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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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: Anderson, Atlantic City, Dayton, Elko, Gander, Great Falls and Oklahoma City, Kansas City (WAAS) and Salt Lake City (WAAS). During the reported quarter, the Gander receiver experienced mechanical problems that limited the amount of useful data from this site. In future reports data from Gander will be omitted from this report. This analysis verifies the GPS SPS performance as compared to the performance parameters stated in the SPS Specification Annex A.

This report, Report #33, includes data collected from 1 January through 31 March 2001. The next quarterly report will be issued 31 July 2001.

Analysis of this data includes the following categories: Coverage Performance, Service Availability Performance, Position Performance, Range Performance, Solar Storm Effects on GPS SPS performance and GPS/GLONASS 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 99.9% or better.

Availability was verified by reviewing the “Notice: Advisory to Navstar Users” (NANU) reports issued between 1 January and 31 March 2001 and by calculating the satellite availability from the data obtained from the nine sites. A total of seventeen outages were reported in the NANU’s. Sixteen of the outages were scheduled and one was unscheduled. The quarterly availabilities for Anderson, Atlantic City, Dayton, Elko, Great Falls, Oklahoma City, Kansas City, and Salt Lake City were 100%, 100%, 100%, 100%, 100%, 99.999%, 100%, 100%, respectively. Each of these availabilities is within the SPS value of 99.85%. In this quarter, SPS specifications were not exceeded. Both the 95% and 99.99% horizontal and vertical accuracy requirement passed. 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 Anderson site. The data was collected in one-second samples. All of the satellites met the range error specifications. The maximum range error recorded was 28.708 meters on Satellite PRN 10. The SPS specification states that the range error should never exceed 150 meters. The maximum range rate error recorded was 1.02668 Meters/second on Satellite PRN 13. The SPS specification states that the range rate error should never exceed 2 meters/second. The maximum range acceleration error recorded was 0.01033 Millimeters/second^2 on Satellite PRN 13. The SPS specification states that the range acceleration error should never exceed 19 Millimeters/second^2.

A GLONASS/GPS performance section was added to the PAN report. In April 1999, ACT-360 was tasked to monitor, analyze and characterize GLONASS and GPS/GLONASS system performance. The objective of this task is to evaluate the ability of GLONASS to provide navigation by itself and with SPS GPS and to assess the incremental benefit to WAAS obtained from using GLONASS. A GPS/GLONASS receiver was used in the NSTB laboratory at the FAA Technical Center. The GPS/GLONASS performance (from an Ashtech GG24) was compared against GPS-only performance (collected from a Novatel receiver). The 95% horizontal error and vertical error for the GPS/GLONASS solution were 5.574 Meters and 9.333

Meters, respectively. Earlier test results using the GG24 were subject to an error that had not been resolved at the time of the last PAN report. The problem has now been identified as an error in the receiver configuration. The solution reported previously did not include any ionospheric correction. On October 31 new firmware was loaded in the receiver and it was reconfigured to apply corrections using a standard ionospheric model. All data reported on in this document was collected using the correct ionospheric model.

From the analysis performed on data collected between 1 January and 31 March 2000, 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:

- Anderson, SC
- Atlantic City, NJ
- Dayton, OH
- Elko, NV
- Gander, NFLD (Canada)
- Great Falls, ND
- Oklahoma City, OK
- Kansas City, KS
- Salt Lake City, UT

(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.

Table 1-2 and 1-3 lists the non-precision and precision, respectively, performance parameters that will be evaluated for the Wide Area Augmentation System (WAAS) in future versions of 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 nine 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.

Section 7 provides the analysis on GPS/GLONASS performance. A GPS/GLONASS receiver was used in the NSTB laboratory at the FAA Technical Center.

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 not met in one instance during the entire 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	✓
Repeatable Accuracy ≤ 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	✓
Relative Accuracy ≤ 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
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 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	✓

Table 1-2 Future WAAS Performance Summary
En Route through Non-Precision Approach (from FAA-Spec-2892B)

Performance Parameter	***Requirements from WAAS Specification***
Accuracy	100 m (95% Horizontal Position) 500 m (99.999% Horizontal Position)
Integrity	10^{-7} probability of Hazardously Misleading Information 8 seconds to alarm Alarm Limit: 556 m - Total System HPL bound error - WAAS
Availability	0.999 Navigation and fault detection functions are operational Signal-in-Space meets accuracy and continuity requirements
Service Volume	50% in CONUS 35% of Total Service Volume

Table 1-3 Future WAAS Performance Summary
Precision Approach (from FAA-Spec-2892B)

Performance Parameter	***Requirements from WAAS Specification***
Accuracy	7.6 m (95% Horizontal Position) 7.6 m (95% Vertical Position)
Integrity	$4x10^{-8}$ probability of Hazardously Misleading Information 6.2 seconds to alarm
Availability	0.95 Navigation and fault detection functions are operational Signal-in-Space meets accuracy and continuity requirements
Service Volume	50% in CONUS

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

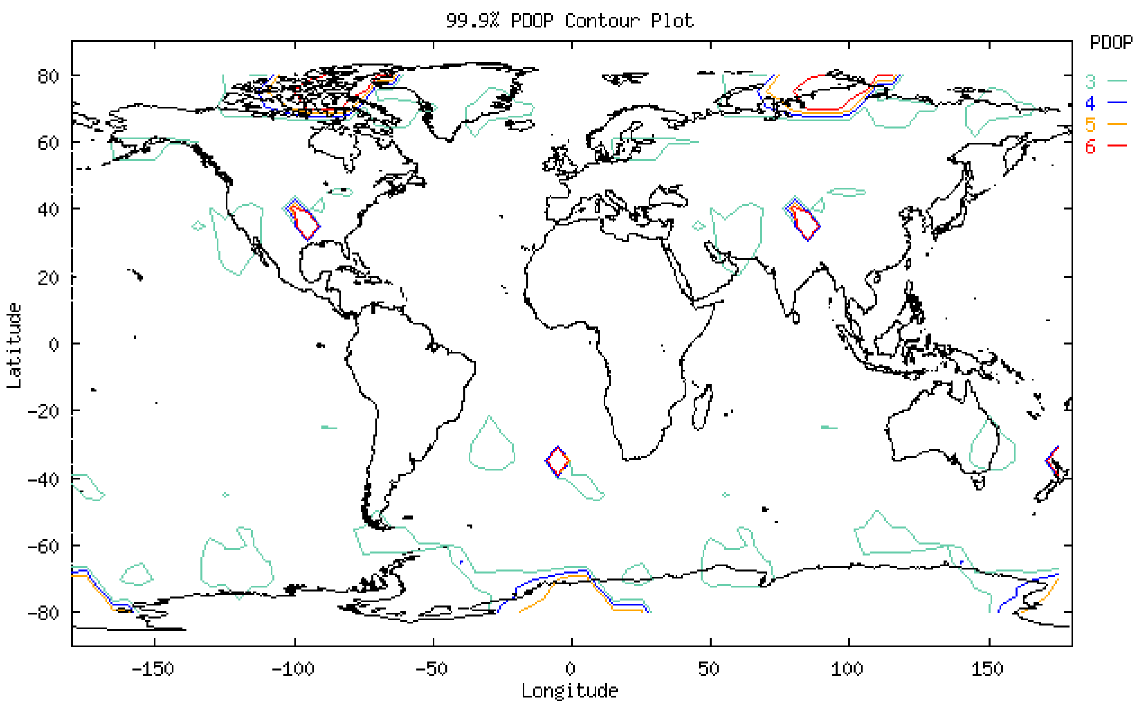
Almanacs for GPS weeks 71-83 used for this coverage portion of the report were obtained from the Coast Guard web site (www.navcen.uscg.mil). Using these almanacs, an SPS coverage area program developed by ACT-360 was used to calculate the PDOP at every 5^{o} point between longitudes of 180W to 180E and 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 3.811 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

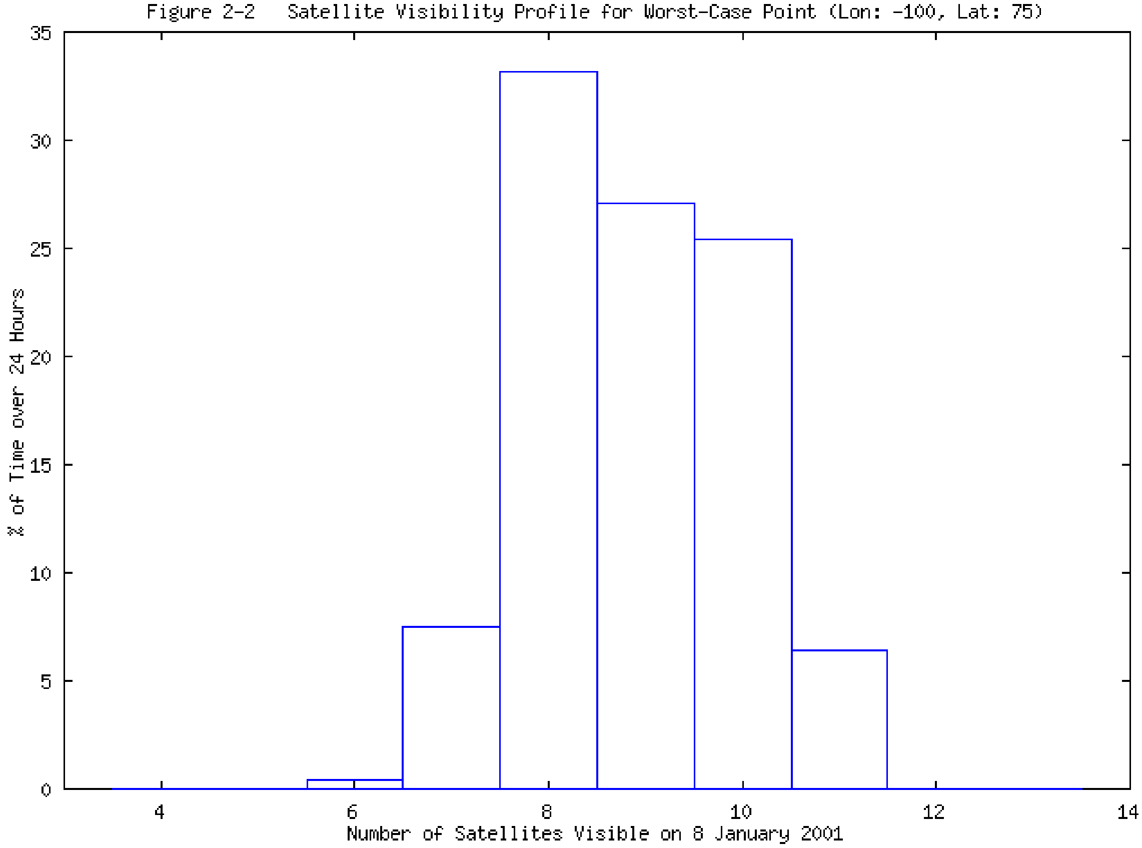
GPS Week	Global 99.9% PDOP Value*	Global Average* (Spec: ≥ 99.9%)	Worst-Case Point (Spec: ≥ 96.9%)
71	3.063	99.989%	99.028%
72	3.065	99.990%	99.028%
73	3.065	99.990%	99.097%
74	3.070	99.991%	99.236%
75	3.070	99.991%	99.236%
76	3.196	99.991%	99.167%
77	3.207	99.991%	99.236%
78	3.058	100%	99.931%
79	3.050	99.999%	99.583%
80	3.112	99.996%	99.375%
81	3.146	99.995%	99.444%
82	3.811	99.992%	99.167%
83	3.246	99.999%	99.653%

