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

Submitted To

Federal Aviation Administration
GPS Product Team
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Submitted by

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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. Quarterly data from Gander has been omitted from this report, however the receiver has been fixed and data will be included in the next report. This analysis verifies the GPS SPS performance as compared to the performance parameters stated in the SPS Specification Annex A.

This report, Report #32, includes data collected from 1 October through 31 December 2000. The next quarterly report will be issued 30 April 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 October and 31 December 2000 and by calculating the satellite availability from the data obtained from the nine sites. A total of fourteen outages were reported in the NANU’s. Eleven of the outages were scheduled and three were unscheduled. The quarterly availabilities for Anderson, Atlantic City, Dayton, Elko, Great Falls, Oklahoma City, Kansas City, and Salt Lake City were 99.988%, 99.996%, 99.991%, 100%, 100%, 99.992%, 99.988%, 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 24.04 meters on Satellite PRN 5. The SPS specification states that the range error should never exceed 150 meters. The maximum range rate error recorded was 1.05396 Meters/second on Satellite PRN 31. The SPS specification states that the range rate error should never exceed 2 meters/second. The maximum range acceleration error recorded was 10.54 Millimeters/second^2 on Satellite PRN 31. 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 6.556 Meters and 27.557 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.

From the analysis performed on data collected between 1 October and 31 December 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 met for 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	✓
<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	✓

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

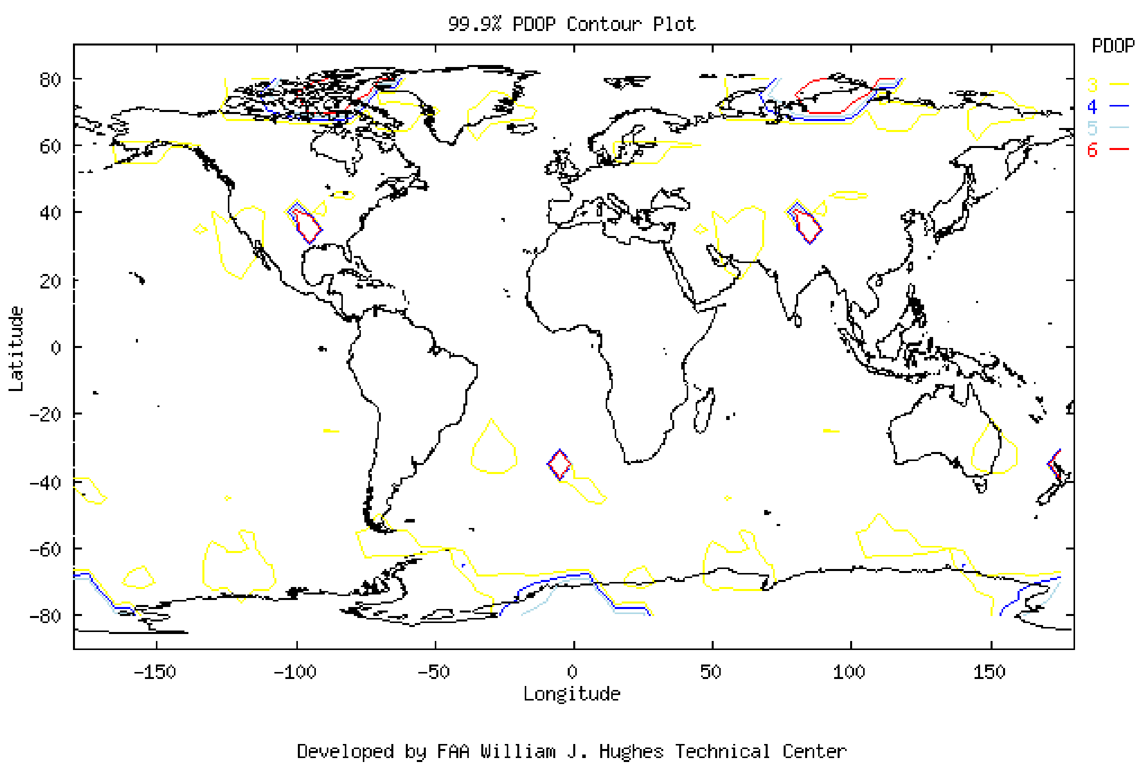
Almanacs for GPS weeks 58-70 used for this coverage portion of the report were obtained from the Coast Guard web site (www.navcen.uscg.mil). Using these almanacs, an SPS coverage area program developed by ACT-360 was used to calculate the PDOP at every 5^{o} point between longitudes of 180W to 180E and 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 5.52 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%)
58	4.48	99.90%	98.19%
59	3.33	99.98%	98.61%
60	5.52	99.92%	98.05%
61	3.35	99.98%	98.54%
62	3.35	99.98%	98.61%
63	3.35	99.98%	98.68%
64	3.34	99.98%	98.81%
65	3.34	99.98%	98.81%
66	3.33	99.98%	98.81%
67	3.51	99.98%	98.81%
68	3.31	99.98%	98.47%
69	3.07	99.99%	98.88%
70	3.06	99.98%	98.95%

Figure 2-1 SPS Coverage (24-Hour Period: 15 October 2000)



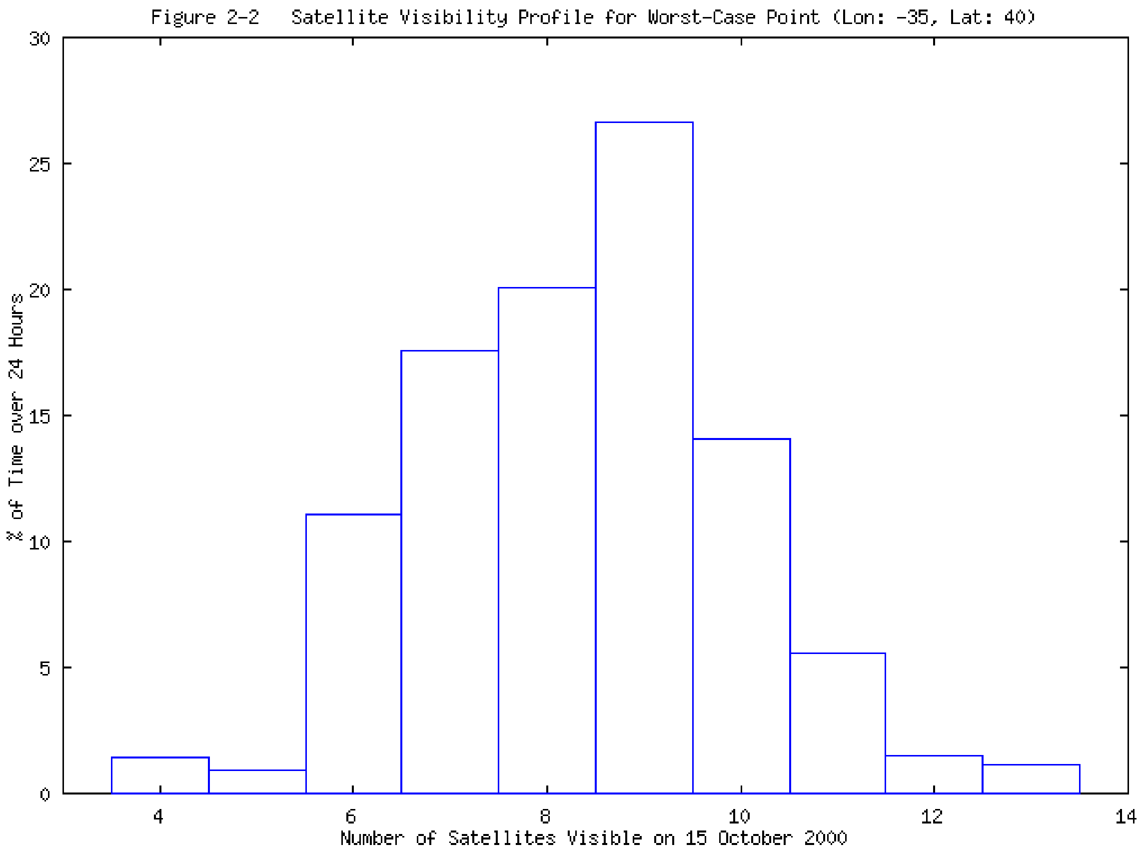


Figure 2-2 Satellite Visibility Profile for Worst-Case Point (Lon: -35, Lat: 40)
% of Time over 24 Hours
30
25
20
15
10
5
0
4
6
8
10
12
14
Number of Satellites Visible on 15 October 2000

