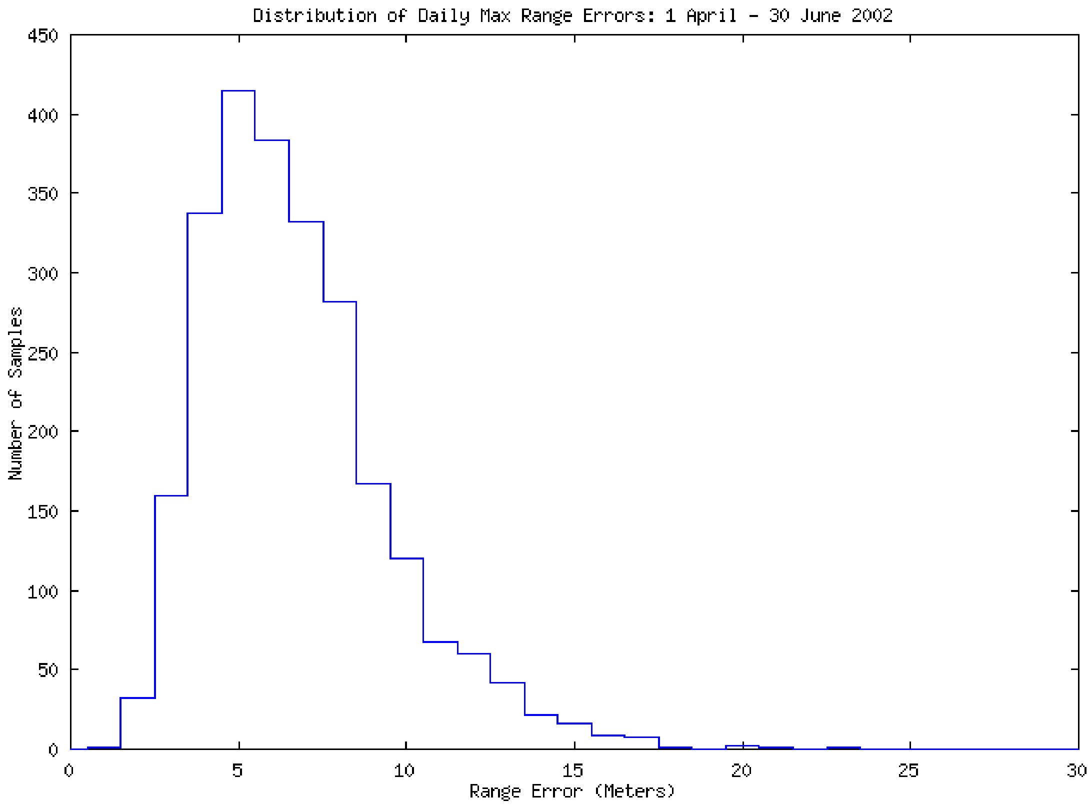


Figure 5-5: Distribution of Daily Max Range Rate Errors

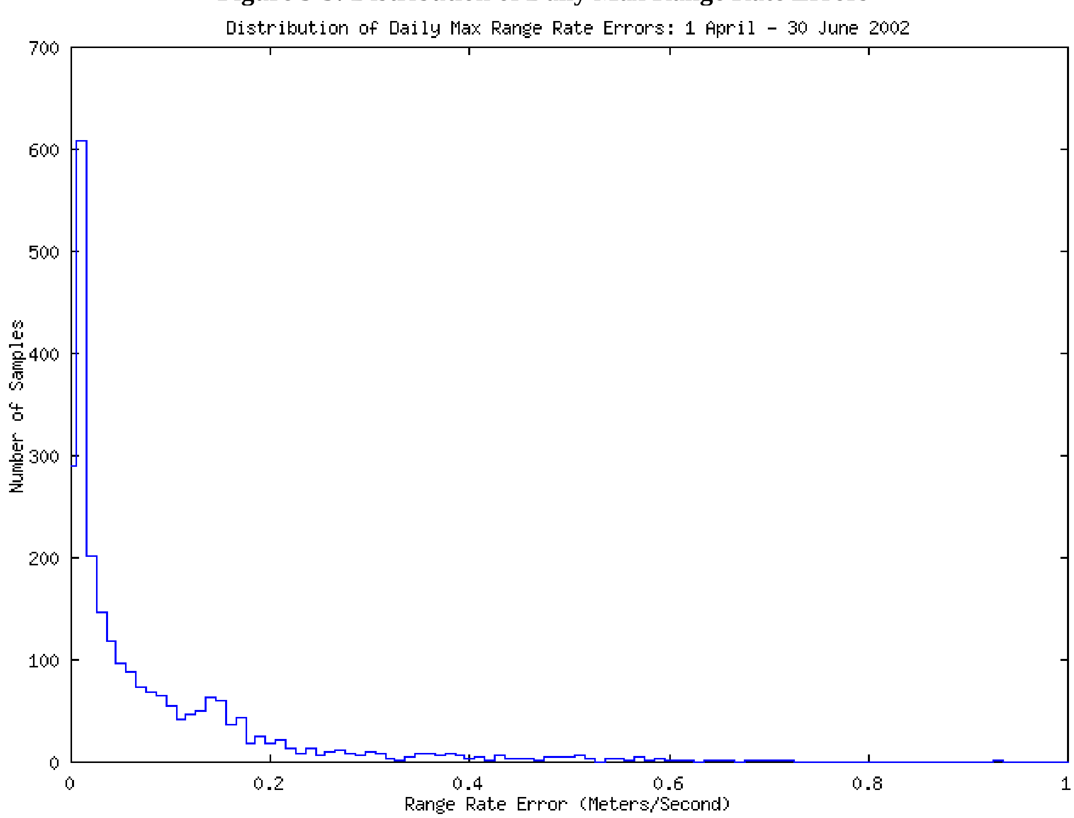