Figure 2-1 SPS Coverage (24-Hour Period: 8 January 2001)



Developed by FAA William J. Hughes Technical Center

Figure 2-2 Satellite Visibility Profile for Worst-Case Point (Lon: -100, Lat: 75)



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 (NANUs). During this reporting period, 1 January through 31 March 2001, there were a total of fourteen reported outages. Eleven of these outages were maintenance activities and were reported in advance. Three were unscheduled outages. A complete listing of outage NANUs for the reporting period is provided in Table 3-1. A complete listing of the forecasted outage NANUs for the reporting period can be found in Table 3-2. Canceled outage NANUs 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 Unschedule	Total Scheduled	Total
1001	28	S	3-Jan	14:36	3-Jan	19:33		4.95	4.95
1005	9	S	5-Jan	17:23	5-Jan	0:47		7.40	7.40
1009	19	S	8-Jan	13:27	8-Jan	18:56		5.48	5.48
1013	21	S	19-Jan	14:22	19-Jan	18:21		3.98	3.98
1014	28	S	23-Jan	12:29	23-Jan	16:56		4.45	4.45
1023	19	S	9-Feb	13:18	9-Feb	17:01		3.72	3.72
1024	28	S	11-Feb	11:33	11-Feb	16:16		4.72	4.72
1027*	18	S	15-Feb	15:51	N/A	N/A		N/A	N/A
1032	10	S	24-Feb	21:39	25-Feb	2:20		4.68	4.68
1033	6	S	27-Feb	20:28	28-Feb	4:02		7.57	7.57
1035	13	S	1-Mar	8:42	1-Mar	16:15		7.55	7.55
1040	5	S	7-Mar	12:22	7-Mar	13:36		1.23	1.23
1041	18	S	9-Mar	9:47	9-Mar	19:11		9.40	9.40
1043	28	S	13-Mar	8:47	13-Mar	12:05		3.30	3.30
1046	8	S	16-Mar	14:05	16-Mar	19:16		5.18	5.18
1049	4	S	26-Mar	16:28	26-Mar	21:31		5.05	5.05
1051	28	S	27-Mar	8:55	27-Mar	20:34		11.65	11.65
1015**	15	U	30-Jan	2:11	N/A	N/A	N/A	N/A	N/A
1018***	3	U	31-Jan	4:34	N/A	N/A	N/A	N/A	N/A
1021***	3	U	31-Jan	4:34	31-Jan	15:09	10.58	0.00	10.58
1044****	19	U	16-Mar	1:26	N/A	N/A	N/A	N/A	N/A
ıal Unscheduled and Scheduled Downtime and Total Actual Downtime							**10.58**	**90.31**	**100.89**

Type: S = Scheduled U = Unscheduled

*Note: NANU 1027 declared PRN 18 operational again after an outage beginning before this quarter.
**Note: NANU 1015 declared PRN 15 unusable until further notice for an unscheduled outage.
***Note: NANUs 1018 and 1021 refer to PRN 3 being declared unusable for an unscheduled outage until further notice and then coming back into service.
****Note: NANU 1044 declared PRN 19 unusable until further notice for an unscheduled outage.

Table 3-2 NANUs Forecasted to Affect Satellite Availability								
NANU #	PRN	Type	Start Date	Start Time	End Date	End Time	Total	Comments
1002	19	F	8-Jan	13:00	9-Jan	1:00	12	See NANU 1009
1003	19	F	16-Jan	14:00	17-Jan	2:00	12	See NANU 1006
1004	28	F	18-Jan	13:00	19-Jan	1:00	12	See NANU 1007
1011	21	F	19-Jan	14:00	20-Jan	2:00	12	See NANU 1013
1012	28	F	23-Jan	12:00	24-Jan	0:00	12	See NANU 1014
1016	19	F	9-Feb	12:15	10-Feb	0:15	12	See NANU 1023
1017	28	F	11-Feb	11:00	11-Feb	23:00	12	See NANU 1024
1022	10	F	16-Feb	22:00	17-Feb	10:00	12	See NANU 1025
1026	18	F	14-Feb	14:00	N/A	N/A	N/A	See NANU 1027
1028	10	F	24-Feb	21:00	25-Feb	9:00	12	See NANU 1032
1029	13	F	1-Mar	8:00	1-Mar	20:00	12	See NANU 1035
1030	6	F	2-Mar	20:00	3-Mar	8:00	12	See NANU 1031
1034	5	F	7-Mar	12:00	8-Mar	0:00	12	See NANU 1037
1036	5	F	7-Mar	12:00	8-Mar	0:00	12	See NANU 1040
1038	18	F	9-Mar	9:00	9-Mar	21:00	12	See NANU 1041
1039	28	F	13-Mar	8:30	13-Mar	20:30	12	See NANU 1043
1042	8	F	16-Mar	13:30	17-Mar	1:30	12	See NANU 1046
1047	4	F	26-Mar	16:00	27-Mar	4:00	12	See NANU 1049
1048	28	F	27-Mar	8:45	27-Mar	20:45	12	See NANU 1051
1031	6	F/Rescheduled	27-Feb	20:00	28-Feb	8:00	12	See NANU 1033
				Total Forecast Downtime			**228**	

Table 3-3 NANUs Canceled					
NANU#	PRN	Type	Start Date	Start Time	Comments
1006	19	C	16-Jan	14:00	See NANU 1003
1007	28	C	18-Jan	13:00	See NANU 1004
1025	10	C	16-Feb	22:00	See NANU 1022
1037	5	C	7-Mar	22:00	See NANU 1034

Satellite Reliability, Maintainability, and Availability (RMA) data is being collected based on published "Notice: Advisory to Navstar Users" messages (NANUs). 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 NANUs. 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 Jan - 31 March, 2001**	**12 December, 1998- 31 March, 2001 (qtrs = 9.21)**
Total Forecast Downtime (hrs):	228	2804.47
Total Actual Downtime (hrs):	100.89	4537.8
Total Actual Scheduled Downtime (hrs):	90.31	1227.89
Total Actual Unscheduled Downtime (hrs):	10.58	3285.93
Total Satellite Observed MTTR (hrs):	5.93	17.29
Scheduled Satellite Observed MTTR (hrs):	5.64	6.99
Unscheduled Satellite Observed MTTR (hrs):	10.58	50.37
# Total Satellite Outages:	17	186
# Scheduled Satellite Outages:	16	149
# Unscheduled Satellite Outages:	1	37
Percent Operational -- Scheduled Downtime:	99.85%	99.78%
Percent Operational -- All Downtime:	99.84%	98.92%

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 January and 31 March 2001.

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
Anderson	1.324	5.972	5.394	1.933	5.750	5.245	7855941
Atlantic City	1.221	5.667	5.033	1.854	4.363	3.905	7857262
Dayton	1.240	5.996	5.139	1.855	3.953	3.570	7857134
Elko	1.199	5.999	5.408	1.880	5.700	5.040	7843174
Great Falls	1.382	5.999	5.786	2.073	5.516	4.994	7619035
Oklahoma City	1.219	10.234	9.594	1.851	7.245	6.685	7847304
Kansas City	1.151	5.089	4.506	1.855	3.682	3.294	7457114
Salt Lake City	1.177	5.875	4.781	1.820	5.446	4.697	7509892

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.

On March 26, 2001 the Satellite Availability data evaluated did not meet the requirements stated in the SPS.

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
Anderson	83_1	10.234	817	1049/PRN4	86386	99.054%
Worst-Case Point on Worst-Case Day = 99.054% (SPS Spec. ≥ 83.92%)						

Global Average on Worst-Case Day = 99.887 % (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
Anderson	7855941	0	100%
Atlantic City	7857262	0	100%
Dayton	7857134	0	100%
Elko	7843174	0	100%
Great Falls	7619035	0	100%
Oklahoma City	7847304	817	99.990%
Kansas City	7457114	0	100%
Salt Lake City	7509892	0	100%
Worst Single Point Average = 99.990% (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 nine 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)
Anderson	7855941	19.5
Atlantic City	7857262	23.5
Dayton	7857134	21.9
Elko	7843174	13.7
Great Falls	7619035	20.7
Oklahoma City	7847304	16.5
Kansas City	7457114	16.5
Salt Lake City	7509892	13.7

None of the horizontal error exceeded the 500-meter threshold for this quarter.

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 January through 31 March 2001 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)
Anderson	5.578	7.811	17.031	23.060
Atlantic City	5.245	6.783	19.486	21.718
Dayton	7.232	8.122	18.413	28.313
Elko	5.254	7.638	11.096	25.019
Great Falls	5.255	7.297	14.690	23.927
Oklahoma City	5.103	7.507	15.837	18.642
Kansas City	5.169	6.922	14.475	20.686
Salt Lake City	5.168	7.330	10.808	22.970

Figures 5-1 and 5-2 are the combined histograms of the vertical and horizontal errors for all seven NSTB and two WAAS sites from 1 January to 31 March 2001.