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 October through 31 December 2000, 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 Unscheduled	Total Scheduled	Total
155	25	S	1-Oct	19:30	2-Oct	4:02		8.53	8.53
162	15	S	5-Oct	15:00	4-Oct	21:06		6.10	6.10
164	11	S	5-Oct	8:12	5-Oct	18:27		10.25	10.25
167	13	S	10-Oct	6:15	11-Oct	1:59		19.73	19.73
168	20	S	11-Oct	14:29	11-Oct	16:19		1.83	1.83
171	11	S	12-Oct	7:40	13-Oct	16:39	8.98	24.00	32.98
174	28	S	17-Oct	13:13	18-Oct	6:32		17.32	17.32
175	26	S	19-Oct	8:38	19-Oct	15:57		7.32	7.32
181	27	S	27-Oct	14:38	27-Oct	18:50		4.20	4.20
182	11	S	30-Oct	11:14	30-Oct	18:50		7.60	7.60
183	27	S	1-Nov	18:47	2-Nov	2:59		8.20	8.20
188	5	S	16-Nov	1:34	16-Nov	11:29		9.92	9.08
191	21	S	22-Nov	11:53	22-Nov	20:55		9.03	9.03
192	3	S	29-Nov	5:09	29-Nov	11:22		6.22	6.22
194	13	S	1-Dec	12:27	1-Dec	17:53		5.43	5.43
198	27	S	4-Dec	18:37	4-Dec	23:38		5.02	5.02
199	17	S	6-Dec	3:46	6-Dec	4:59		1.22	1.22
204	23	S	11-Dec	21:22	12-Dec	7:27		10.08	10.08
207	28	S	17-Dec	15:26	17-Dec	20:56		5.50	5.50
208	30	S	18-Dec	22:03	19-Dec	2:06		2.05	2.05
209	31	S	19-Dec	18:55	20-Dec	4:02		9.12	9.12
212	30	S	21-Dec	21:33	22-Dec	4:12		6.65	6.65
156	25	U	2-Oct	16:52	N/A	N/A	N/A	N/A	N/A
158	25	U	2-Oct	16:52	4-Oct	3:38	34.77	0.00	34.77
179	24	U	26-Oct	23:20	N/A	N/A	N/A	N/A	N/A
180	24	U	26-Oct	23:20	27-Oct	9:19	9.98	0.00	9.98
185	20	U	10-Nov	2:36	N/A	N/A	N/A	N/A	N/A
186	20	U	10-Nov	2:36	10-Nov	7:36	5.00	0.00	5.00
196	22	U	2-Dec	6:33	N/A	N/A	N/A	N/A	N/A
197	22	U	2-Dec	6:33	4-Dec	20:23	61.83	0.00	61.83
202	14	U	10-Dec	21:12	N/A	N/A	N/A	N/A	N/A
Actual Unscheduled and Scheduled Downtime and Total Actual Downtime							**120.56**	**176.79**	**296.51**
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
149	15	F	4-Oct	14:00	4-Oct	20:00	6	See NANU 159
151	25	F	1-Oct	19:00	2-Oct	7:00	12	See NANU 155
150	11	F	5-Oct	8:00	5-Oct	20:00	12	See NANU 164
157	13	F	10-Oct	6:00	11-Oct	7:00	25	See NANU 167
163	20	F	11-Oct	14:00	12-Oct	2:00	12	See NANU 168
165	11	F	12-Oct	11:15	12-Oct	23:15	12	See NANU 166
169	28	F	17-Oct	12:00	18-Oct	0:00	12	See NANU 173
170	26	F	19-Oct	8:30	9-Oct	20:30	12	See NANU 175
176	27	F	27-Oct	14:00	28-Oct	2:00	12	See NANU 181
177	11	F	30-Oct	10:45	30-Oct	22:45	12	See NANU 182
178	27	F	1-Nov	18:00	2-Nov	6:00	12	See NANU 183
184	5	F	16-Nov	1:30	16-Nov	13:30	12	See NANU 188
187	21	F	22-Nov	11:15	22-Nov	23:15	12	See NANU 191
189	3	F	29-Nov	4:45	29-Nov	16:45	12	See NANU 192
190	13	F	1-Dec	12:00	2-Dec	0:00	12	See NANU 194
193	27	F	4-Dec	18:00	5-Dec	6:00	12	See NANU 198
195	17	F	6-Dec	3:15	6-Dec	15:15	12	See NANU 199
200	23	F	11-Dec	21:00	12-Dec	9:00	12	See NANU 204
201	28	F	17-Dec	15:00	18-Dec	3:00	12	See NANU 207
203	30	F	18-Oct	21:30	19-Dec	9:30	12	See NANU 208
205	31	F	19-Dec	18:15	20-Dec	6:15	12	See NANU 209
206	30	F	21-Dec	21:30	22-Dec	9:30	12	See NANA 212
159	15	Extended	5-Oct	15:00	N/A	N/A	0	See NANU 160
161	15	Extended	4-Oct	15:00	N/A	N/A	0	See NANU 162
166	11	Rescheduled	12-Oct	7:30	13-Oct	19:30	24	See NANU 171
173	28	Extended	17-Oct	12:00	N/A	N/A	0	See NANU 174
				Total Forecast Downtime			295	

	Table 3-3 NANUs Canceled				
NANU#	PRN	Type	Start Date	Start Time	Comments
160	15	C	5-Oct	15:00	See NANU 159

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 Oct - 31 December, 2000	12 December, 1998- 31 December, 2000
Total Forecast Downtime (hrs):	295	2576.47
Total Actual Downtime (hrs):	296.51	4436.91
Total Actual Scheduled Downtime (hrs):	176.97	1137.58
Total Actual Unscheduled Downtime (hrs):	120.56	3275.35
Total Satellite Observed MTTR (hrs):	11.4	18.68
Scheduled Satellite Observed MTTR (hrs):	8.04	7.15
Unscheduled Satellite Observed MTTR (hrs):	19.2	55.22
# Total Satellite Outages:	26	169
# Scheduled Satellite Outages:	22	133
# Unscheduled Satellite Outages:	4	36
Percent Operational -- Scheduled Downtime:	99.87%	99.78%

3.2 Service Availability

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

To verify availability, the data collected from receivers at the nine NSTB/WAAS sites was reduced to calculate DOP information and reported in Tables 3-5 to 3-7. The data was collected at one-second intervals between 1 October and 31 December 2000.

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	1.300	6.622	6.394	1.887	4.115	3.693	7628460
Atlantic City	1.232	7.481	4.276	1.871	4.151	3.604	7154892
Dayton	1.251	8.388	8.120	1.834	3.750	3.241	7621945
Elko	1.208	6.565	6.005	1.864	5.642	5.102	7603956
Gander*	-	-	-	-	-	-	-
Great Falls	1.407	13.596	3.636	2.104	5.270	4.519	6764233
Oklahoma City	1.152	6.865	5.934	1.836	3.751	3.242	7644710
Kansas City	1.151	6.825	6.742	1.845	3.512	3.055	7112641
Salt Lake City	1.196	5.954	4.866	1.836	3.782	3.164	6904733

* Not analyzed due to mechanical problems.

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.

All of the Satellite Availability data evaluated met 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	58_1	6.622	464	155 (PRN 25)	85412	98.457%
Worst-Case Point on Worst-Case Day = 98.457% (SPS Spec. ≥ 83.92%)						

Global Average on Worst-Case Day = 99.823 % (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	7628460	913	99.988
Atlantic City	7154892	245	99.996
Dayton	7621945	686	99.991
Elko	7603956	4	100
Gander*	-	-	-
Great Falls	6764233	9	100
Oklahoma City	7644710	595	99.992
Kansas City	7112641	827	99.988
Salt Lake City	6904733	0	100
Worst Single Point Average = 99.457% (SPS Spec. ≥ 99.16%)			

* Not analyzed due to mechanical problems.

Global Average over Reporting Period = 99.994% (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	7628460	16.9
Atlantic City	7154892	21.3
Dayton	7621945	16.8
Elko	7603956	20.7
Gander	-	-
Great Falls	6764233	20.2
Oklahoma City	7644710	22.1
Kansas City	7112641	17.6
Salt Lake City	6904733	17.5

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 October through 31 December 2000 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	5.421	8.954	8.988	16.399
Atlantic City	6.228	8.708	9.892	15.753
Dayton	5.939	8.659	9.475	15.439
Elko	5.457	8.382	9.023	16.968
Gander *	-	-	-	-
Great Falls	7.401	8.190	11.045	13.424
Oklahoma City	5.522	8.537	8.598	13.608
Kansas City	5.606	8.251	8.777	13.487
Salt Lake City	5.586	8.223	8.318	12.943

* Not analyzed due to mechanical problems.

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 October to 31 December 2000.

Figure 5-1 Combined Vertical Error Histogram

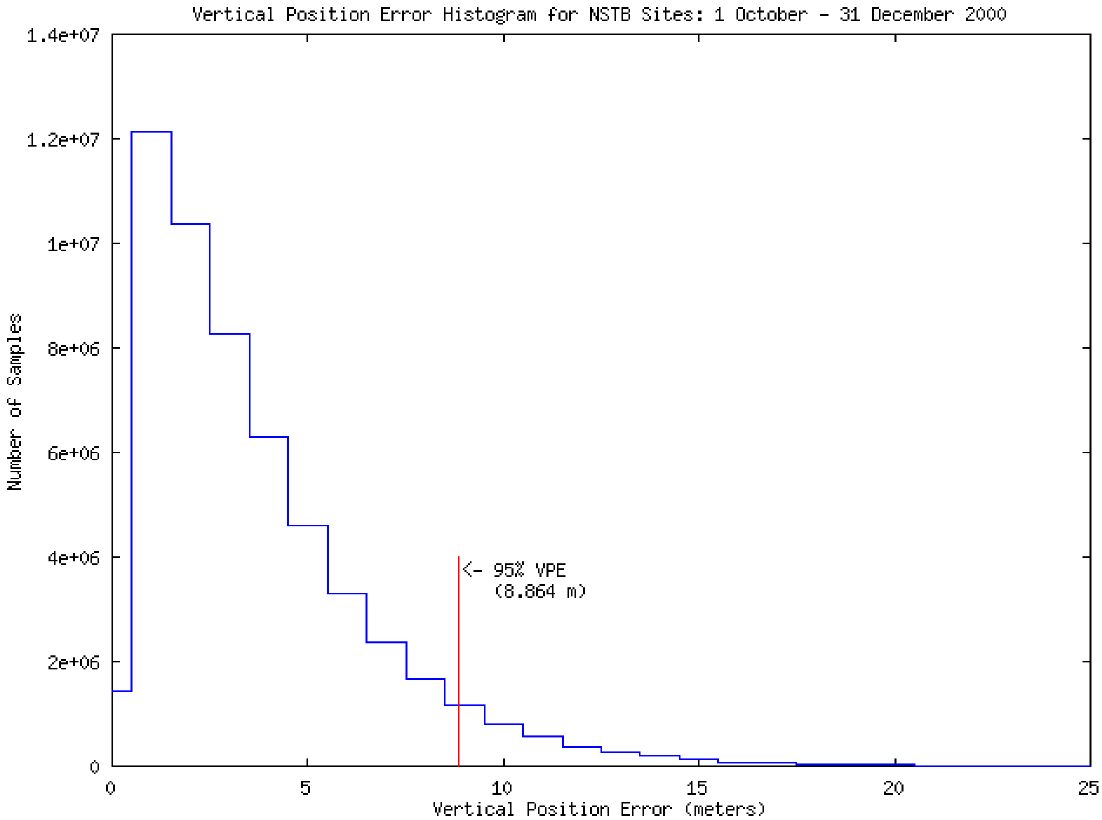
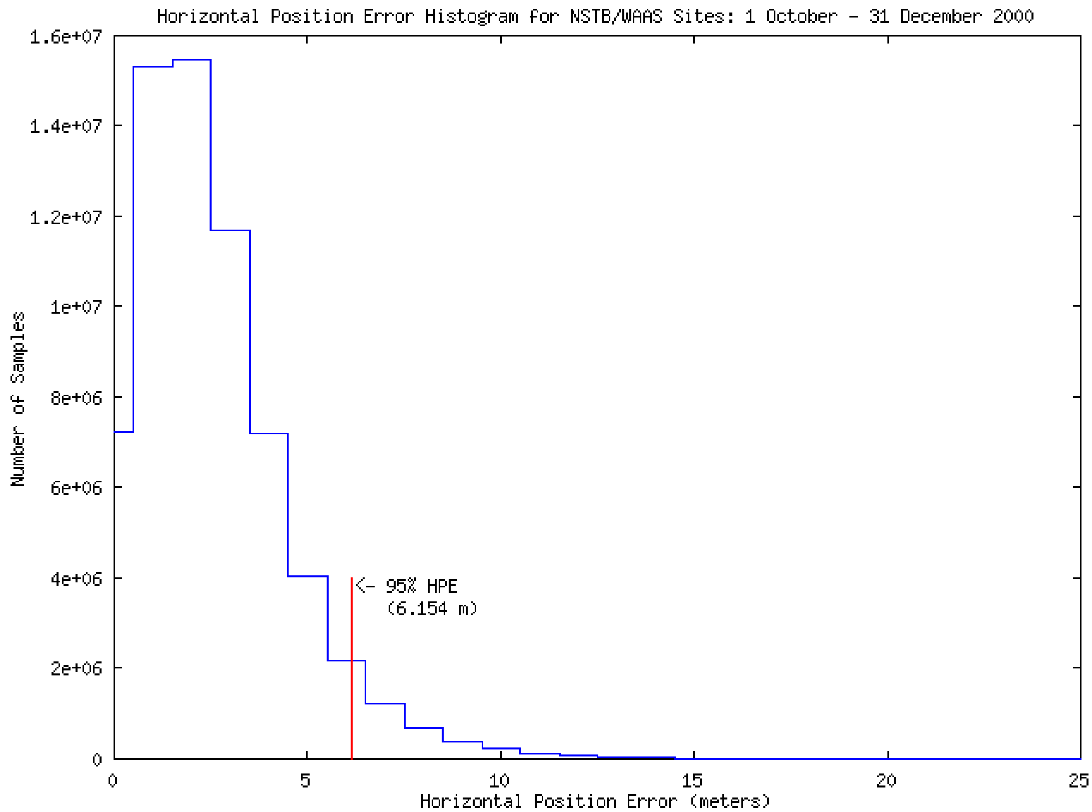