Figure 5-6: Distribution of Daily Max Acceleration Rate Errors

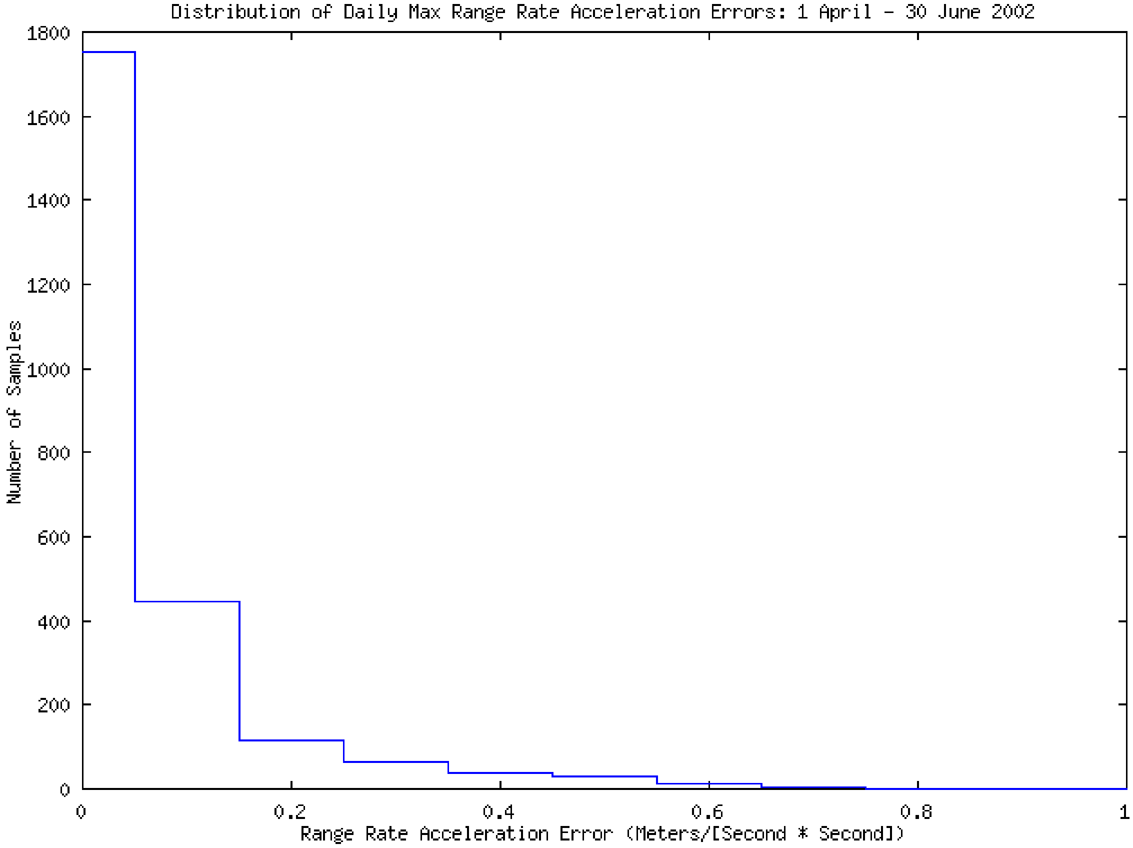


Figure 5-7: Maximum Range Error Per Satellite