Figure 5-1 Combined Vertical Error Histogram

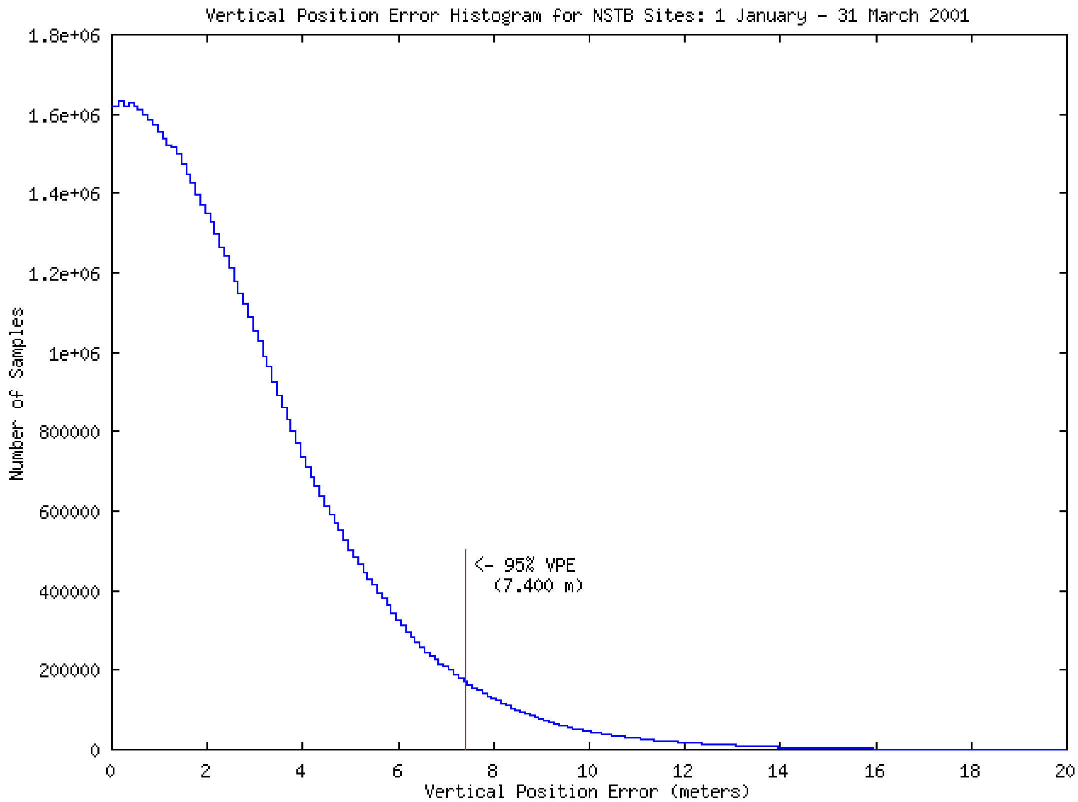
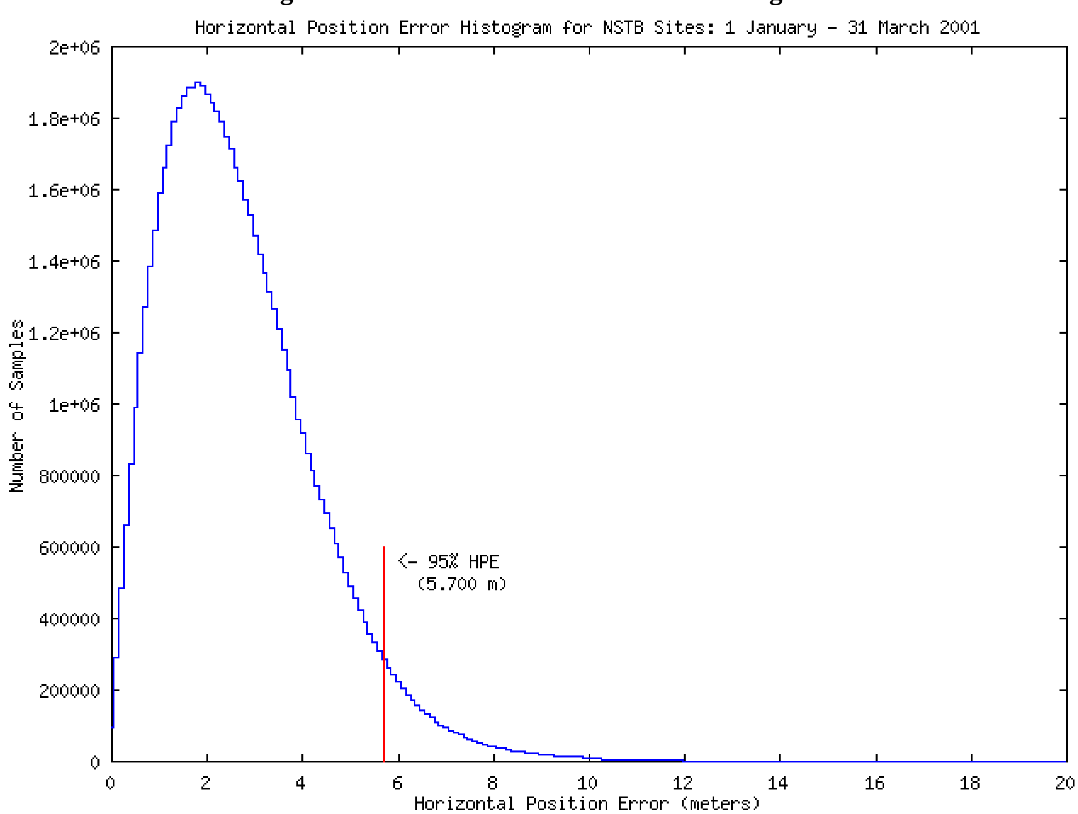


Figure 5-2 Combined Horizontal Error Histogram



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)
Anderson	2.340	6.117
Atlantic City	1.895	4.214
Dayton	2.313	5.060
Elko	2.016	5.143
Great Falls	1.664	3.891
Oklahoma City	1.564	3.974
Kansas City	1.747	4.159
Salt Lake City	1.856	3.943

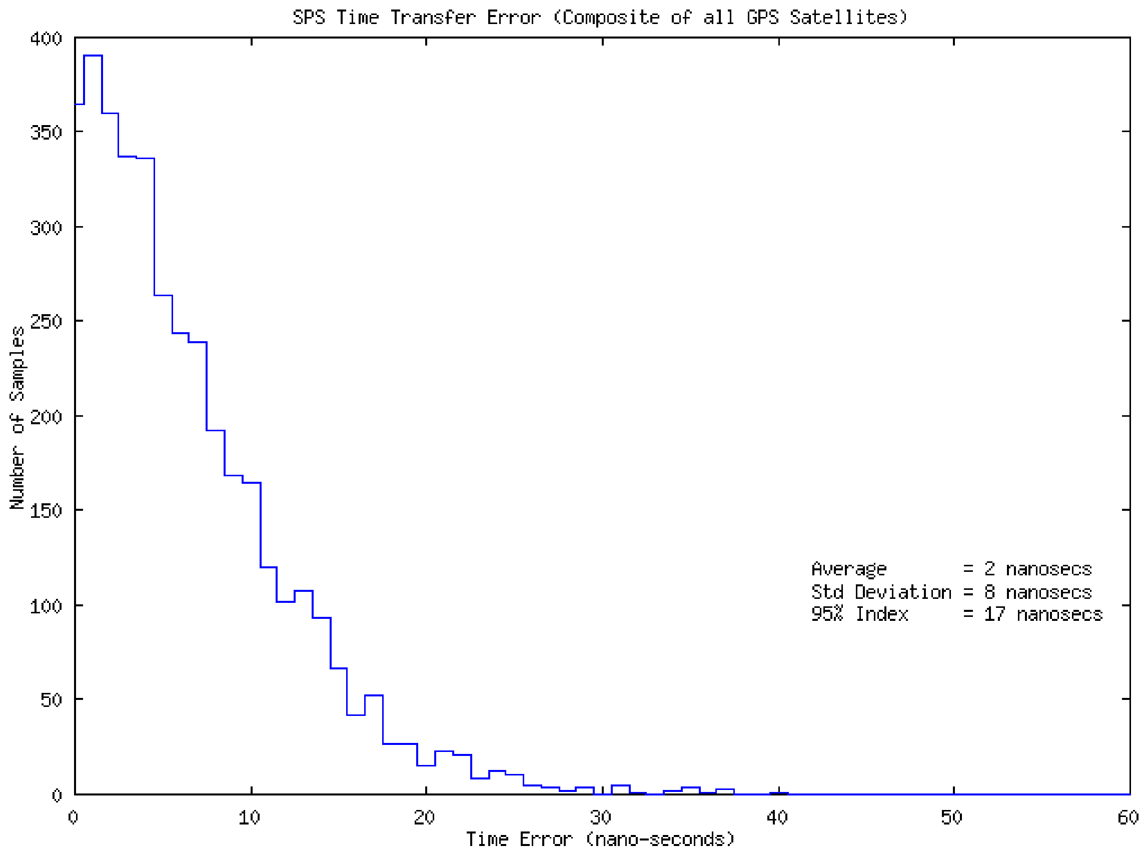
5.3 Relative Accuracy

To be included in future reports.

5.4 Time Transfer Accuracy

The GPS time error data between 1 January and 31 March 2001 was down loaded from USNO internet site. The USNO data file contains the time difference between the USNO master clock and GPS system time for each GPS satellites during the time period. Over 10,000 samples of GPS time error are contained in the USNO data file. In order to evaluate the GPS time transfer error, the data file was used to create a histogram (Fig 5-3) to represent the distribution of GPS time error. The histogram was created by taking the absolute value of time difference between the USNO master clock and GPS system time, then creating data bins with one nanosecond precision. The number of samples in each bin was then plotted to form the histogram in Fig 5-3. The mean, standard deviation, and 95% index are within the requirements of GPS SPS time error.

Figure 5-3 Time Transfer Error



5.5 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 January and 31 March 2001. 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	1σ	95% Range Error	Max Range Error (SPS Spec. ≤ 150 m)	Samples
1	-0.599	3.195	3.138	6.430	14.630	1732851
2	-0.041	4.048	4.048	8.050	18.948	2109094
3	-0.133	3.266	3.263	6.480	18.890	2185100
4	-1.168	4.015	3.842	7.664	15.280	2141641
5	1.322	3.318	3.043	6.543	26.662	2503433
6	-0.179	3.309	3.304	6.560	21.860	2114611
7	-0.376	3.927	3.909	7.692	16.860	2332929
8	-0.256	3.621	3.612	7.020	20.202	1758441
9	0.187	2.957	2.951	5.730	18.789	2407756
10	-0.098	4.078	4.077	7.960	28.708	2062927
11	-0.460	3.177	3.143	6.230	21.004	2156890
13	-1.783	3.357	2.844	6.736	22.760	2201073
14	0.491	2.458	2.408	4.920	11.710	2337758
15	1.364	3.861	3.612	7.890	13.960	583986
17	-0.051	3.501	3.501	6.920	14.590	2006044
18	-1.989	3.516	2.900	7.000	13.347	869600
19	-0.790	3.490	3.399	6.600	13.310	1690884
20	-0.629	2.996	2.930	6.040	19.531	2481639
21	0.556	3.063	3.012	6.070	12.600	2111281
22	0.726	3.261	3.179	6.459	13.634	1922483
23	0.571	3.118	3.066	6.270	19.463	2391127
24	-0.398	4.293	4.274	8.200	20.078	2367730
25	0.596	2.692	2.626	5.180	10.910	2250678
26	-0.727	3.708	3.636	7.313	25.610	1767585
27	-1.176	3.595	3.397	7.120	14.663	1928749
28	-0.720	3.163	3.080	6.200	11.730	1934744
29	0.387	2.523	2.494	4.976	11.120	2355595
30	0.100	2.551	2.549	5.160	19.040	2402732
31	-0.585	3.695	3.649	7.370	18.120	1803600

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	0.00527	0.00526	0.01008	0.22530	1732851
2	-0.0012	0.00619	0.00619	0.01203	0.20487	2109094
3	0.00004	0.00771	0.00771	0.01473	0.51357	2185100
4	-0.00045	0.00677	0.00675	0.01417	0.11668	2141641
5	-0.00021	0.00943	0.00943	0.01741	0.67233	2503433
6	0.00000	0.00988	0.00988	0.01751	0.81059	2114611
7	-0.00005	0.00659	0.00659	0.01384	0.15493	2332929
8	0.00004	0.00615	0.00615	0.01226	0.22337	1758441
9	0.00016	0.01053	0.01052	0.02098	0.59584	2407756
10	-0.00037	0.00657	0.00656	0.01270	0.64789	2062927
11	-0.00020	0.00938	0.00937	0.01745	0.43612	2156890
13	0.00028	0.01012	0.01012	0.01975	1.02668	2201073
14	-0.00006	0.00638	0.00638	0.01256	0.06034	2337758
15	0.00006	0.00645	0.00645	0.01107	0.28567	583986
17	-0.00013	0.00617	0.00617	0.01026	0.35856	2006044
18	-0.00015	0.00931	0.00930	0.01608	0.20303	869600
19	0.00007	0.00695	0.00695	0.01238	0.28391	1690884
20	-0.00032	0.00952	0.00952	0.01910	0.61418	2481639
21	0.00003	0.00642	0.00642	0.01183	0.30238	2111281
22	-0.00006	0.00746	0.00746	0.01351	0.66202	1922483
23	-0.00019	0.00702	0.00702	0.01419	0.20838	2391127
24	-0.00040	0.00634	0.00632	0.01200	0.25704	2367730
25	0.00000	0.00576	0.00576	0.01110	0.29949	2250678
26	-0.00014	0.00811	0.00811	0.01448	0.58728	1767585
27	0.00014	0.00595	0.00595	0.01164	0.21344	1928749
28	-0.00021	0.00594	0.00594	0.01206	0.21820	1934744
29	-0.00001	0.00669	0.00669	0.01354	0.59586	2355595
30	-0.00002	0.00915	0.00915	0.01861	0.59912	2402732
31	-0.00019	0.00773	0.00772	0.01375	0.90125	1803600