Figure 5-2 Combined Horizontal Error Histogram



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	2.430	6.219
Atlantic City	2.678	5.869
Dayton	2.652	6.125
Elko	2.425	5.373
Gander	-	-
Great Falls	2.642	4.993
Oklahoma City	2.147	4.686
Kansas City	2.339	4.965
Salt Lake City	2.475	5.263

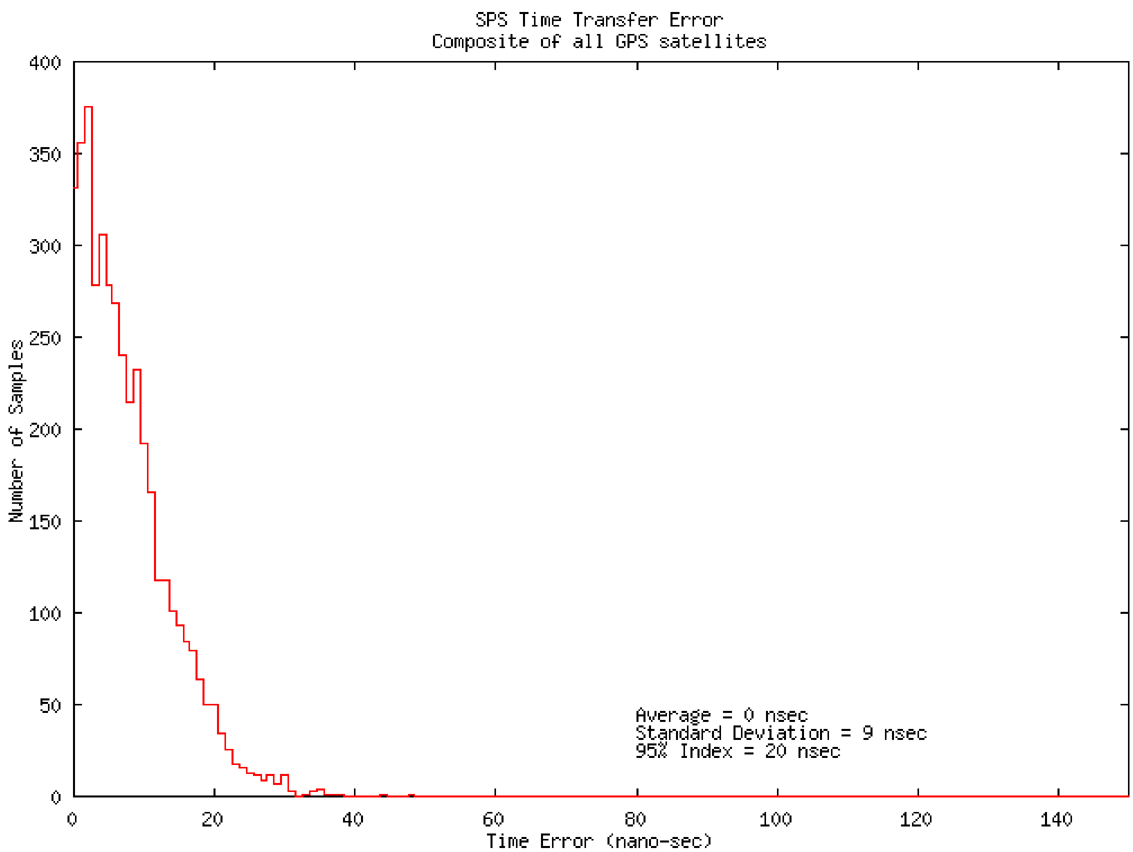
5.3 Relative Accuracy

To be included in future reports.

5.4 Time Transfer Accuracy

The GPS time error data between 1 October and 31 December 2000 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 October and 31 December 2000. 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	-1.585	3.565	2.369	2.930	15.450	1739824
2	1.519	3.365	2.719	4.401	22.940	2131075
3	-1.400	3.380	2.541	4.793	20.700	2161952
4	0.156	2.224	1.982	5.185	15.460	2172751
5	0.331	2.520	2.268	5.195	24.040	2442302
6	0.241	2.607	2.208	5.244	19.440	2130692
7	1.788	3.296	2.611	6.087	23.310	2339223
8	1.422	2.934	2.121	3.989	18.560	1810112
9	0.012	2.880	2.589	6.302	22.850	2405962
10	0.510	2.106	1.760	4.567	22.690	2015880
11	-0.440	2.619	2.360	5.391	23.260	2209330

13	-1.146	2.889	2.273	3.293	23.120	2065482
14	0.647	2.169	1.968	4.930	9.690	476530
15	-0.296	3.569	2.667	9.791	15.210	1691422
17	0.577	2.892	2.328	5.224	18.110	1975177
19	-0.935	3.294	2.349	1.931	14.820	2058401
20	-1.332	2.931	2.427	3.724	22.830	2442630
21	-0.821	3.467	2.433	3.117	15.820	2029626
22	-1.830	4.022	2.756	3.842	18.410	1817454
23	-0.492	3.326	2.677	8.497	19.860	2317102
24	0.596	2.326	1.966	5.665	12.170	2317738
25	-2.442	3.994	2.561	3.028	16.030	2139578
26	0.702	2.230	1.913	4.724	22.410	1728316
27	0.140	3.092	2.397	2.676	15.000	1898672
28	-2.036	3.894	2.479	5.361	17.780	2034032
29	-1.654	3.571	2.588	4.685	15.570	2278154
30	-0.707	2.784	2.423	3.499	19.750	2359099
31	-0.171	3.339	2.626	7.282	22.110	1779023

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	-0.00028	0.00562	0.00528	0.01019	0.23579	1739824
2	-0.00061	0.00641	0.00626	0.01197	0.23645	2131075
3	-0.00053	0.00820	0.00789	0.01423	0.94974	2161952
4	-0.00066	0.00637	0.00600	0.01232	0.14521	2172751
5	-0.00086	0.00980	0.00943	0.01737	0.76377	2442302
6	0.00006	0.01011	0.00977	0.02026	0.62804	2130692
7	-0.00066	0.00629	0.00610	0.01309	0.16730	2339223
8	-0.00057	0.00546	0.00529	0.01091	0.19204	1810112
9	-0.00049	0.01048	0.01016	0.01961	0.98193	2405962
10	-0.00059	0.00647	0.00613	0.01149	0.58662	2015880
11	-0.00055	0.01133	0.01109	0.01737	0.91365	2209330
13	-0.00032	0.01010	0.00988	0.01941	0.85519	2065482
14	0.00004	0.00559	0.00559	0.01099	0.10914	476530
15	-0.00052	0.00684	0.00637	0.01243	0.39924	1691422
17	-0.00049	0.00575	0.00528	0.01054	0.25615	1975177
19	-0.00035	0.00652	0.00619	0.01220	0.32033	2058401
20	-0.00032	0.00995	0.00973	0.01737	0.96019	2442630
21	-0.00047	0.00631	0.00583	0.01153	0.20414	2029626
22	-0.00028	0.00637	0.00636	0.01229	0.61794	1817454
23	-0.00068	0.00731	0.00687	0.01474	0.23715	2317102

24	-0.00066	0.00607	0.00572	0.01148	0.25531	2317738
25	-0.00055	0.00601	0.00562	0.01142	0.19839	2139578
26	-0.00054	0.00899	0.00863	0.01299	0.80010	1728316
27	-0.00046	0.00577	0.00549	0.01104	0.21425	1898672
28	-0.00071	0.00604	0.00565	0.01183	0.20926	2034032
29	-0.00069	0.00659	0.00614	0.01337	0.34017	2278154
30	-0.00079	0.00942	0.00904	0.01757	1.00533	2359099
31	-0.00061	0.00747	0.00714	0.01307	1.05396	1779023

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

PRN	Range Acceleration Error Mean *	Range Acceleration Error RMS	Range Acceleration 1 s	% ≤ 0.008 (SPS Spec. 95% of Time)	Max Range Acceleration Error (SPS Spec. ≤ 0.019 m/s2)	Samples
1	0	0.00005	0.00005	100	0.00238	1739824
2	0	0.00006	0.00006	100	0.00236	2131075
3	0	0.00007	0.00007	100	0.00954	2161952
4	0	0.00005	0.00005	100	0.00149	2172751
5	0	0.00009	0.00009	100	0.00766	2442302
6	0	0.00010	0.00010	100	0.00635	2130692
7	0	0.00005	0.00005	100	0.00166	2339223
8	0	0.00004	0.00004	100	0.00195	1810112
9	0	0.00010	0.00010	100	0.00989	2405962
10	0	0.00005	0.00005	100	0.00584	2015880
11	0	0.00010	0.00010	100	0.00913	2209330
13	0	0.00010	0.00010	100	0.00857	2065482
14	0	0.00004	0.00004	100	0.00116	476530
15	0	0.00005	0.00005	100	0.00400	1691422
17	0	0.00005	0.00005	100	0.00250	1975177
19	0	0.00006	0.00006	100	0.00317	2058401
20	0	0.00010	0.00010	99.999	0.00963	2442630
21	0	0.00005	0.00005	100	0.00198	2029626

22	0	0.00006	0.00006	100	0.00615	1817454
23	0	0.00007	0.00007	100	0.00239	2317102
24	0	0.00005	0.00005	100	0.00258	2317738
25	0	0.00005	0.00005	100	0.00199	2139578
26	0	0.00009	0.00009	100	0.00802	1728316
27	0	0.00005	0.00005	100	0.00212	1898672
28	0	0.00006	0.00006	100	0.00209	2034032
29	0	0.00005	0.00005	100	0.00343	2278154
30	0	0.00009	0.00009	100	0.01016	2359099
31	0	0.00007	0.00007	100	0.01054	1779023

* The Range Acceleration Error Mean's resolution in our statistics calculation does not allow us to see the true value of the mean. Taking into consideration our resolution, the mean value for each satellite is actually (0.00000 meters/second^2)

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 5 with an error of 24.040 meters. Satellite 14 had the lowest maximum range error of 9.690.