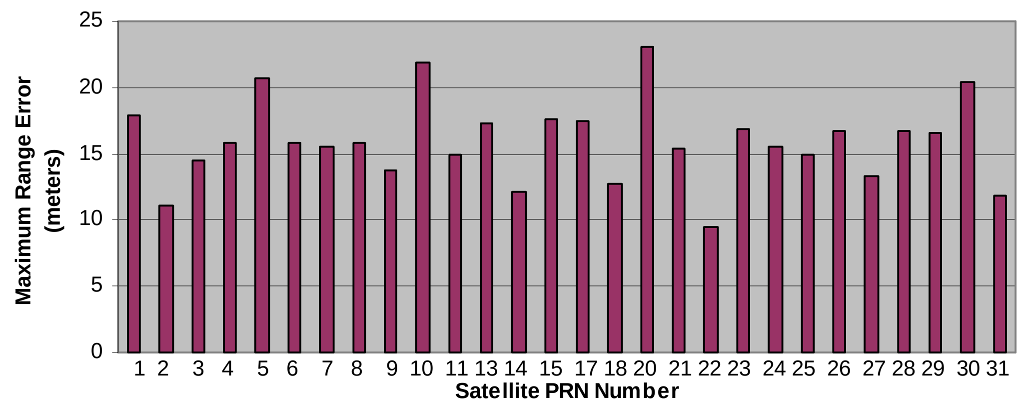


Figure 5-8: Maximum Range Rate Error Per Satellite

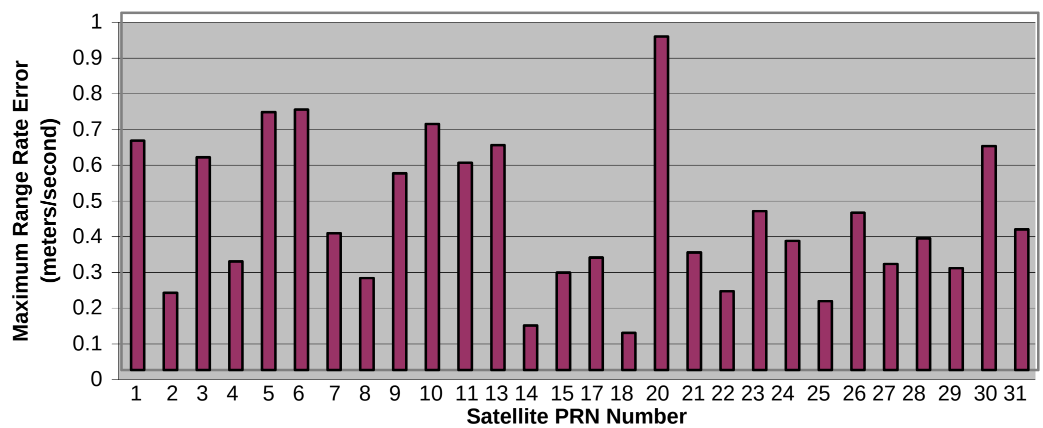
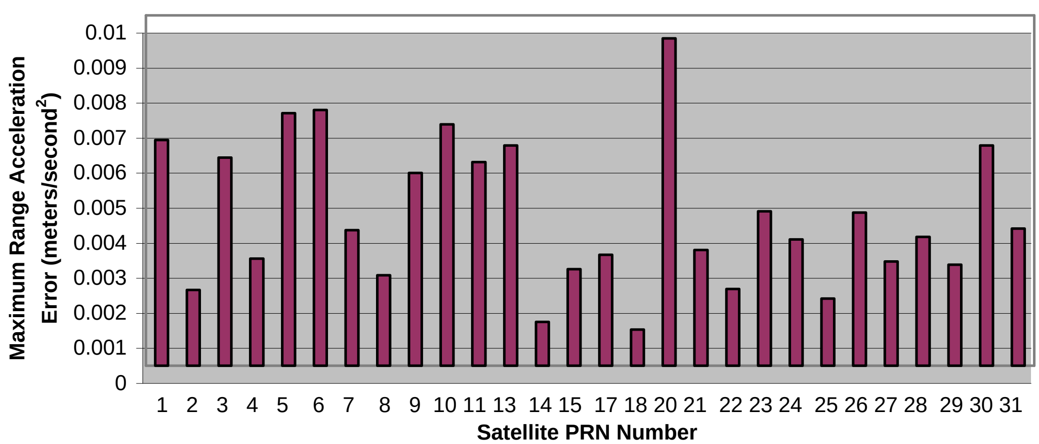