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	0.00000	0.00004	0.00004	100	0.00228	1732851
2	0.00000	0.00005	0.00005	100	0.00201	2109094
3	0.00000	0.00007	0.00007	100	0.00513	2185100
4	0.00000	0.00006	0.00006	100	0.00115	2141641
5	0.00000	0.00008	0.00008	100	0.00678	2503433
6	0.00000	0.00009	0.00009	99.9999	0.00812	2114611
7	0.00000	0.00005	0.00005	100	0.00163	2332929
8	0.00000	0.00005	0.00005	100	0.00222	1758441
9	0.00000	0.00009	0.00009	100	0.00596	2407756
10	0.00000	0.00006	0.00006	100	0.00643	2062927
11	0.00000	0.00008	0.00008	100	0.00435	2156890
13	0.00000	0.00009	0.00009	99.9999	0.01033	2201073
14	0.00000	0.00005	0.00005	100	0.00058	2337758
15	0.00000	0.00005	0.00005	100	0.00285	583986
17	0.00000	0.00005	0.00005	100	0.00357	2006044
18	0.00000	0.00008	0.00008	100	0.00211	869600
19	0.00000	0.00006	0.00006	100	0.00284	1690884
20	0.00000	0.00008	0.00008	100	0.00609	2481639
21	0.00000	0.00006	0.00006	100	0.00312	2111281
22	0.00000	0.00007	0.00007	100	0.00662	1922483
23	0.00000	0.00006	0.00006	100	0.00208	2391127
24	0.00000	0.00005	0.00005	100	0.00262	2367730
25	0.00000	0.00005	0.00005	100	0.00298	2250678
26	0.00000	0.00007	0.00007	100	0.00581	1767585
27	0.00000	0.00005	0.00005	100	0.00213	1928749
28	0.00000	0.00005	0.00005	100	0.00223	1934744
29	0.00000	0.00006	0.00006	100	0.00600	2355595
30	0.00000	0.00008	0.00008	100	0.00603	2402732
31	0.00000	0.00007	0.00007	99.9999	0.00904	1803600

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 10 with an error of 28.708 meters. Satellite 25 had the lowest maximum range error of 10.910.

Figure 5-4 Distribution of Daily Max Range Errors

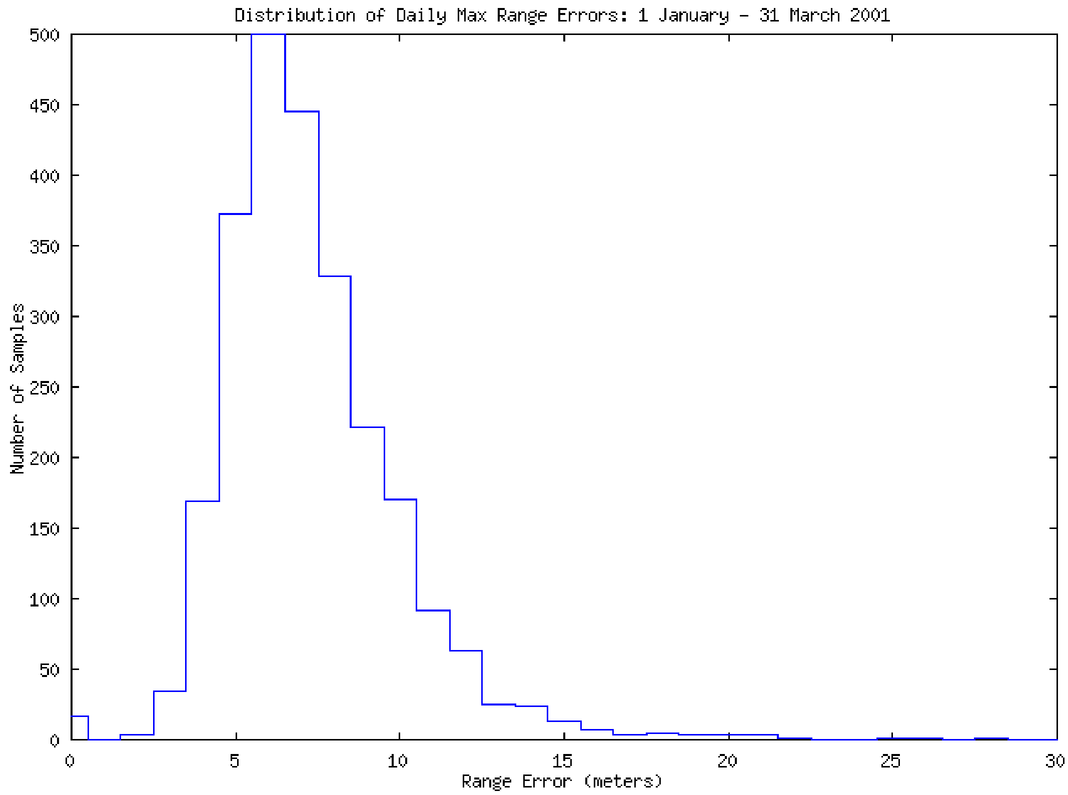


Figure 5-5: Distribution of Daily Max Range Rate Errors

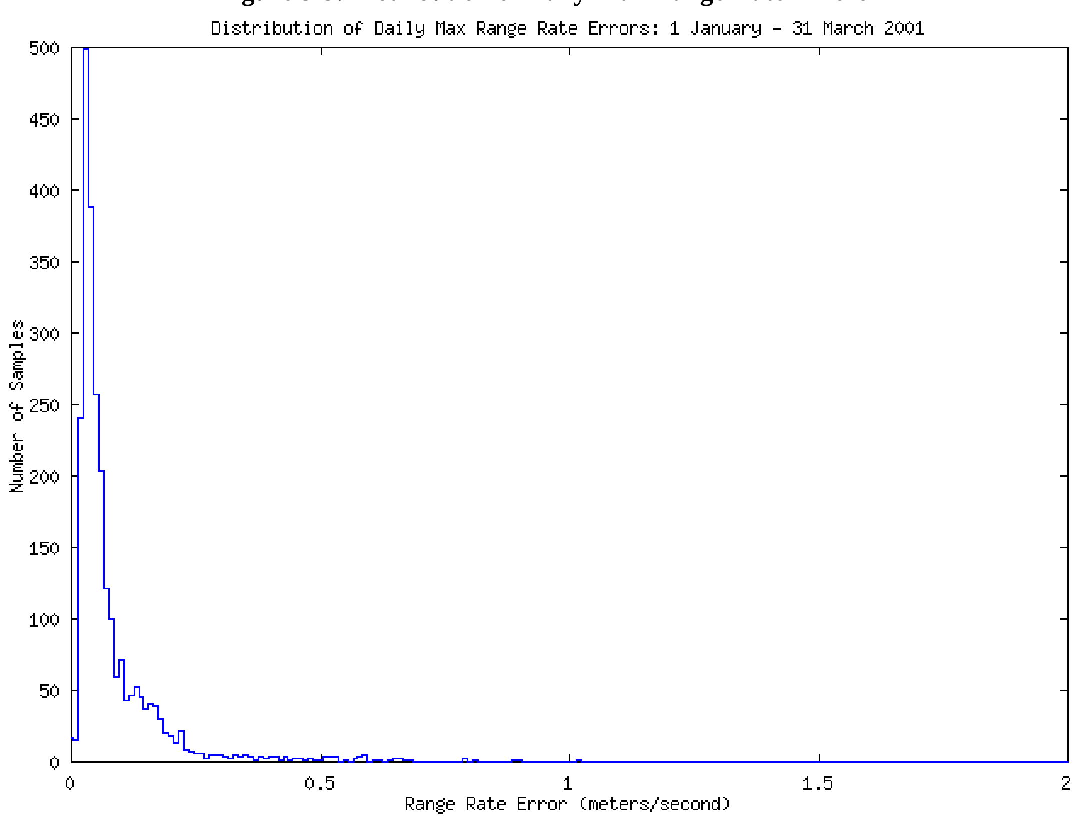
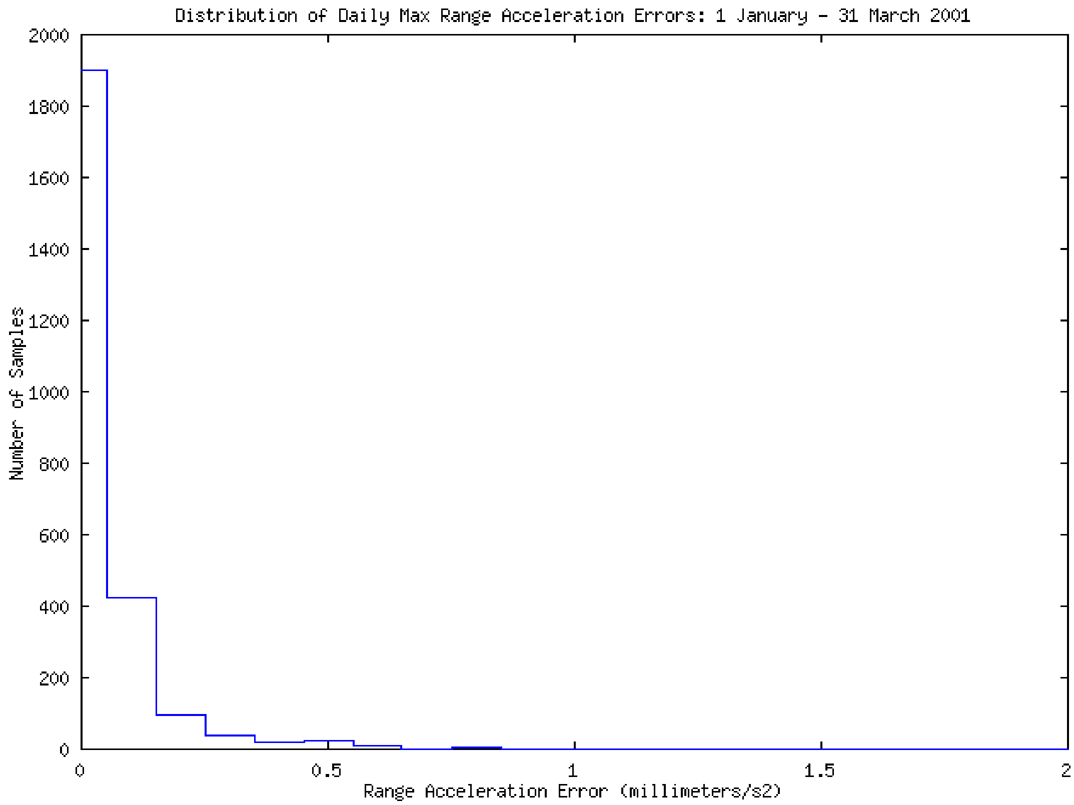