Figure 5-4 Distribution of Daily Max Range Errors

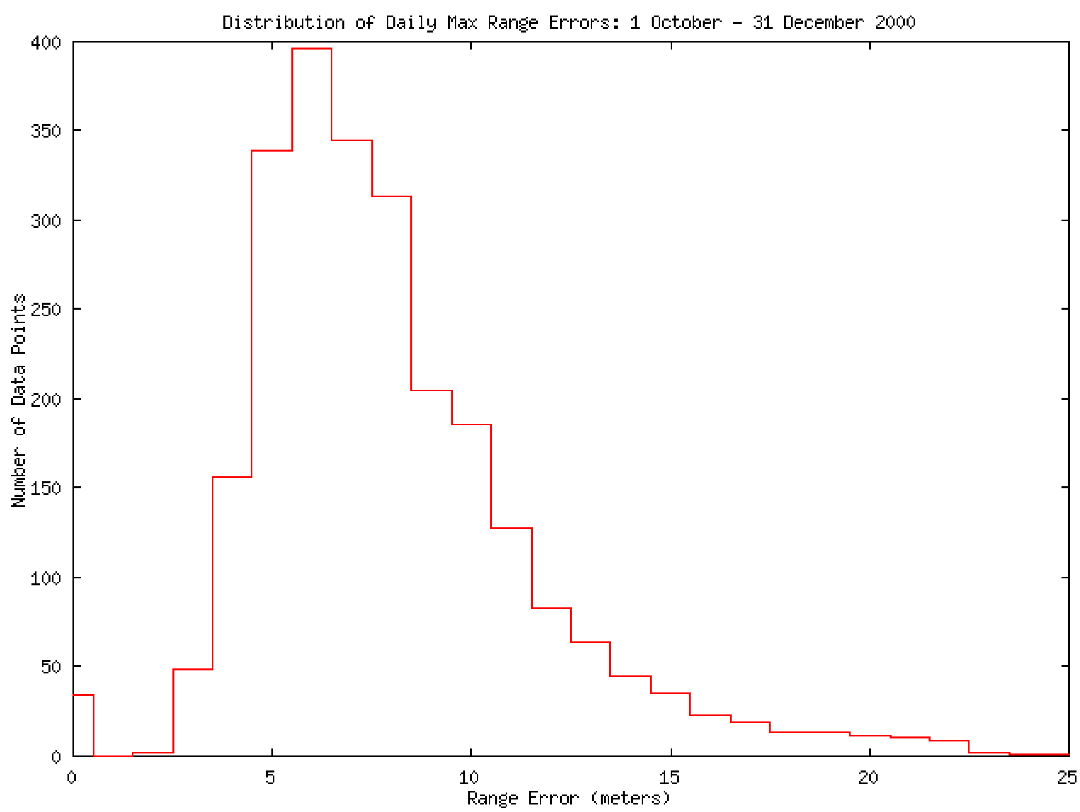


Figure 5-5: Distribution of Daily Max Range Rate Errors

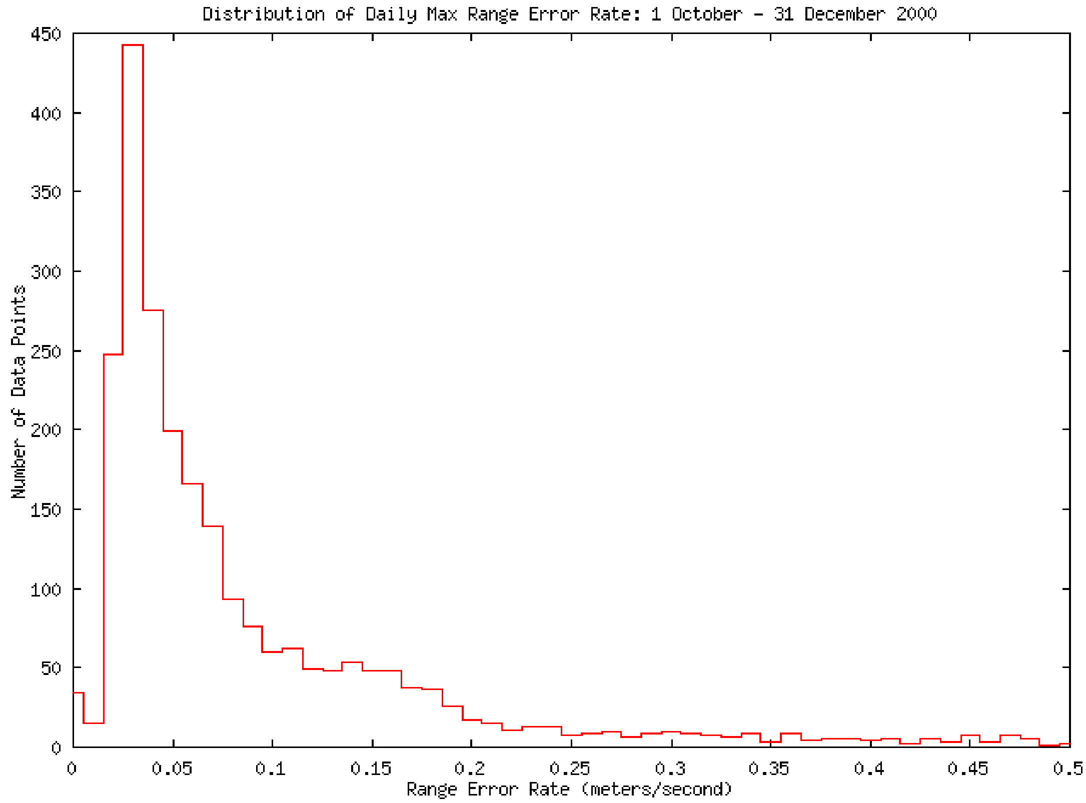
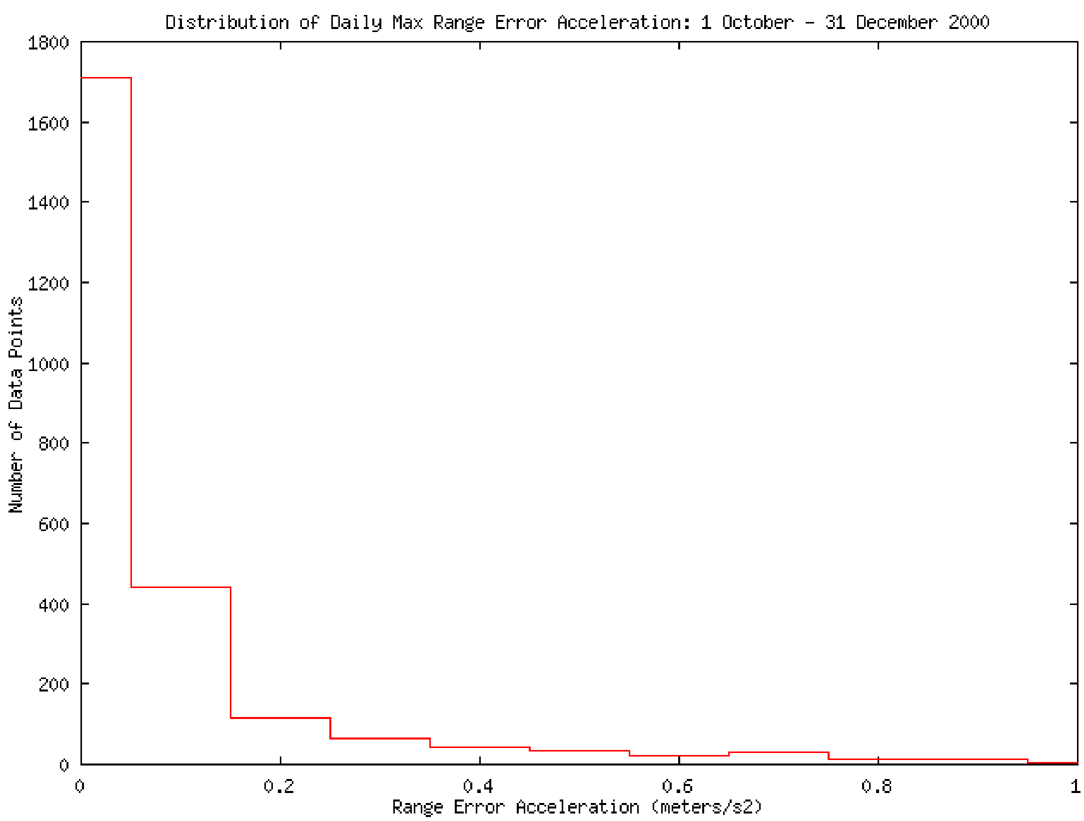