Figure 5-9: Maximum Range Acceleration Per Satellite



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 17-19 April 2002

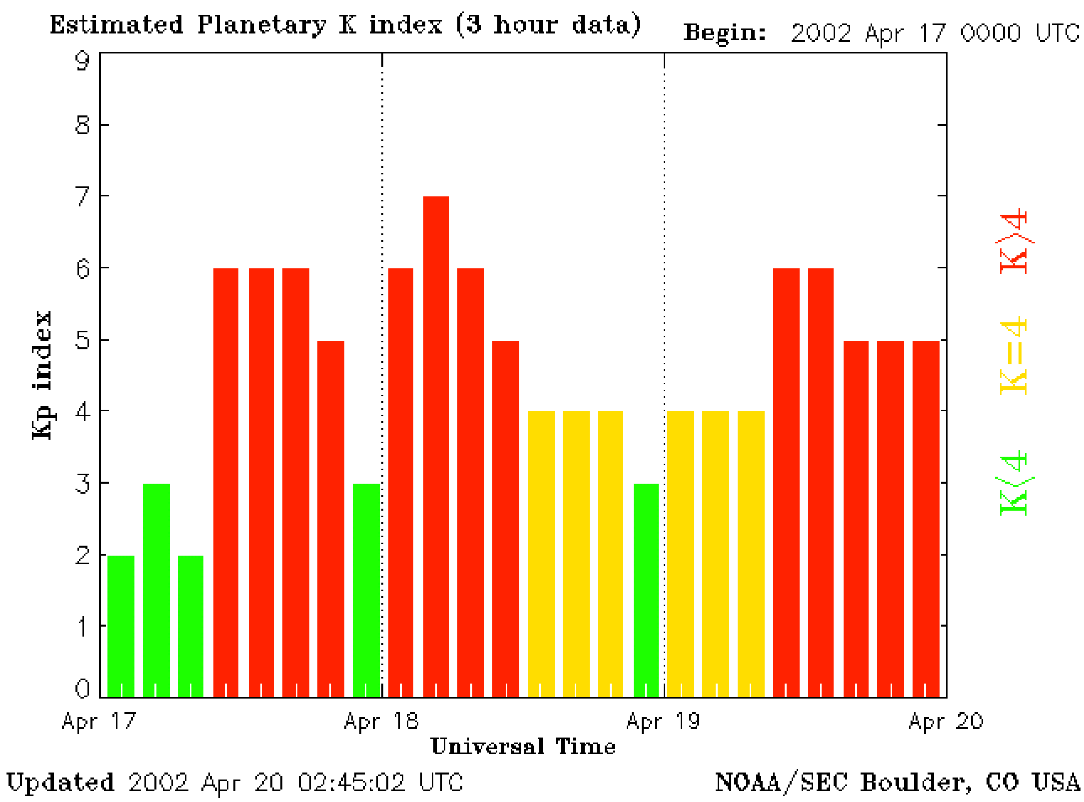


Figure 6-2 K-Index for 20-22 April 2002

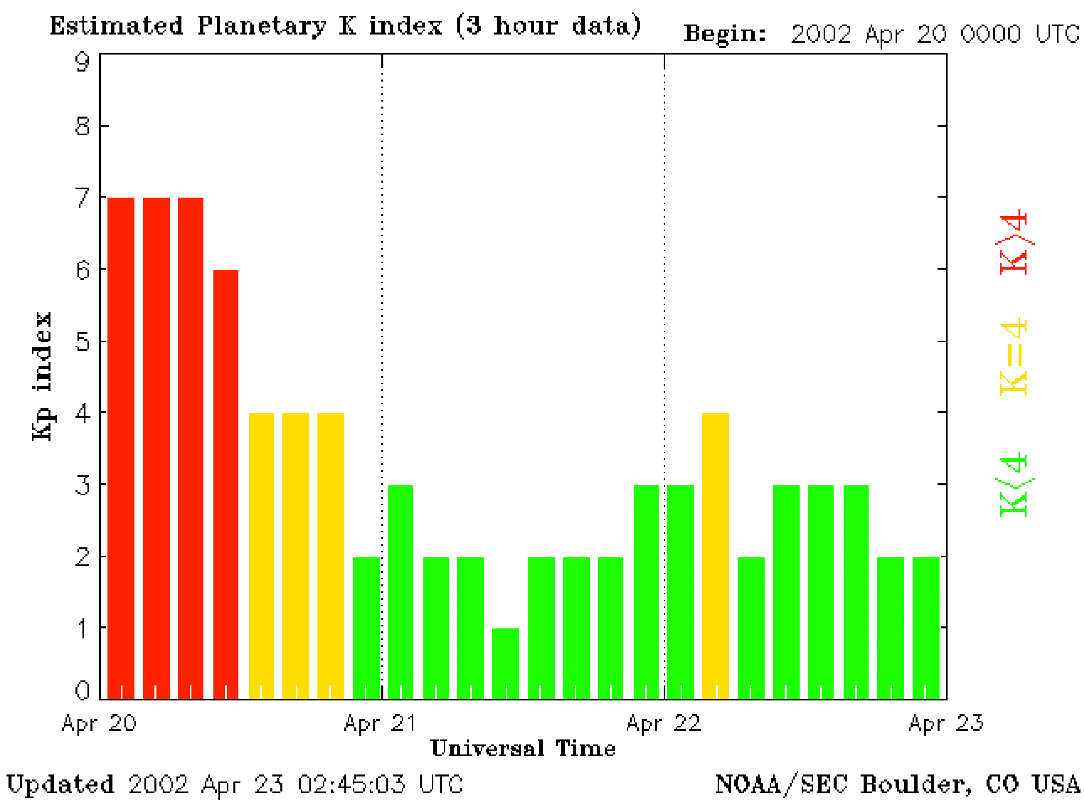
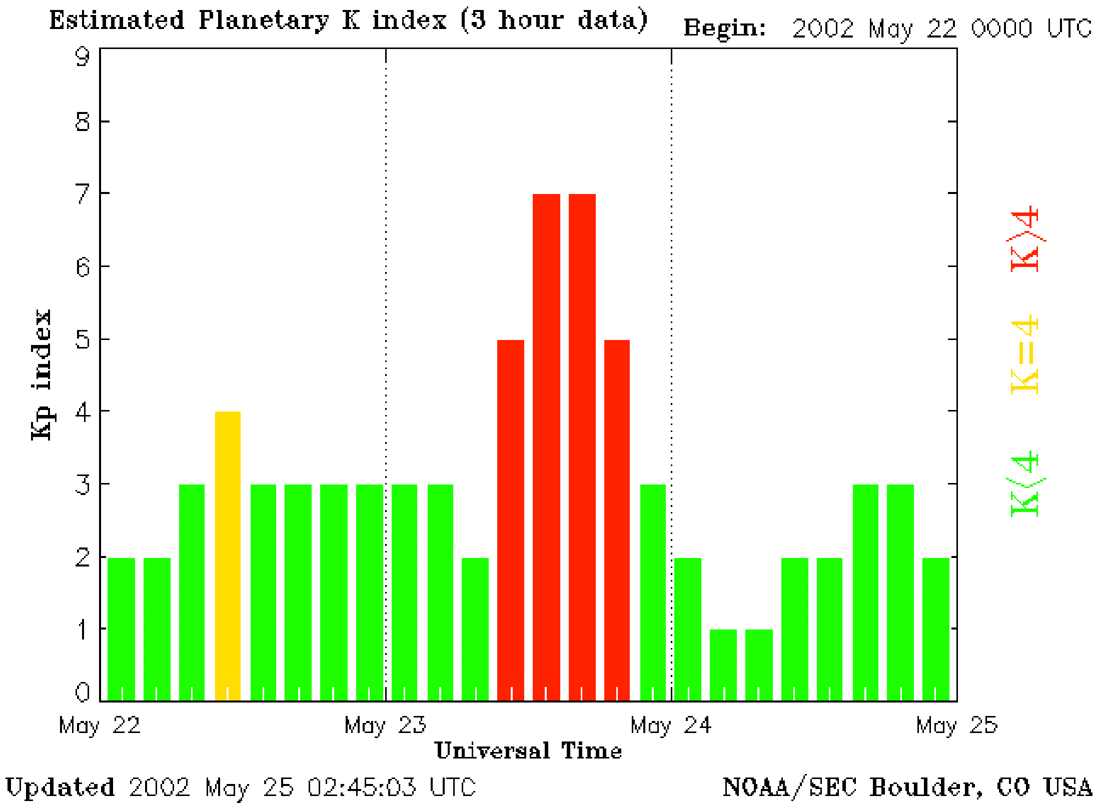