Figure 5-6: Distribution of Daily Max Acceleration Rate Errors



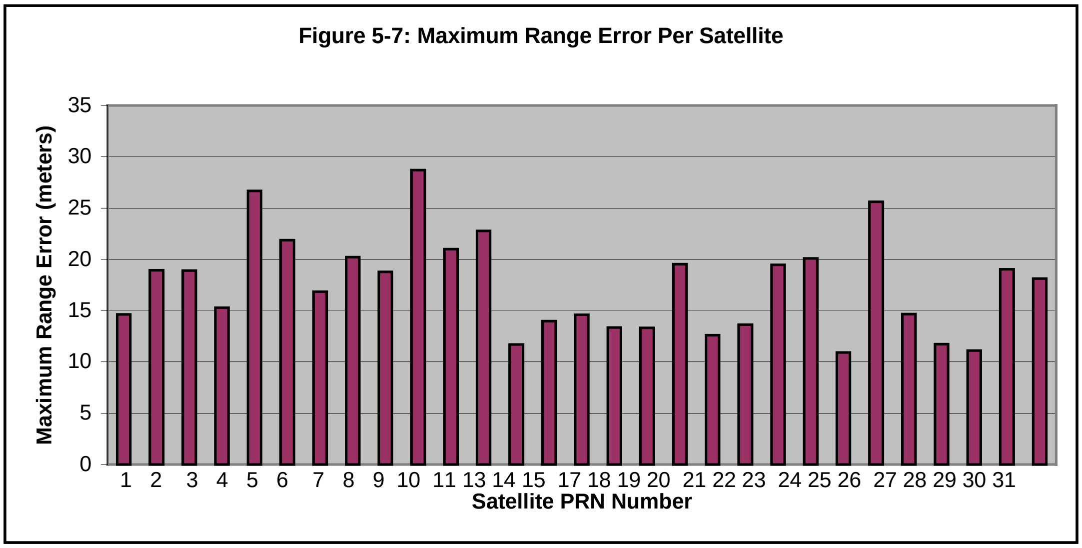


Figure 5-7: Maximum Range Error Per Satellite
Maximum Range Error (meters)
0
5
10
15
20
25
30
35
1 2 3 4 5 6 7 8 9 10 11 13 14 15 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Satellite PRN Number

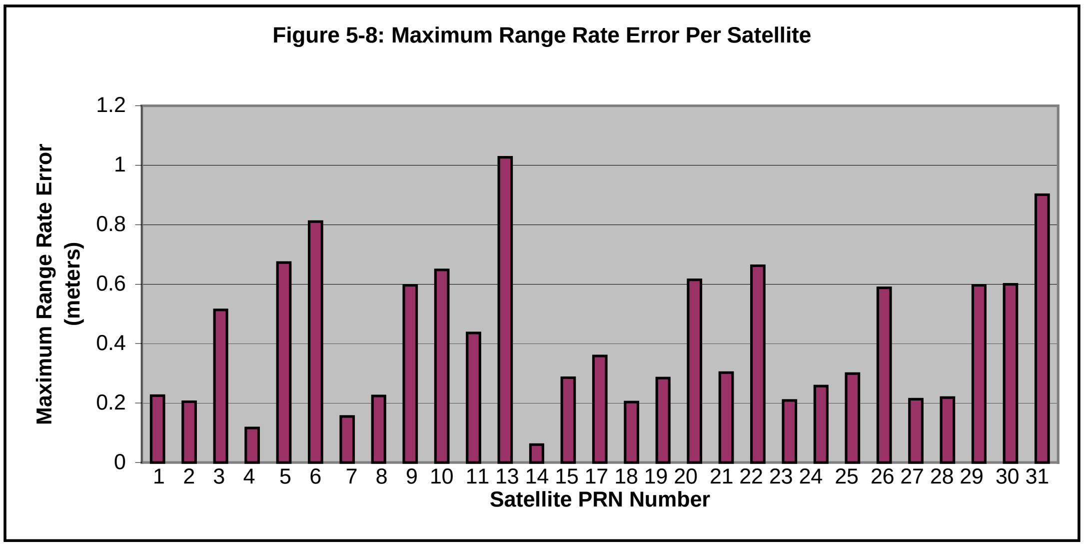


Figure 5-8: Maximum Range Rate Error Per Satellite
Maximum Range Rate Error (meters)
0
0.2
0.4
0.6
0.8
1
1.2
1 2 3 4 5 6 7 8 9 10 11 13 14 15 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Satellite PRN Number

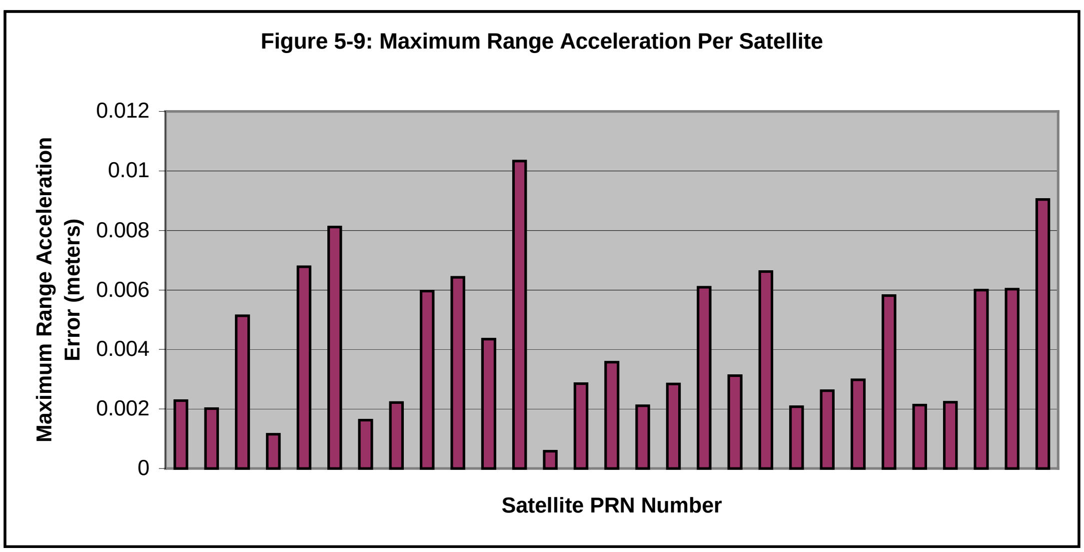


Figure 5-9: Maximum Range Acceleration Per Satellite
Maximum Range Acceleration Error (meters)
0
0.002
0.004
0.006
0.008
0.01
0.012
Satellite PRN Number

6.0 Solar Storms

Solar storm activity is being monitored in order to assess the possible impact on GPS SPS performance. Solar activity is reported by the Space Environment Center (SEC) , a division of the National Oceanic and Atmospheric Administration (NOAA). When storm activity is indicated, ionospheric delays of the GPS signal, satellite outages, position accuracy and availability will be analyzed.

The following article was taken from the SEC web site http://sec.noaa.gov. It briefly explains some of the ideas behind the association of the aurora with geomagnetic activity and a bit about how the ‘K-index’ or ‘K-factor’ works.

The aurora is caused by the interaction of high-energy particles (usually electrons) with neutral atoms in the earth's upper atmosphere. These high-energy particles can ‘excite’ (by collisions) valence electrons that are bound to the neutral atom. The ‘excited’ electron can then ‘de-excite’ and return back to its initial, lower energy state, but in the process it releases a photon (a light particle). The combined effect of many photons being released from many atoms results in the aurora display that you see.

The details of how high energy particles are generated during geomagnetic storms constitute an entire discipline of space science in its own right. The basic idea, however, is that the Earth’s magnetic field (let us say the ‘geomagnetic field’) is responding to an outwardly propagating disturbance from the Sun. As the geomagnetic field adjusts to this disturbance, various components of the Earth’s field change form, releasing magnetic energy and thereby accelerating charged particles to high energies. These particles, being charged, are forced to stream along the geomagnetic field lines. Some end up in the upper part of the earth’s neutral atmosphere and the auroral mechanism begins.

An instrument called a magnetometer may also measure the disturbance of the geomagnetic field. At NOAA’s operations center magnetometer data is received from dozens of observatories in one-minute intervals. The data is received at or near to ‘real-time’ and allows NOAA to keep track of the current state of the geomagnetic conditions. In order to reduce the amount of data NOAA converts the magnetometer data into three-hourly indices, which give a quantitative, but less detailed measure of the level of geomagnetic activity. The K-index scale has a range from 0 to 9 and is directly related to the maximum amount of fluctuation (relative to a quiet day) in the geomagnetic field over a three-hour interval.

The K-index is therefore updated every three hours. The K-index is also necessarily tied to a specific geomagnetic observatory. For locations where there are no observatories, one can only estimate what the local K-index would be by looking at data from the nearest observatory, but this would be subject to some errors from time to time because geomagnetic activity is not always spatially homogenous.

Another item of interest is that the location of the aurora usually changes geomagnetic latitude as the intensity of the geomagnetic storm changes. The location of the aurora often takes on an ‘oval-like’ shape and is appropriately called the auroral oval.

Figures 6-1 through 6-3 show the K-index for three time periods with significant solar activity. Although there were other days with increased solar activity, these time periods were selected as examples. (See Appendix B for the actual geomagnetic data for this reporting period.)