Figure 5-6: Distribution of Daily Max Acceleration Rate Errors



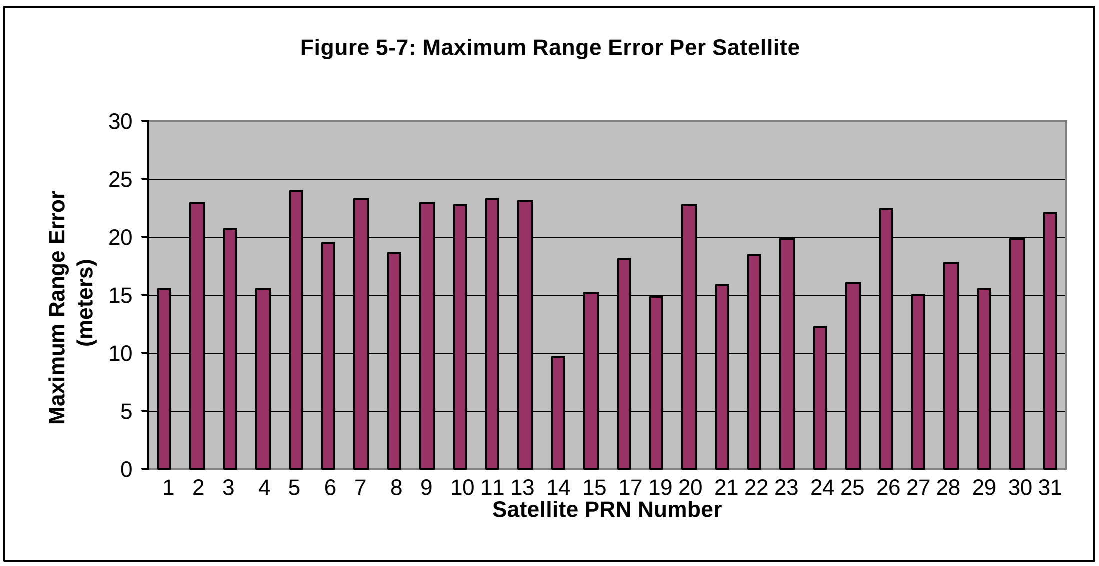


Figure 5-7: Maximum Range Error Per Satellite
Maximum Range Error (meters)
0
5
10
15
20
25
30
1 2 3 4 5 6 7 8 9 10 11 13 14 15 17 19 20 21 22 23 24 25 26 27 28 29 30 31
Satellite PRN Number

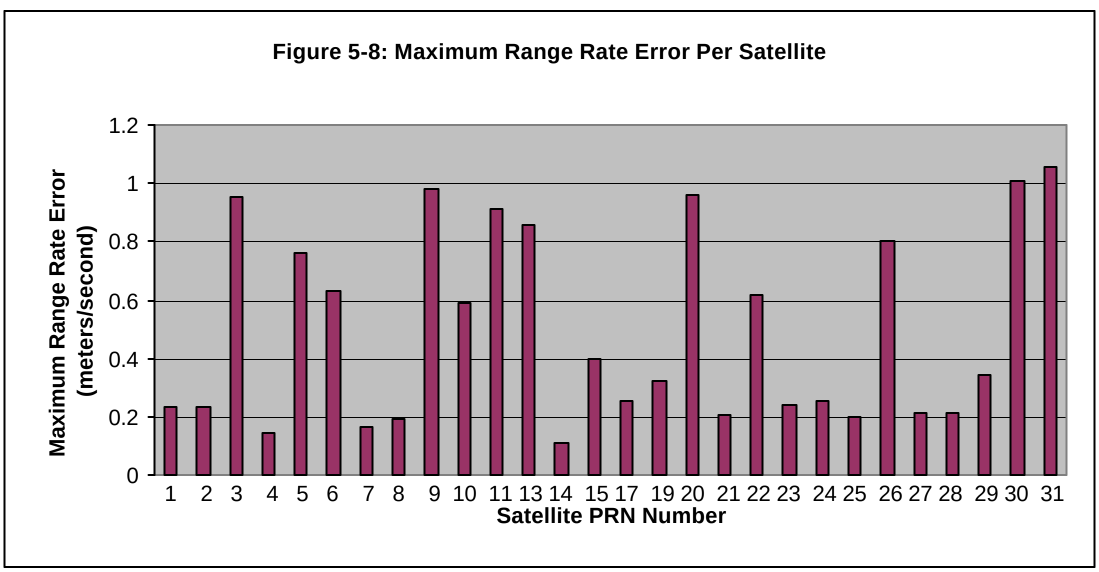
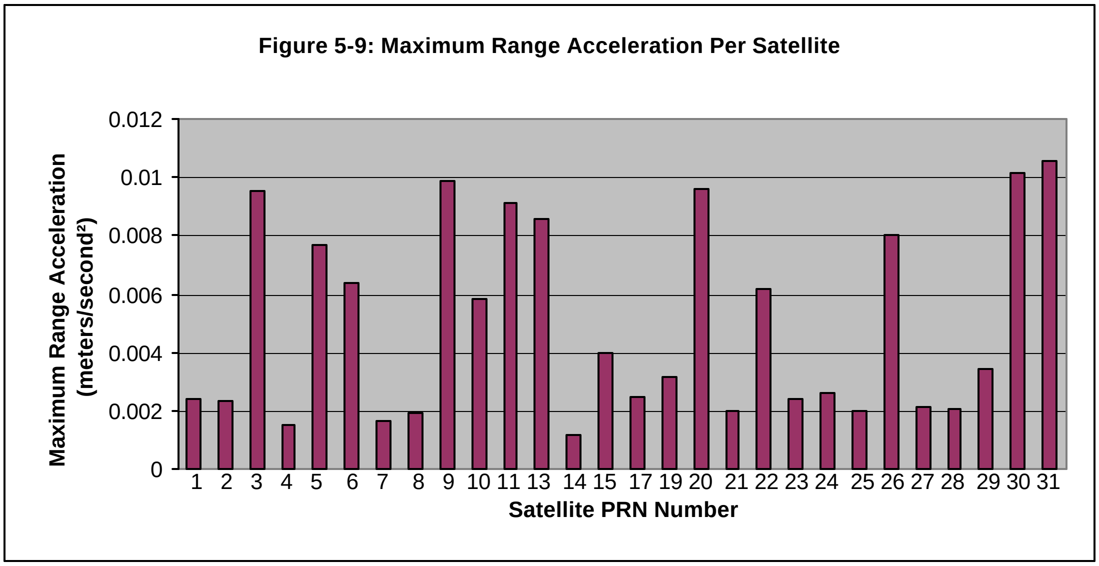


Figure 5-8: Maximum Range Rate Error Per Satellite
Maximum Range Rate Error (meters/second)
0
0.2
0.4
0.6
0.8
1
1.2
1 2 3 4 5 6 7 8 9 10 11 13 14 15 17 19 20 21 22 23 24 25 26 27 28 29 30 31
Satellite PRN Number