Figure 6-3 K-Index for 22 – 24 May 2002



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 18 April 2002

NSTB/WAAS Site	Min PDOP	Max PDOP	Mean PDOP	99.99% PDOP	99.99% VDOP
Atlantic City	1.239	4.340	1.888	4.337	3.748
Columbus	1.264	3.323	1.814	2.859	2.380
Denver	1.251	3.817	1.831	3.811	3.132
Grand Forks	1.278	4.228	1.869	4.228	3.783
Green Bay	Not	Evaluated	Due	To	Maintenance
Greenwood	1.333	4.201	1.839	4.197	3.563
Prescott	1.436	5.120	2.214	5.110	4.948
Billings	1.217	3.077	1.790	3.074	2.764
Anchorage	1.226	4.533	1.797	4.262	3.867
Chicago	1.280	4.190	1.805	4.189	3.749
Kansas City	1.271	2.563	1.789	2.563	2.137
Salt Lake City	1.277	3.210	1.800	3.208	2.942
Miami	1.219	3.360	1.800	3.360	3.081
Atlanta	1.321	4.286	1.850	4.285	3.596

Table 6-2 Horizontal & Vertical Accuracy Statistics for 18 April 2002

NSTB Site	95% Horizontal (Meters)	95% Vertical (Meters)	99.99% Horizontal (Meters)	99.99% Vertical (Meters)
Atlantic City	8.358	8.016	14.825	13.193
Columbus	9.097	9.055	11.226	13.098
Denver	8.986	8.889	10.562	11.683
Grand Forks	6.456	9.624	8.121	13.155
Green Bay	Not	Evaluated	Due To	Maintenance
Greenwood	10.755	9.326	15.330	13.947
Prescott	8.670	9.468	10.525	15.563
Billings	6.162	9.139	8.065	12.524
Anchorage	4.678	9.350	7.034	21.445
Chicago	9.663	9.871	12.703	11.759
Kansas City	10.451	9.522	13.318	13.344
Salt Lake City	8.047	9.650	8.886	11.635
Miami	11.164	9.185	14.732	14.035
Atlanta	11.235	9.920	14.747	11.860