Figure 6-1 K-Index for 29-31 March 2001

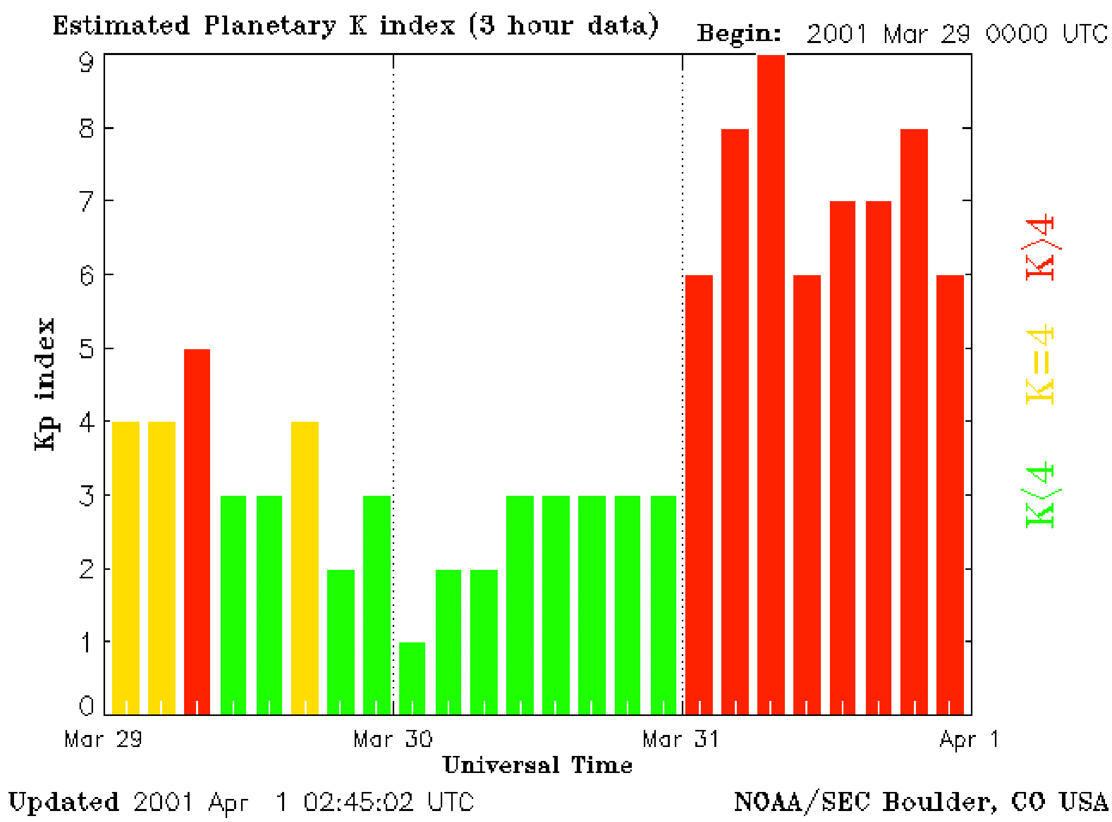


Figure 6-2 K-Index for 19-21 March 2001

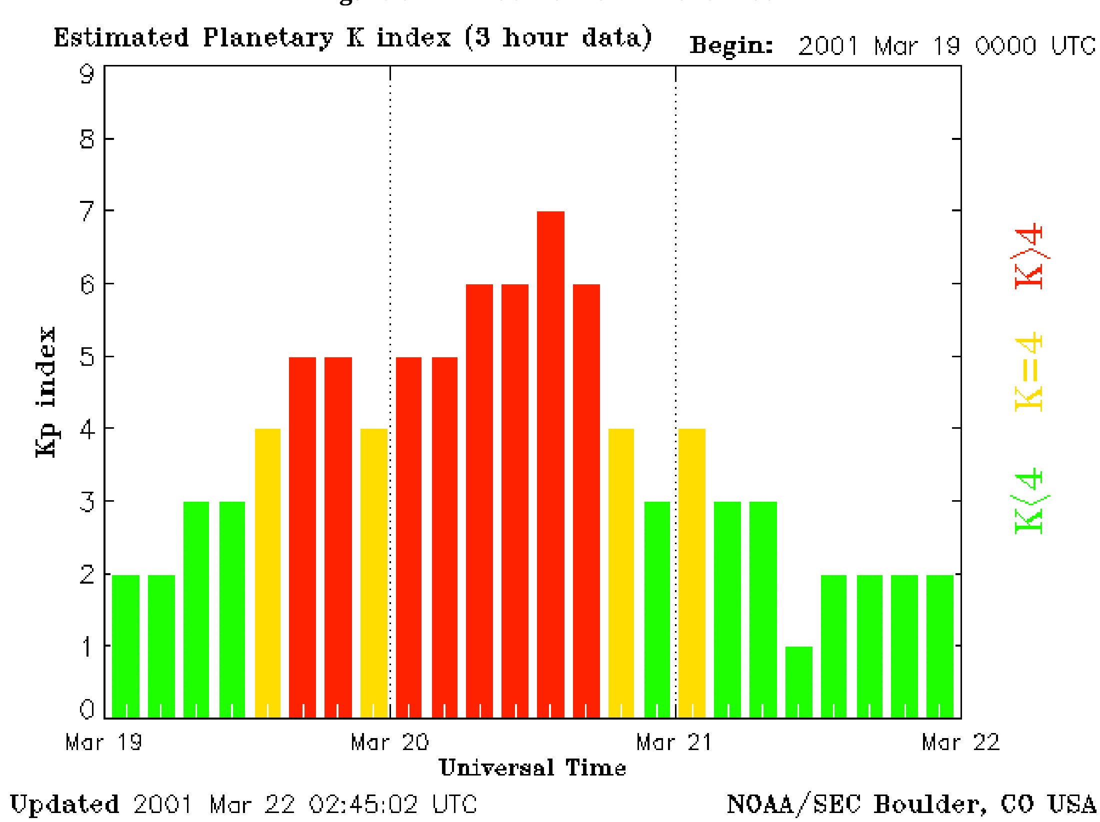
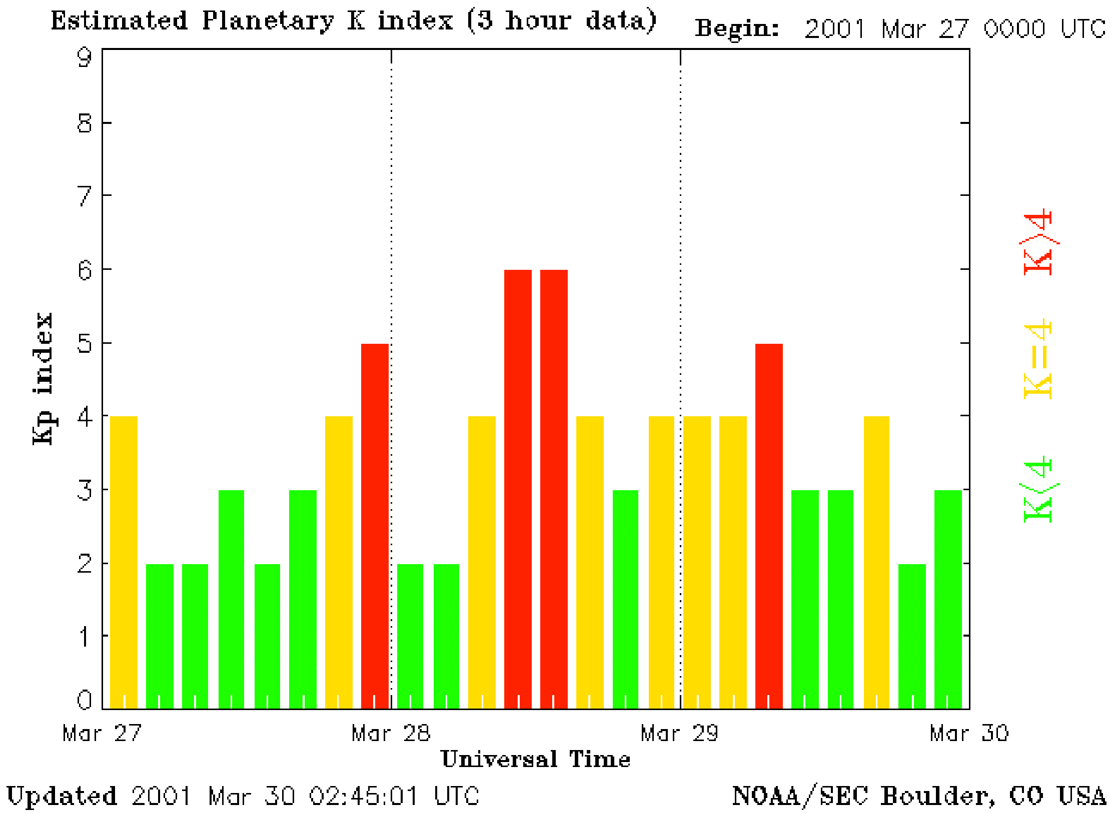


Figure 6-3 K-Index for 27-29 March 2001



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

NSTB Site	Min	Max	Mean	99.99%	99.99% VDOP
Anderson					
03/31/01	1.328	5.730	2.054	5.730	5.455
Atlantic City					
03/31/01	1.289	4.794	1.940	4.782	4.290
Dayton					
03/31/01	1.281	4.155	1.910	4.149	3.855
Elko					
03/31/01	1.241	5.904	2.000	5.877	5.292
Great Falls					
03/31/01	1.386	5.844	2.169	5.837	5.518
Oklahoma City					
03/31/01	1.308	3.449	1.918	3.449	3.075
Kansas City					
03/31/01	1.327	3.317	1.893	3.315	2.944
Salt Lake City					
03/31/01	1.241	3.517	1.875	3.517	2.751

Table 6-2 Horizontal & Vertical Accuracy Statistics*

NSTB Site	95% Horizontal (m)	95% Vertical (m)	99.99% Horizontal (m)	99.99% Vertical (m)
Anderson				
	14.460	10.834	19.473	22.094
Atlantic City				
	15.758	11.316	23.461	20.275
Dayton				
	16.108	12.437	21.867	45.951
Elko				
	5.787	11.320	10.698	20.443
Great Falls				
	6.591	18.376	10.004	25.467
Oklahoma City				
	12.869	12.211	16.455	15.807
Kansas City				
	12.088	15.348	16.407	21.900
Salt Lake City				
	6.759	11.229	10.878	16.375

7.0 GLONASS/GPS Performance

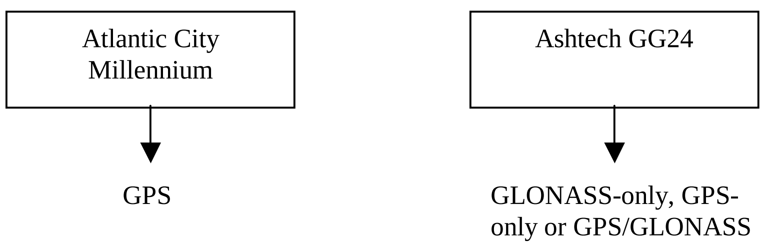
7.1 Introduction

In April 1999, ACT-360 was tasked to monitor, analyze and characterize GLONASS and GPS/GLONASS system performance. The objective of this task is to evaluate the ability of GLONASS to provide navigation by itself and with SPS GPS and to assess the incremental benefit to WAAS obtained from using GLONASS.

7.2 Approach

The GPS, GLONASS and blended data will be collected daily at one-second intervals. Since ACT-360 already collects the GPS data from the NSTB reference station sites, existing techniques and software programs will be used for the GLONASS and blended data collection and analysis. Initially, GPS/GLONASS receivers will be placed only at one site, Atlantic City. The Ashtech GG24 provides the three solutions but only one at a time. Therefore we have the Ashtech permanently outputting a blended solution.

Figure 7-1 Receivers with Corresponding Solutions



Analysis will include the comparison of the different solutions obtained from the Ashtech GG24 and the NSTB Millennium receiver. The GPS/GLONASS receiver solutions will be compared to the Millennium GPS-only and GPS/WAAS-corrected solutions.

The following table summarizes the performance data that will be reported on a quarterly basis.

Performance	**GPS**	**GLONASS**	**GPS+GLONASS**
Coverage	X	X	X
Service Availability	X	X	X
Position Accuracy	X	X	X
Range Accuracy	X	X	X
Time Accuracy	X	X	X
Satellite Visibility	X	X	X
Ionospheric Effects	X	X	X

7.3 Quarter Results

For this quarter, data collected from the Atlantic City Ashtech GG24 Glonass/GPS receiver and the Millennium GPS receiver will be analyzed and compared. Earlier test results using the GG24 were subject to an error that had not been resolved at the time of the last PAN report. The problem has now been identified as an error in the receiver configuration. The solution reported previously did not include any ionospheric correction. On October 31 new firmware was loaded in the receiver and it was reconfigured to apply corrections using a standard ionospheric model. All data included in this report now is acquired using the correct ionospheric model.

Tables 7-1 and 7-2 provide PDOP and Position Accuracy statistics for the two receivers from 1 January through 31 March 2001. The statistics are cumulative.

Table 7-1 PDOP Statistics for Ashtech GG24 & Atlantic City

Receiver	Solution	Maximum PDOP	Minimum PDOP	Mean PDOP	95% PDOP	Number of Samples
Ashtech GG24	GPS/GLONASS	5.738	1.000	1.719	2.385	7668701
Millenium	GPS Only Atlantic City	5.667	1.221	1.854	2.559	7857262

Table 7-2 Position Accuracy Statistics for Ashtech GG24 & Atlantic City

Receiver	Solution	95% Horizontal (m)	95% Vertical (m)	99.99% Horizontal (m)	99.99% Vertical (m)	Number of Samples
Ashtech GG24	GPS/GLONASS	5.574	9.333	24.429	51.983	7668701
Millenium	GPS Only Atlantic City	5.245	6.783	19.486	21.718	7857262

Figures 7-3 and 7-4 show the Horizontal and Vertical Error histograms for the GG24 GLONASS/GPS solution and the GPS-only solution, respectively.