6.0 Solar Storms

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

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

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

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

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

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

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

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

Figure 6-1 K-Index for 04-06 October 2000

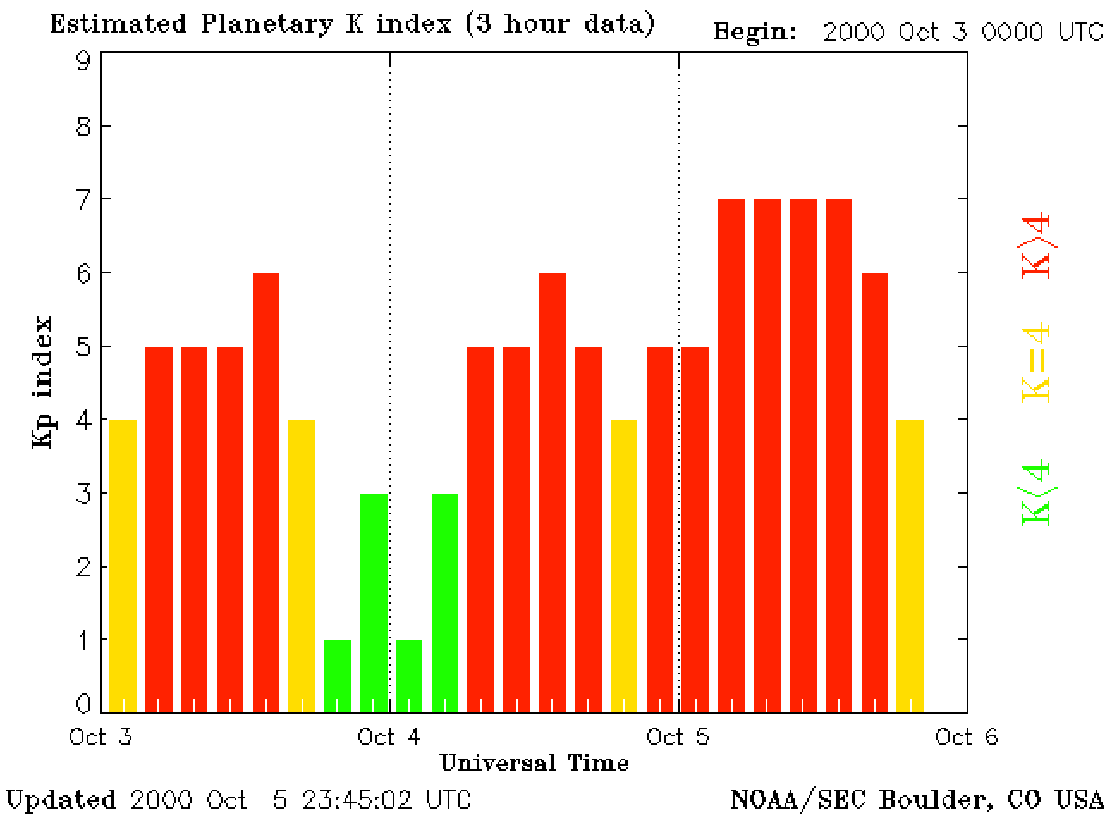


Figure 6-2 K-Index for 07-09 November 2000

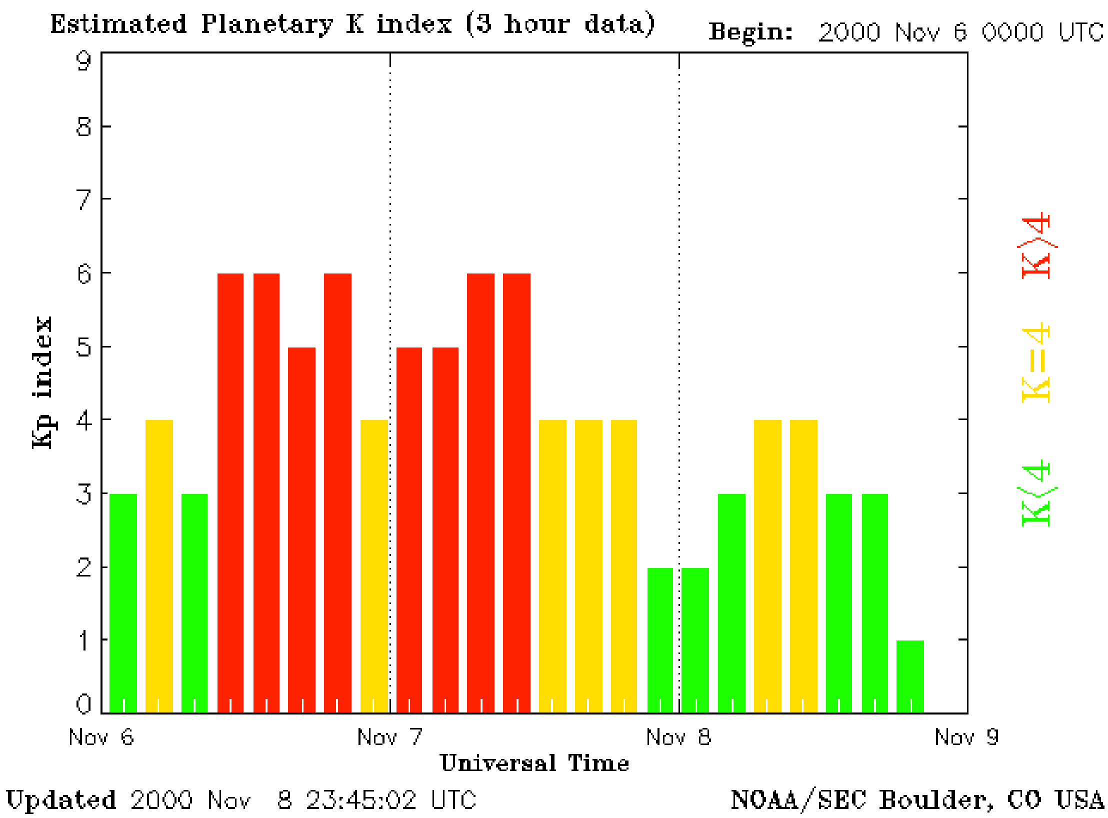
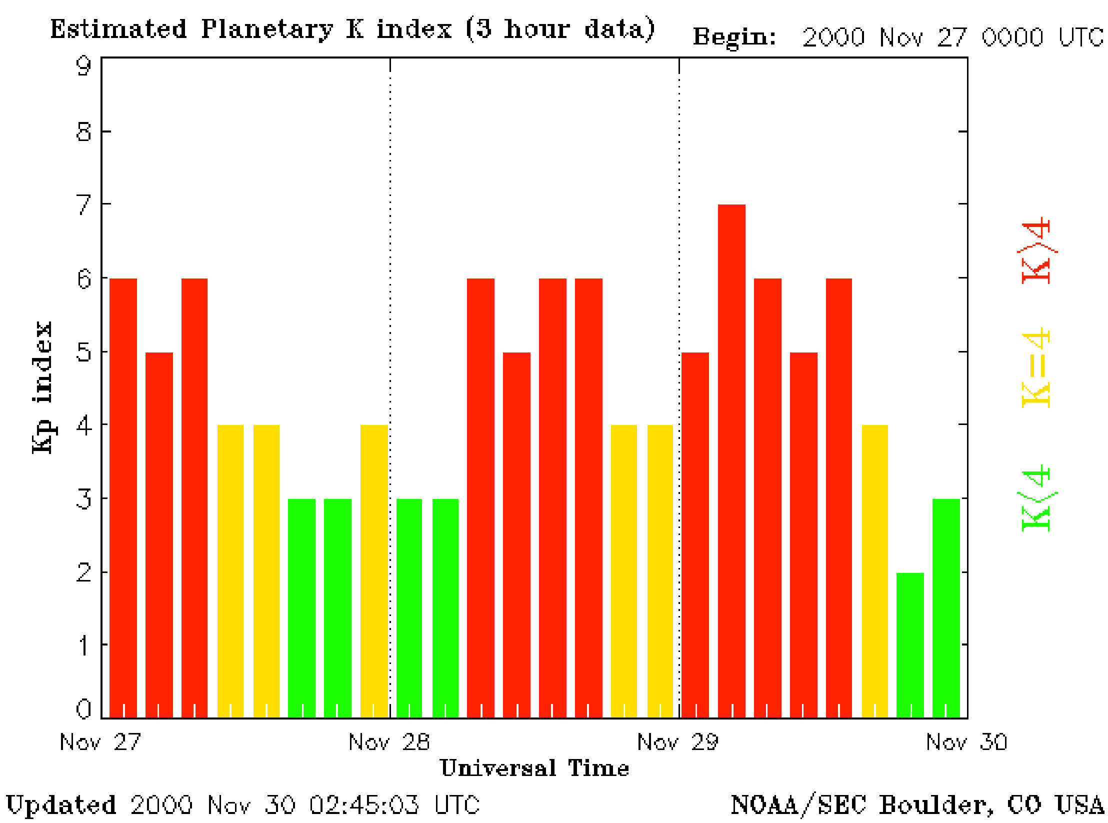


Figure 6-3 K-Index for 28-30 November 2000



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					
10/06/00	1.307	5.322	1.900	3.863	3.377
Atlantic City					
10/06/00	1.322	3.267	1.849	3.266	2.864
Dayton					
10/06/00	1.286	4.655	1.835	4.640	3.992
Elko					
10/06/00	1.215	5.999	1.877	5.975	5.516
Great Falls					
10/06/00	1.466	5.545	2.089	5.527	4.691
Oklahoma City					
10/06/00	1.156	3.396	1.793	3.395	2.876
Kansas City					
10/06/00	1.157	3.227	1.806	3.222	2.709
Salt Lake City					
10/06/00	1.270	3.382	1.820	3.382	2.869

Table 6-2 Horizontal & Vertical Accuracy Statistics*

NSTB Site	95% Horizontal (m)	95% Vertical (m)	99.99% Horizontal (m)	99.99% Vertical (m)
Anderson				
	6.323	10.307	8.678	20.217
Atlantic City				
	6.264	8.478	9.977	18.604
Dayton				
	6.058	8.381	9.555	16.414
Elko				
	5.540	11.122	10.780	19.636
Great Falls				
	7.623	11.293	11.930	14.641
Oklahoma City				
	6.616	9.995	8.242	14.555
Kansas City				
	6.198	9.600	8.713	13.385
Salt Lake City				
	6.116	10.211	9.886	13.538

7.0 GLONASS/GPS Performance

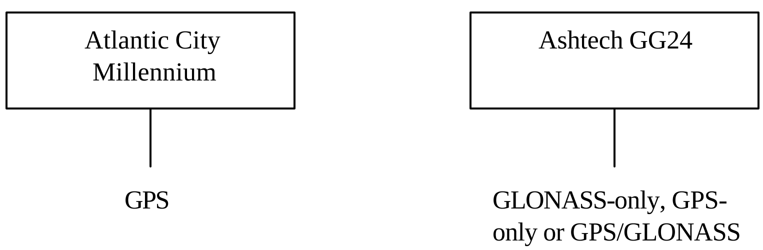
7.1 Introduction

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.

Tables 7-1 and 7-2 provide PDOP and Position Accuracy statistics for the two receivers from 1 October through 31 December 2000. 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	6.539	1.131	1.729	2.360	7680991
Millenium	GPS Only Atlantic City	7.481	1.232	1.871	2.615	7154892

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	6.556	27.557*	25.141	58.099*	7680991
Millenium	GPS Only Atlantic City	6.228	8.708	9.892	15.753	7154892

* The Vertical Accuracy for the Glonass receiver was affected by the hardware configuration problem described above in section 7.3.