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	99.994%
• 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	99.236% Availability 99.9% PDOP was 3.678
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	99.991%
• Conditioned on coverage standard • Standard represents a worst-case 24 hour interval, averaged over the globe	≥ 95.87% global average on worst-case day	99.929%
• 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	99.200%
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	≤7.238m HE 95% ≤16.828m HE 99.99% ≤9.573m VE 95% ≤21.749m 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	≤2.516m HE 95% ≤5.592m 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	≤16 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 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	Range Domain Accuracy ≤ 150 m NTE range error ≤ 2 m/s NTE range rate error ≤ 19 mm/s^2 NTE range acceleration error ≤ 8 mm/s^2 range acceleration error 95% of time	23.066m NTE Range Error 0.93353m/s NTE Rate Error 9.340mm/s^2 NTE Accl. Error ≤8mm/s^2 99.999% of the time

```
Product: Daily Geomagnetic Data     quar_DGD.txt
Issued: 2120 UT 07 Jul 2002
#
#  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 04 01     11  2 4 3 2 3 2 2 1    29  2 5 6 5 3 3 3 2    16  3 4 4 3 3 3 3 2
2002 04 02      9  1 4 3 2 2 1 2 1    27  2 5 6 5 3 2 2 2    15  2 4 4 4 2 2 3 2
2002 04 03      9  3 3 2 1 2 2 2 2    18  3 3 4 5 3 2 2 2    13  3 4 3 3 3 3 3 3
2002 04 04      3  1 1 1 1 1 1 1 0    11  1 1 3 4 4 2 1 0     8  2 1 2 3 3 3 2 2
2002 04 05      3  0 2 0 0 1 1 2 1     1  1 0 0 0 0 0 1 0     6  1 2 1 1 2 2 3 2
2002 04 06      3  1 1 0 1 1 1 1 1     2  1 1 0 1 1 0 1 1     5  2 1 0 2 2 2 2 2
2002 04 07      6  1 1 2 2 3 2 1 1     8  1 1 1 3 4 2 1 0     7  2 1 2 2 3 3 2 2
2002 04 08      2  0 0 1 1 1 1 1 1    -1 -1-1-1-1-1-1-1-1     5  1 0 1 1 2 3 2 1
2002 04 09      2  0 0 1 0 1 2 1 1     1  0 0 1 0 0 0 0 1     6  2 0 1 1 2 3 3 2
2002 04 10      4  0 1 1 2 1 2 1 2     5  0 0 0 4 1 2 1 2     7  1 0 1 3 3 3 3 2
2002 04 11     10  2 1 2 3 3 2 2 3    11  2 1 2 4 3 2 2 3    13  2 1 2 3 3 4 3 4
2002 04 12     14  4 2 2 2 4 2 3 3    24  4 1 5 5 5 2 2 2    13  4 2 2 2 3 3 3 3
2002 04 13      9  2 2 2 3 3 2 2 3    24  1 3 4 4 5 5 3 2    14  3 2 3 4 3 3 3 3
2002 04 14      8  3 2 1 1 3 3 0 1    31  3 3 3 2 7 5 1 1    13  3 3 2 2 4 3 3 2
2002 04 15      3  2 1 0 0 1 1 1 2    -1 -1 1-1 0 3 3 2 1     7  2 1 1 2 2 3 3 3
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2002 04 17     27  2 3 2 4 5 6 4 2    73  2 4 6 7 6 7 6 4    41  2 3 2 6 6 6 5 3
2002 04 18     35  6 6 4 4 4 3 2 3    76  5 5 8 6 5 6 5 3    54  6 7 6 5 4 4 4 3
2002 04 19     36  3 4 3 5 6 5 4 4   106  3 3 4 6 7 9 7 4    44  4 4 4 6 6 5 5 5
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2002 05 17      4  1 0 2 0 1 2 2 2     8  1 0 1 0 5 1 1 1    10  1 1 2 2 3 4 3 2
2002 05 18     15  1 2 1 1 2 1 5 5     9  1 1 0 1 1 1 4 4    15  2 1 1 2 3 3 5 5
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2002 05 22     10  2 2 3 3 3 2 2 2    -1 -1-1-1-1-1-1-1-1    14  2 2 3 4 3 3 3 3
2002 05 23     52  3 4 2 5 7 7 4 3    -1 -1-1-1-1-1-1-1-1    54  3 3 2 5 7 7 5 3
2002 05 24      3  2 0 1 0 2 1 1 1    -1 -1-1-1-1-1-1-1-1     7  2 1 1 2 2 3 3 2
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2002	06	30	12	2	3	3	3	3	1	2	3	21	2	4	5	5	3	2	2	2	16	2	3	3	4	3	3	3	3

Appendix C Performance Analysis (PAN) Problem Report

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.