Figure 7-2 Horizontal Position Error Histogram for GPS/GLONASS

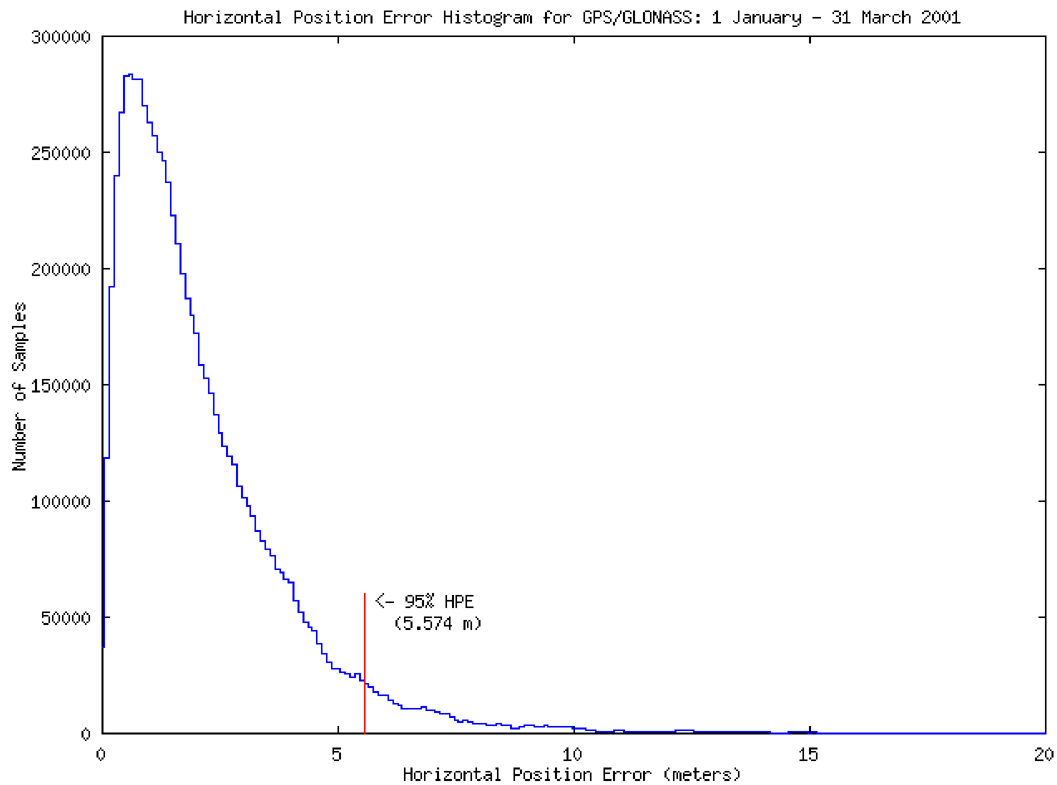


Figure 7-3 Vertical Position Error Histogram for GPS/GLONASS

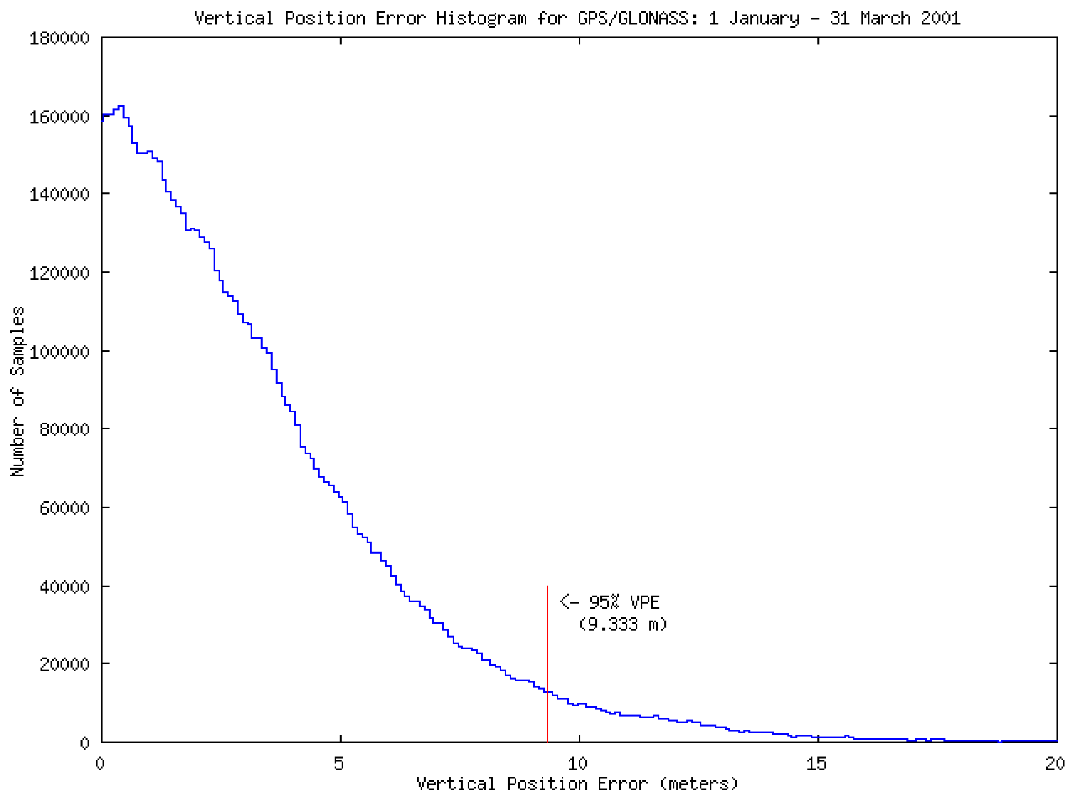
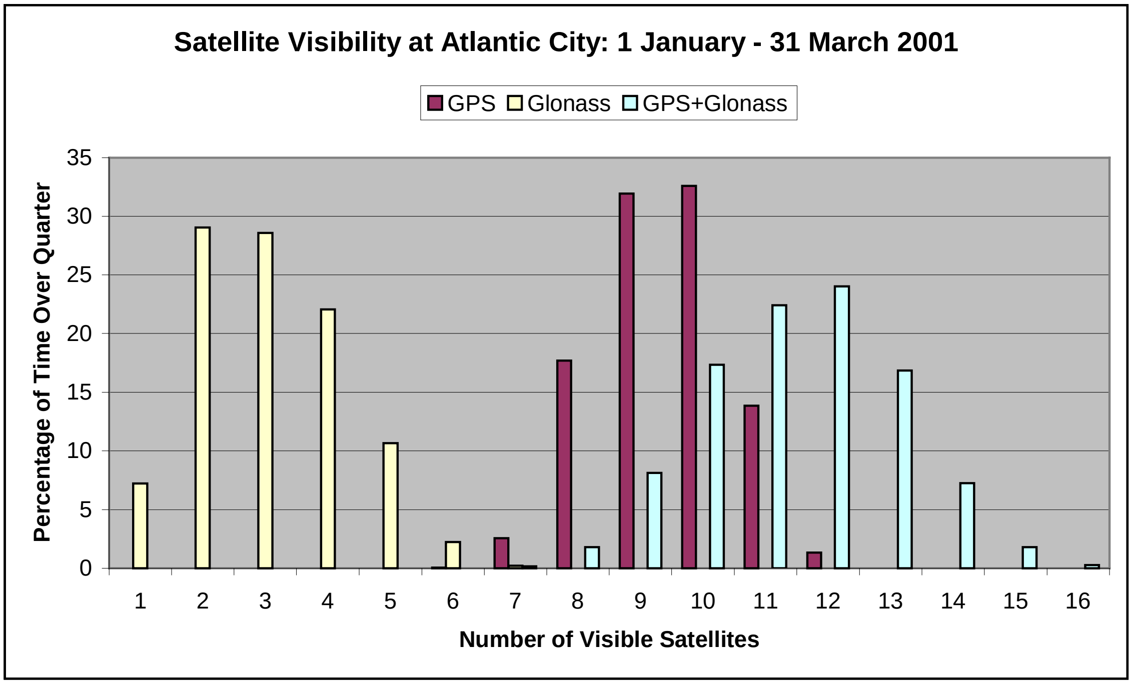