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

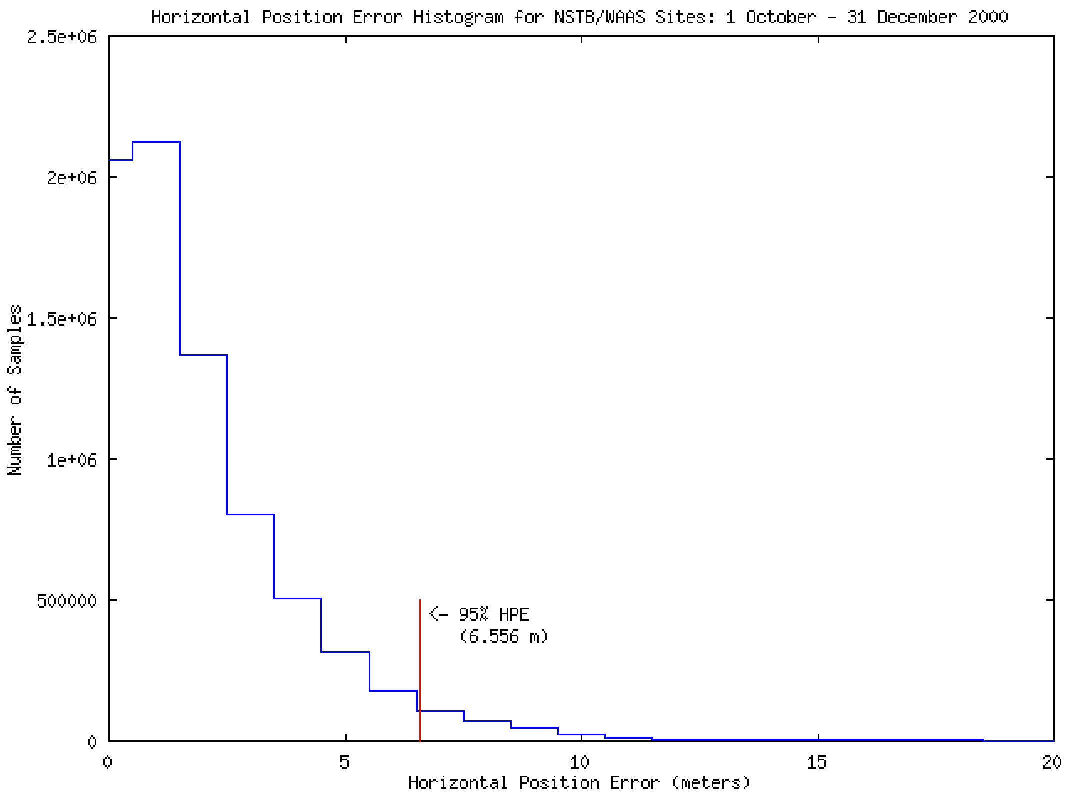


Figure 7-3 Vertical Position Error Histogram for GPS/GLONASS

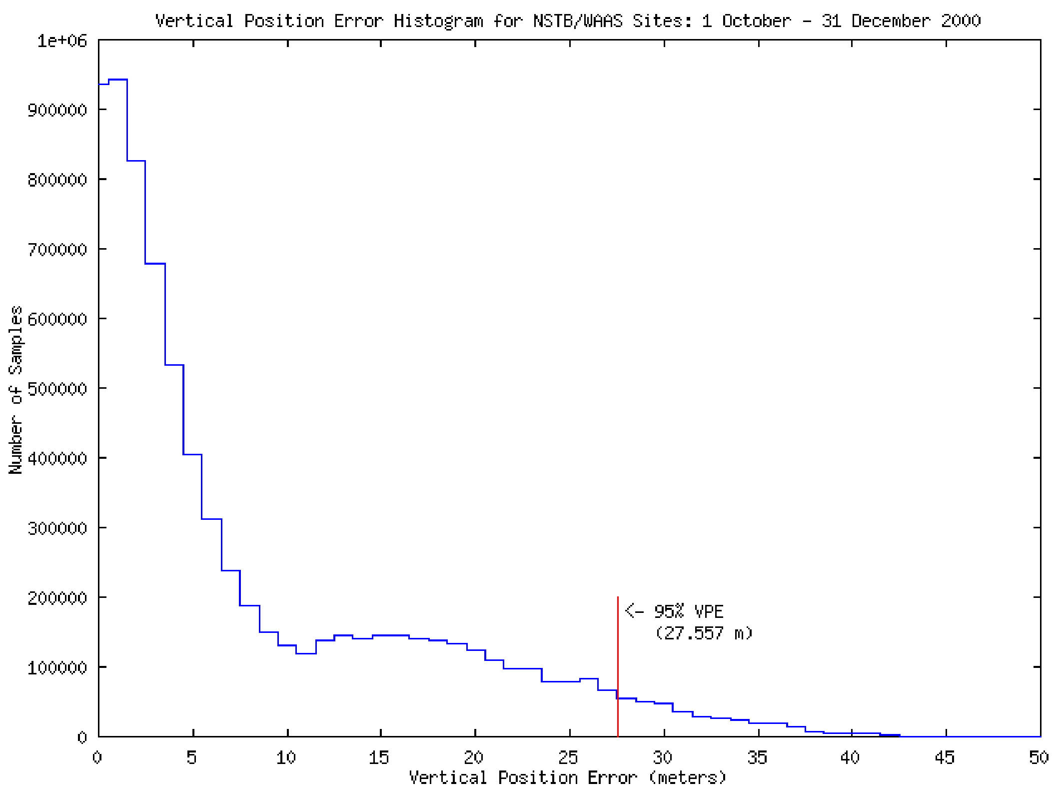
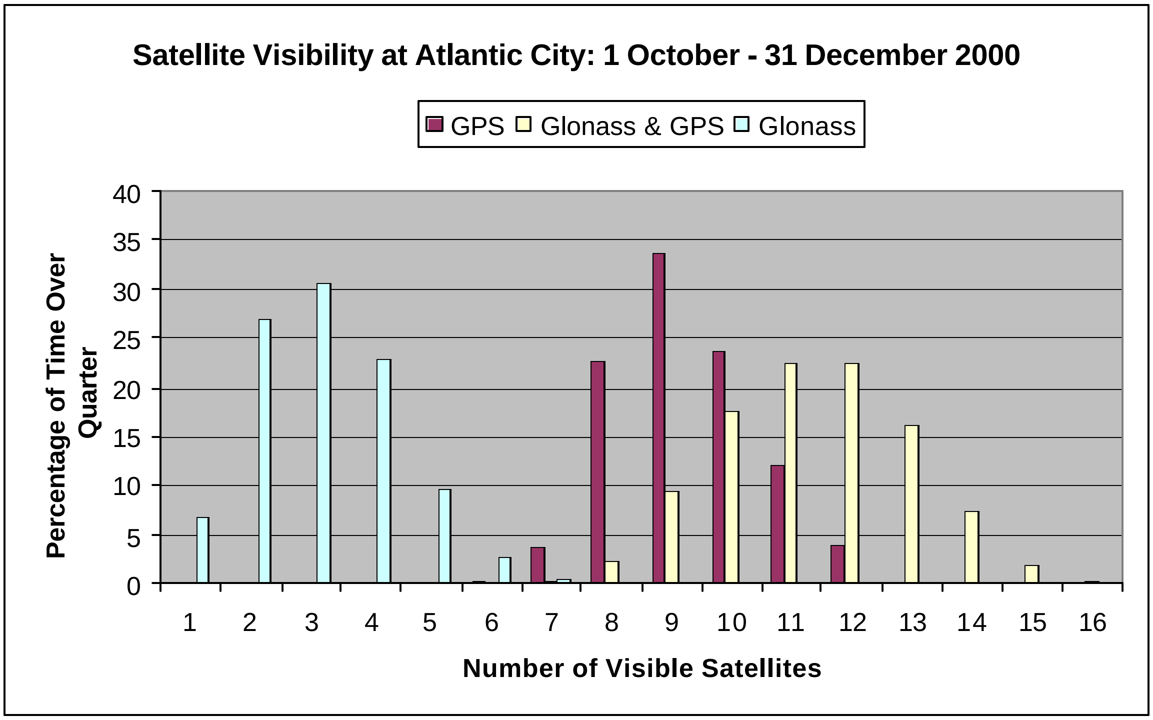


Figure 7-3 Glonass and GPS Satellite Visibility



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	99.970%
• 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	98.632% Availability 99.9% PDOP was 5.52
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	99.994%
• 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	99.457%
• Conditioned on coverage standard • Standard represents a worst-case 24 hour interval, averaged over the globe	≥ 95.87% global average on worst-case day	99.823%
• 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	98.457%
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	≤7.401m horz error 95% ≤11.045m horz error 99.99% ≤8.954m vert error 95% ≤16.968m 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	≤2.678m horz error 95% ≤6.219m 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	≤18 ns 95% of the time
• Conditioned on satellite indicating healthy status • Standard based on a measurement interval of 24 hours, for any point on the globe • Standard restricted to range domain errors allocated to space/control segments • Standards are not constellation values -- each	Range Domain Accuracy ≤ 150 m NTE range error ≤ 2 m/s NTE range rate error ≤ 19 mm/s^2 NTE range	24.04m NTE Range Error 1.05 m/s NTE Rate Error 10.54mm/s^2 NTE Accel Error

satellite is required to meet the standards • Assessment requires minimum of four hours of data over the 24 hour period for a satellite in order to evaluate that satellite against the standard	acceleration error ≤ 8 mm/s^2 range acceleration error 95% of time	≤8mm/s^2 100% of the time

Appendix B Geomagnetic Data

```
Product: Daily Geomagnetic Data     quar_DGD.txt
Issued: 2120 UT 07 Jan 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        High Latitude           Estimated
               - Fredericksburg -     ---- College ----       --- Planetary ---
   Date        A     K-indices        A     K-indices        A     K-indices
2000 10 01     9   4 3 3 1 1 1 1 1   17   4 3 3 5 3 2 2 1   13   4 4 3 3 2 3 2 2
2000 10 02     6   1 1 1 1 2 3 2 2   20   1 1 2 4 3 6 3 2   11   1 2 2 2 3 4 3 3
2000 10 03    19   4 4 4 3 4 3 1 2   51   4 6 6 6 6 5 2 2   37   4 5 5 5 6 4 1 3
2000 10 04    25   2 3 5 5 4 3 3 4   78   2 2 6 6 7 7 7 4   45   1 3 5 5 6 5 4 5
2000 10 05    58   5 6 7 6 5 5 2 3  105   4 5 5 8 8 7 5 5   96   5 7 7 7 7 6 4 4
2000 10 06     3   1 1 0 0 1 1 2 1    5   3 1 2 2 2 0 1 0    6   2 1 1 2 2 3 2 2
2000 10 07     6   1 2 2 2 3 1 1 0    9   0 1 3 4 3 2 1 0    7   2 1 1 2 2 3 2 2
2000 10 08     1   0 1 0 0 0 0 0 2    0   0 0 0 0 0 0 0 0    5   1 1 1 1 2 2 2 3
2000 10 09     2   0 0 0 0 1 1 1 1    8   1 1 0 0 1 1 4 4    5   1 1 1 1 2 2 2 2
2000 10 10     7   1 1 3 3 2 1 1 1   14   0 2 4 5 3 2 1 1   12   2 2 4 4 3 3 3 2
2000 10 11    13   4 4 2 2 3 2 2 1   20   2 4 3 3 6 2 2 1   14   3 4 3 2 4 2 2 2
2000 10 12     5   2 1 1 1 2 1 0 3    7   1 1 2 3 2 2 1 2    8   3 1 2 2 2 3 2 3
2000 10 13    22   5 5 3 3 3 3 3 1   20   5 5 2 2 3 3 3 1   27   5 6 3 3 3 4 3 3
2000 10 14    27   3 3 4 4 5 4 4 4   -1   3 6-1-1-1-1-1-1   42   3 3 5 6 6 5 4 4
2000 10 15     9   1 2 1 1 3 3 3 3   -1  -1-1-1-1-1-1-1-1    8   2 2 1 1 2 3 3 3
2000 10 16    11   4 2 1 2 2 3 3 2   -1  -1-1-1-1-1-1 2 2    8   4 2 1 1 2 2 2 2
2000 10 17     8   3 2 1 2 3 1 2 2    8   3 2 1 3 2 2 2 2    9   3 3 1 3 2 2 3 2
2000 10 18     6   2 2 1 2 2 1 1 2   11   2 2 1 4 4 2 2 1    8   2 2 1 3 3 2 2 2
2000 10 19     9   3 2 3 1 3 1 1 2   10   1 2 4 3 3 2 1 1    9   3 3 3 2 3 2 2 2
2000 10 20     2   1 1 0 1 0 0 1 0   -1   0 0 0-1-1 0 1 0    4   1 1 0 1 2 2 1 2
2000 10 21     5   1 0 0 1 3 3 1 0    3   0 0 0 0 3 1 1 0    4   1 0 0 1 2 2 2 1
2000 10 22     7   0 0 1 2 3 3 2 2   35   0 0 0 4 6 6 6 3   13   1 1 1 3 4 4 4 3
2000 10 23    13   4 3 4 2 3 1 2 1   23   3 4 4 6 4 1 1 1   15   4 3 4 4 3 2 2 2
2000 10 24    10   3 1 2 3 4 1 1 1   32   1 1 6 6 6 2 1 1   11   2 2 3 4 3 2 2 2
2000 10 25     9   0 1 3 3 4 2 2 1   -1   0 1 4 5 6 1-1 0    8   1 0 2 3 3 2 2 2
2000 10 26     9   2 2 3 3 3 2 1 2   17   1 3 4 4 5 2 1 1    7   2 2 2 3 2 2 1 2
2000 10 27     3   2 0 1 1 1 1 1 1    6   3 0 1 3 3 0 1 0    5   2 0 2 2 2 2 1 1
2000 10 28    17   0 1 2 4 4 3 2 5   32   0 0 2 6 7 2 2 3   19   2 0 3 5 4 3 3 5
2000 10 29    24   5 5 3 5 3 3 2 1   41   2 6 4 5 5 6 4 2   26   5 5 4 4 4 3 3 2
2000 10 30    -1   5 2 3 3 2 1-1 0   -1   3 3 1 5 3 3-1 0   13   5 3 2 4 1 3 2 1
2000 10 31     8   3 2 2 1 1 3 2 2   15   1 1 3 5 2 3 3 3   11   3 2 2 3 2 4 3 3
2000 11 01     4   2 2 1 0 0 1 1 2    7   3 2 3 0 2 2 1 1    6   2 2 2 1 2 2 2 2
2000 11 02     1   1 0 0 0 1 0 1 0   -1   2 0 0 0-1 0 0 0    4   2 1 0 1 1 2 2 1
```