Figure 7-3 Glonass and GPS Satellite Visibility



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	98.028% Availability 99.9% PDOP was 3.065
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	99.990%
• Conditioned on coverage standard • Standard represents a worst-case 24 hour interval, averaged over the globe	≥ 95.87% global average on worst-case day	99.887%
• 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	98.054%
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	≤7.232m horz error 95% ≤19.486m horz error 99.99% ≤8.122m vert error 95% ≤28.313m vert error 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	≤2.340m horz error 95% ≤6.117m vert error 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	≤17 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	28.708m NTE Range Error 1.0266m/s NTE Rate Error 10.33mm/s^2 NTE Accel Error ≤8mm/s^2 100% of the time

```
Product: Daily Geomagnetic Data      quar_DGD.txt
Issued: 2120 UT 07 Apr 2001
#
#  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 - Fredericksburg -		High Latitude ---- College ----		Estimated --- Planetary ---	
Date	A	K-indices	A	K-indices	A	K-indices
2001 01 01	2	0 0 2 2 0 1 1 0	-1	0 1-1 0 0 0 0 0	3	0 0 1 1 1 0 1 1
2001 01 02	2	1 0 0 0 0 1 1 2	0	0 0 0 0 0 0 0 1	4	1 0 0 0 2 2 2 2
2001 01 03	7	2 3 2 3 1 0 1 1	22	1 3 3 6 5 0 0 3	11	2 4 2 3 3 2 2 2
2001 01 04	11	2 1 3 2 2 4 3 2	8	0 1 3 2 3 3 1 1	10	2 1 3 2 3 3 3 2
2001 01 05	5	2 2 1 1 0 0 1 3	2	0 0 1 1 2 0 0 1	6	1 1 1 1 1 3 2 3
2001 01 06	5	3 2 1 1 0 1 0 2	4	2 0 0 2 3 1 0 0	6	2 1 2 1 2 3 2 2
2001 01 07	6	2 2 2 1 1 2 2 2	-1	0 1-1-1-1-1-1-1	5	2 2 1 1 1 2 2 2
2001 01 08	8	2 2 1 1 2 2 3 3	-1	-1-1-1-1-1 1 2 3	10	2 2 1 1 2 2 3 3
2001 01 09	2	1 0 0 1 1 1 1 1	10	2 0 1 3 4 1 4 1	5	1 1 0 1 2 2 2 1
2001 01 10	5	0 0 0 0 1 3 2 3	4	0 0 0 0 1 3 1 2	4	0 0 0 0 1 3 2 2
2001 01 11	4	1 1 1 1 2 2 1 1	6	0 0 0 1 3 3 3 1	5	1 0 0 1 2 2 3 2
2001 01 12	5	2 3 2 2 1 1 0 0	10	2 2 2 5 2 0 0 0	7	2 3 2 3 2 2 1 1
2001 01 13	5	1 1 1 2 3 1 1 1	-1	1 0 1 1-1 1 1 0	5	1 0 1 2 3 2 2 1
2001 01 14	6	1 3 2 1 1 1 2 2	7	1 1 2 4 2 0 2 0	8	1 2 2 2 2 3 3 2
2001 01 15	3	0 0 2 1 1 0 1 2	17	0 0 1 5 5 3 2 3	7	0 0 2 3 3 2 2 3
2001 01 16	4	1 0 2 2 2 1 1 0	-1	2 0 2 2 5 3-1-1	6	0 0 2 2 3 2 3 1
2001 01 17	4	2 1 0 0 1 2 2 1	-1	-1 0 0 0 0 2 2 0	7	3 1 0 1 2 3 3 2
2001 01 18	4	1 0 1 1 2 2 1 1	3	0 0 1 1 3 0 0 0	4	0 0 1 2 1 2 2 2
2001 01 19	3	1 2 0 0 1 0 1 2	1	0 0 0 0 2 0 0 1	4	1 1 0 0 2 2 2 2
2001 01 20	6	0 1 3 2 2 1 1 2	17	0 0 5 3 5 3 2 1	8	0 0 3 2 3 2 3 3
2001 01 21	12	2 1 3 4 3 2 2 3	36	1 1 4 7 4 5 4 3	18	2 2 3 5 4 3 3 4
2001 01 22	8	3 2 2 2 2 2 2 2	17	2 2 2 4 3 4 4 3	10	3 3 2 2 3 3 2 2
2001 01 23	7	1 1 0 3 2 2 3 2	15	2 1 0 3 4 4 3 4	11	1 1 0 3 3 3 4 3
2001 01 24	12	2 2 0 3 4 3 3 2	44	2 3 1 6 6 6 6 2	18	2 3 1 4 5 4 4 3
2001 01 25	2	2 0 0 0 0 1 1 1	3	2 1 0 1 0 0 2 1	4	1 0 0 1 1 2 2 2
2001 01 26	9	2 1 4 2 2 2 2 2	15	1 2 5 4 3 2 2 1	10	2 2 4 3 2 2 2 3
2001 01 27	2	1 2 0 0 1 1 0 0	2	1 1 1 2 0 0 0 1	4	2 2 1 0 1 2 2 1
2001 01 28	6	0 1 1 1 3 2 2 2	10	0 0 2 4 4 2 2 1	6	0 1 1 2 3 2 2 2
2001 01 29	16	5 4 2 1 2 1 3 3	16	5 5 3 2 0 2 2 1	13	4 4 3 1 1 2 2 3
2001 01 30	3	1 3 0 0 1 1 0 0	1	1 1 0 0 0 0 0 0	4	1 3 0 0 1 1 1 1
2001 01 31	11	0 1 3 3 3 3 3 2	34	0 0 4 6 5 6 4 2	18	0 0 4 5 4 4 3 3
2001 02 01	5	2 3 1 1 1 1 1 1	8	1 3 3 2 3 1 1 1	7	1 3 3 2 2 1 1 2
2001 02 02	3	3 1 0 1 0 1 1 0	2	0 1 0 3 0 0 1 1	5	3 2 0 2 1 2 2 1
2001 02 03	0	0 0 0 0 0 0 1 0	0	0 0 0 0 0 0 0 0	2	1 0 0 0 1 1 1 0
2001 02 04	1	0 0 0 1 0 0 1 0	0	0 0 0 0 0 0 1 0	2	0 0 0 0 1 1 1 0
2001 02 05	2	0 0 0 0 1 0 2 1	1	0 0 0 0 1 0 1 0	3	0 0 0 0 1 1 2 2
2001 02 06	11	2 2 4 1 1 2 3 3	17	1 1 5 5 3 2 2 2	11	2 1 4 3 2 3 2 3
2001 02 07	5	2 3 1 0 1 1 1 1	5	2 2 1 2 1 1 2 1	5	2 3 1 1 1 2 2 2
2001 02 08	5	1 1 2 2 1 2 1 2	3	0 1 1 3 0 0 1 1	6	1 2 2 3 0 2 2 3
2001 02 09	3	1 0 0 1 1 2 2 0	-1	1 0 0 1 3-1 1 0	4	0 0 0 1 2 2 2 2
2001 02 10	4	1 2 1 1 2 2 1 0	6	1 1 1 3 1 3 1 0	5	1 2 1 2 2 3 2 1
2001 02 11	5	2 2 2 2 2 0 1 1	11	1 0 4 4 4 0 1 1	7	2 2 3 3 2 2 1 1
2001 02 12	5	2 0 0 0 3 2 1 2	3	1 0 0 1 1 1 1 2	4	1 0 2 0 1 2 2 2
2001 02 13	16	2 3 3 3 3 4 3 3	24	2 3 4 4 4 5 4 3	19	2 4 4 3 3 4 4 4
2001 02 14	14	4 3 2 3 3 1 3 3	26	3 4 2 4 5 5 4 2	17	4 4 3 4 4 3 3 3
2001 02 15	3	1 0 2 2 0 1 1 0	6	1 0 1 4 2 1 1 0	5	1 1 2 3 1 1 2 1
2001 02 16	2	0 1 0 1 1 1 1 1	2	0 0 0 1 1 1 1 1	3	0 0 0 1 1 1 2 2
2001 02 17	2	1 0 0 0 1 1 2 0	1	1 0 0 1 0 1 0 0	3	1 0 0 1 1 2 2 1
2001 02 18	2	1 1 0 1 0 1 1 0	1	0 0 0 0 1 1 0 0	4	1 0 0 0 1 2 2 2
2001 02 19	3	0 1 2 1 2 1 1 0	4	0 0 2 3 1 2 1 0	6	1 1 2 2 2 3 1 2
2001 02 20	9	2 1 2 4 3 2 1 2	-1	-1-1-1-1-1-1-1-1	8	1 1 2 3 3 2 2 2
2001 02 21	6	3 1 0 2 3 2 0 1	13	4 0 1 4 5 1 0 0	6	2 1 1 2 3 2 2 2
2001 02 22	7	1 0 3 3 2 2 2 1	-1	1 0-1-1-1 2 1 1	6	0 0 3 2 1 2 2 3
2001 02 23	9	3 2 3 2 3 1 1 1	18	3 3 4 3 5 3 1 1	11	3 3 4 2 3 3 2 2
2001 02 24	3	1 2 0 0 2 1 0 0	3	1 1 0 2 2 1 0 0	5	1 2 0 2 2 3 1 0

2001 02 25	1	0	1	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	3	0	0	1	1	1	2	1	0
2001 02 26	5	1	0	2	1	1	2	2	2	8	0	1	3	3	2	3	1	2	10	2	0	3	2	2	4	3	3
2001 02 27	8	3	3	3	3	1	0	0	1	20	3	2	6	4	4	1	1	0	13	3	3	4	3	3	2	1	1
2001 02 28	6	0	0	1	2	3	3	2	1	14	1	0	0	3	5	4	3	1	7	1	0	1	2	3	3	3	2
2001 03 01	6	3	1	1	1	1	3	2	1	-1	2	1	-1	-1	-1	1	2	1	5	3	1	1	1	1	2	2	1
2001 03 02	6	1	1	2	1	2	2	3	1	12	1	0	2	4	4	3	3	1	8	1	1	2	2	2	3	3	3
2001 03 03	7	2	2	0	2	2	2	3	2	25	2	2	0	5	6	4	4	2	14	2	3	1	4	4	3	4	3
2001 03 04	13	2	2	3	2	3	2	3	4	27	1	3	3	6	5	3	3	4	17	3	3	4	3	3	3	4	4
2001 03 05	14	5	3	3	2	3	1	1	2	22	4	4	4	5	3	3	1	3	18	5	4	4	4	2	2	2	2
2001 03 06	4	1	1	2	1	1	2	2	0	-1	-1	-1	-1	-1	-1	-1	-1	-1	6	1	1	2	2	2	2	3	2
2001 03 07	9	2	2	3	2	2	3	2	1	10	1	1	2	4	3	3	2	1	7	1	2	3	2	2	3	2	1
2001 03 08	7	0	0	2	3	2	3	2	2	8	1	0	3	4	1	2	2	1	6	1	0	2	3	1	2	2	2
2001 03 09	7	3	2	2	1	2	2	1	1	-1	1	1	-1	-1	-1	4	2	0	6	2	1	2	1	2	3	2	1
2001 03 10	3	0	2	1	1	1	1	2	0	3	0	0	1	1	3	0	1	0	5	1	2	1	1	2	2	3	1
2001 03 11	2	1	2	0	0	1	0	0	0	1	0	0	0	1	1	0	0	0	4	0	1	0	1	2	1	2	1
2001 03 12	8	0	0	1	2	3	2	3	3	11	0	0	2	4	4	2	2	3	10	1	0	2	3	3	3	3	3
2001 03 13	6	2	2	2	3	0	1	1	1	-1	-1	-1	2	-1	3	1	0	1	7	2	2	2	3	2	2	2	2
2001 03 14	8	3	2	3	2	2	1	1	2	8	1	1	3	4	3	0	1	0	7	2	2	3	3	2	1	2	1
2001 03 15	2	0	0	1	0	2	0	1	1	2	0	0	1	1	0	0	0	0	3	0	0	2	1	1	1	2	1
2001 03 16	1	0	0	0	0	2	0	0	1	3	0	0	0	3	0	1	1	0	2	0	0	0	0	1	2	2	1
2001 03 17	2	0	0	0	0	2	1	1	1	2	0	0	0	0	1	1	2	1	4	0	0	0	0	2	3	2	1
2001 03 18	5	2	2	2	1	2	0	0	2	8	1	2	2	4	3	1	0	1	7	3	3	2	2	1	2	2	2
2001 03 19	19	2	2	1	2	4	4	5	4	46	0	2	3	3	6	7	6	4	22	2	2	3	3	4	5	5	4
2001 03 20	27	4	4	4	5	4	4	3	3	105	4	5	7	7	7	8	6	4	66	5	5	6	6	7	6	4	3
2001 03 21	7	3	3	3	1	1	1	1	1	-1	2	1	3	-1	-1	-1	0	1	19	4	3	3	1	2	2	2	2
2001 03 22	9	1	1	1	0	3	4	2	3	8	1	1	0	0	2	4	3	2	10	1	0	1	1	3	4	2	3
2001 03 23	17	2	4	3	4	3	3	3	3	31	2	3	4	5	5	6	3	2	21	3	4	4	4	3	4	3	3
2001 03 24	6	1	3	2	1	2	2	2	0	25	2	3	5	5	5	4	2	0	13	1	3	4	3	3	3	3	2
2001 03 25	5	0	2	2	2	2	1	1	1	7	0	1	3	4	2	0	1	0	8	1	2	3	3	2	2	3	2
2001 03 26	2	0	0	0	1	1	1	0	2	6	0	0	0	3	4	0	0	1	6	0	0	1	1	3	2	3	2
2001 03 27	16	4	2	2	1	2	1	4	5	19	3	3	1	4	2	2	4	5	18	4	2	2	3	2	3	4	5
2001 03 28	19	2	1	4	4	5	3	2	3	40	3	2	5	6	6	5	4	3	31	2	2	4	6	6	4	3	4
2001 03 29	17	4	4	4	2	3	3	2	2	26	3	5	5	4	4	4	2	2	22	4	4	5	3	3	4	2	3
2001 03 30	8	2	2	1	1	2	1	3	3	14	1	2	3	3	4	4	2	2	10	1	2	2	3	3	3	3	3
2001 03 31	115	6	8	7	5	6	5	8	5	93	5	7	6	4	6	8	6	5	155	6	8	9	6	7	7	8	6

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:

There was one failure of the GPS Standard Positioning Service Signal Specification (SPS) during this quarter. On March 26, 2001, availability dropped to 99.054% at Oklahoma City. This value was below the 99.16% availability specification. This drop in availability is due to NANU# 1049 for PRN 4. The outage of satellite PRN 4 lasted 5.05 hours. Horizontal accuracy was not noticeably affected, however the vertical accuracy was slightly above the average. The 95% horizontal and vertical error was 5.281 and 11.096 meters respectively. The maximum PDOP for that day was 10.234, with a PDOP mean and 95% of 1.953 and 2.714 respectively.

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.