2000 11 03	5	0 0 0 2 3 2 2 2	8	0 0 0 0 4 2 4 1	5	0 0 1 2 2 2 2 2
2000 11 04	17	3 4 3 3 3 3 4 2	30	1 5 4 6 4 3 4 3	23	2 5 4 4 4 4 4 3
2000 11 05	8	3 2 1 0 3 2 2 2	20	3 3 1 4 4 5 3 2	10	3 3 1 1 3 3 3 3
2000 11 06	28	3 3 3 5 4 4 5 4	102	3 4 5 7 8 8 6 4	42	3 4 3 6 6 5 6 4
2000 11 07	29	5 5 5 4 3 2 4 3	40	3 5 6 5 5 4 5 1	39	5 5 6 6 4 4 4 2
2000 11 08	14	1 3 4 4 3 3 1 2	-1	-1-1-1-1-1-1-1-1	15	2 3 4 4 3 3 1 3
2000 11 09	10	3 1 1 1 3 3 2 3	21	2 2 1 3 5 5 4 3	11	3 1 1 1 3 3 3 3
2000 11 10	29	4 3 5 6 5 3 3 2	37	3 4 5 6 4 5 5 3	41	4 3 6 6 6 4 3 3
2000 11 11	11	2 3 2 2 2 3 3 3	32	3 3 2 6 5 5 4 3	12	2 3 2 3 3 3 3 3
2000 11 12	20	3 5 4 4 3 3 2 2	44	3 4 6 6 5 6 3 2	21	3 5 4 4 3 4 2 2
2000 11 13	5	1 3 0 1 2 1 2 1	10	1 1 0 3 4 3 2 2	8	1 3 1 2 2 3 3 3
2000 11 14	4	2 3 0 1 0 1 0 1	3	1 2 0 1 2 1 1 0	5	1 2 0 1 2 2 2 2
2000 11 15	3	1 1 0 1 1 1 1 1	3	1 1 2 0 1 0 1 1	5	1 1 2 1 2 2 2 2
2000 11 16	1	1 0 0 0 0 0 0 1	-1	0 0 4 0 0 0 0-1	4	1 0 1 1 2 1 2 3
2000 11 17	3	1 1 1 2 2 1 0 0	-1	-1-1-1-1-1-1 0 0	4	1 0 1 2 2 2 1 1
2000 11 18	4	0 0 0 0 2 2 2 2	2	0 0 0 0 0 1 1 2	6	0 0 1 1 2 2 3 3
2000 11 19	7	1 2 2 2 2 1 3 2	16	1 1 4 6 2 1 0 1	7	1 2 2 3 2 2 2 2
2000 11 20	7	1 1 4 2 2 2 1 0	16	0 1 3 4 4 5 2 0	9	1 1 3 2 3 3 3 1
2000 11 21	7	2 2 2 2 2 2 2 1	-1	3 1 4-1 3 4 3 1	9	3 2 2 2 3 3 3 2
2000 11 22	7	1 2 2 2 3 2 1 1	17	2 0 1 4 5 5 1 1	7	2 1 1 2 3 3 2 2
2000 11 23	4	0 2 0 2 2 1 1 0	10	1 2 1 4 4 2 2 0	7	1 3 1 2 3 3 2 1

		Middle Latitude		**High Latitude**		**Estimated**
		- Fredericksburg -		**---- College ----**		**--- Planetary ---**
Date	**A**	**K-indices**	**A**	**K-indices**	**A**	**K-indices**
2000 11 24	9	0 2 1 3 1 3 3 3	8	0 1 2 3 1 1 2 4	9	1 2 2 2 1 3 3 3
2000 11 25	4	3 2 0 0 0 1 2 0	3	2 2 0 0 0 1 1 1	7	3 3 0 1 1 2 3 2
2000 11 26	19	1 2 3 2 4 4 3 5	28	0 0 4 3 4 6 4 5	22	1 1 3 2 4 4 5 5
2000 11 27	27	5 5 5 4 3 2 3 2	51	5 5 7 6 4 4 4 2	38	6 5 6 4 4 3 3 4
2000 11 28	18	3 3 4 4 4 2 2 3	65	2 5 7 6 7 5 4 4	37	3 3 6 5 6 6 4 4
2000 11 29	32	5 6 5 3 4 3 2 3	62	5 6 7 5 6 5 4 4	52	5 7 6 5 6 4 2 3
2000 11 30	4	0 1 1 2 2 1 1 1	8	1 1 2 3 2 3 2 1	6	1 1 2 2 2 3 2 2
2000 12 01	3	2 1 0 2 1 1 0 0	12	1 1 0 3 5 4 1 0	6	2 2 0 2 2 3 2 2
2000 12 02	3	0 0 1 1 2 2 1 1	6	0 0 1 1 3 4 1 0	4	1 0 1 2 2 2 2 2
2000 12 03	7	0 1 3 1 3 1 3 0	22	0 0 4 4 5 5 4 0	12	1 1 3 3 4 4 3 1
2000 12 04	8	1 2 2 2 1 1 1 4	14	0 3 3 5 4 0 1 1	10	2 3 3 3 2 2 3 2
2000 12 05	4	1 1 0 1 3 1 1 1	-1	1 1 1-1-1-1 1 0	4	1 1 1 1 2 2 2 1
2000 12 06	6	1 1 2 1 2 2 2 2	10	0 0 3 2 4 4 1 1	7	0 1 3 2 2 3 2 2
2000 12 07	8	2 2 3 2 2 1 1 3	24	2 3 3 5 5 4 3 3	13	2 3 3 3 4 3 2 3
2000 12 08	11	3 3 2 3 3 2 2 2	28	2 2 4 3 6 5 4 3	17	4 4 3 3 4 4 3 2
2000 12 09	13	2 3 3 2 3 3 3 3	-1	4 3-1-1-1-1-1-1	16	3 4 3 3 3 3 3 4
2000 12 10	9	3 2 2 3 2 2 2 2	-1	-1-1-1-1-1-1-1-1	9	3 3 2 3 2 3 2 2
2000 12 11	7	3 2 2 2 2 1 2 2	-1	-1-1-1-1-1-1 1 1	7	3 2 2 2 2 2 2 2
2000 12 12	3	1 0 0 1 1 1 2 1	7	0 1 0 4 3 1 1 1	5	1 1 1 2 2 2 2 1
2000 12 13	4	3 1 1 1 1 1 0 1	-1	1 1 0 1 4-1 0 1	4	2 1 0 1 2 2 2 1
2000 12 14	2	0 0 0 1 2 1 1 1	6	3 0 0 2 4 0 0 0	4	1 0 0 1 2 2 2 2
2000 12 15	3	1 1 1 1 1 0 0 2	2	1 0 0 2 1 0 0 0	3	0 0 0 1 2 2 1 1
2000 12 16	4	0 1 1 1 2 2 0 2	1	0 0 0 0 1 0 1 1	4	0 0 0 1 2 3 1 2
2000 12 17	6	1 1 1 1 3 2 2 1	15	0 2 2 3 5 4 3 1	8	1 2 1 2 3 3 3 1
2000 12 18	7	1 3 2 2 2 2 1 2	13	1 2 2 5 3 3 2 1	10	2 3 3 3 2 3 2 3
2000 12 19	2	2 1 0 1 1 1 0 0	8	4 0 1 4 2 0 1 0	5	2 1 1 2 2 3 3 1
2000 12 20	2	0 0 1 1 1 1 1 1	-1	0-1-1-1-1-1-1-1	4	1 0 1 2 2 2 2 1
2000 12 21	5	0 1 0 3 2 2 1 2	2	0 0 0 2 2 2 0 0	5	0 0 0 3 2 2 2 1
2000 12 22	6	0 1 1 1 1 0 2 4	5	0 0 2 1 2 2 1 3	7	1 1 1 2 1 3 2 3
2000 12 23	12	3 5 2 2 2 1 1 2	22	3 5 4 5 3 3 2 1	20	4 5 4 4 4 3 2 2
2000 12 24	4	2 2 0 0 2 1 2 1	2	0 2 0 0 0 1 2 0	5	1 2 1 1 2 2 2 2
2000 12 25	6	2 1 1 2 3 2 1 2	10	0 0 0 0 5 4 0 1	6	1 1 0 1 3 3 1 2
2000 12 26	4	1 1 1 1 1 2 1 2	4	0 0 2 3 0 0 1 1	4	1 1 0 1 1 2 2 2
2000 12 27	7	2 1 1 1 3 2 2 2	12	1 0 1 3 4 4 3 1	7	1 1 1 1 3 3 3 1
2000 12 28	4	1 1 1 1 3 1 1 0	6	1 0 2 3 3 2 1 0	5	2 1 1 2 3 1 1 0

2000 12 29	6 2 3 2 0 1 2 1 1	7 0 2 3 3 1 2 1 1	6 1 3 2 2 1 1 2 2
2000 12 30	4 2 1 1 2 2 0 0 1	3 0 0 0 2 3 0 1 0	2 1 0 0 1 1 1 1 1
2000 12 31	1 0 0 0 2 1 1 0 0	1 0 0 0 2 0 0 0 0	2 1 0 0 1 1 0 1 0

Background:

In 1993, the FAA began monitoring and analyzing Global Positioning System (GPS) Standard Positioning Service (SPS) performance data. At present, the FAA has approved GPS for IFR and is developing WAAS and LAAS, both of which are GPS augmentation systems. In order to ensure the safe and effective use of GPS and its augmentation systems within the NAS, it is critical that characteristics of GPS performance as well as specific causes for service outages be monitored and understood. To accomplish this objective, GPS SPS performance data is documented in a quarterly GPS Performance Analysis (PAN) report. The PAN report contains data collected at various National Satellite Test Bed (NSTB) and Wide Area Augmentation System (WAAS) reference station locations. This PAN Problem Report will be issued only when the performance data fails to meet the GPS Standard Positioning Service (SPS) Signal Specification.

Problem Description:

There were no failures of the GPS Standard Positioning Service Signal Specification (SPS) during this quarter.

Appendix D Glossary

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.