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 Reference Station locations: Anderson, Atlantic City, Dayton, Elko, Gander, Great Falls and Seattle. This analysis verifies the GPS SPS performance as compared to the performance parameters stated in the SPS Specification Annex A.

This report, Report #28, includes data collected from 1 October through 31 December 1999. The next quarterly report will be issued at the 30 April 2000.

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 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 1999 and by calculating the satellite availability from the data obtained from the ten NSTB sites. A total of seventeen satellite outages were reported in the NANUs. Sixteen of the outages were scheduled and one was unscheduled. The availabilities for Anderson, Atlantic City, Dayton, Elko, Gander, Great Falls and Seattle were 100%, 99.99%, 100%, 100%, 100%, 100%, and 100%, respectively. Each of these availabilities is within the SPS value of 99.85%. These availability percentages were calculated using DOP data collected at one-second intervals.

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

Position accuracies were verified by calculating the 95% and 99.99% values of horizontal and vertical errors. All of these values were within the SPS limits. The average 95% horizontal error, 95% vertical error, 99.99% horizontal error and 99.99% vertical error for all ten sites was 46 meters, 77 meters, 101 meters and 172 meters, respectively.

Range performance was verified for each satellite using the data collected from the NSTB Elko site. The data was collected in one-second samples. All of the satellites met the range error specifications. The maximum range error recorded was 144 meters on Satellite PRN 23. The SPS specification states that the range error should never exceed 150 meters. The maximum range rate error recorded was 1.86 meters/second on Satellite PRN 4. The SPS specification states that the range rate error should never exceed 2 meters/second. The maximum range acceleration error recorded was 18 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. Two GPS/GLONASS receivers have been added into 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 Millenium receiver). The 95% horizontal error and vertical error for the GPS/GLONASS solution were 33 meters and 74 meters, respectively. The 99.99% horizontal error and vertical error for the GPS-only solution were 71 meters and 148 meters, respectively.

From the analysis performed on data collected between 1 October and 31 December 1999, 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 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 Analysis report. This report contains data collected at the following National Satellite Testbed (NSTB) reference station locations:

- Anderson, SC
- Atlantic City, NJ
- Dayton, OH
- Elko, NV
- Gander, NFLD (Canada)
- Great Falls, ND
- Seattle, WA

Since there have been an increasing number of problems with receivers, the next report will have another section that will document all the problems experienced with receivers and or TRS software. Receiver monitoring software is being developed by ACT-360. This software will output flags any time a receiver in the NSTB network does not track a satellite that it should be tracking using YUMA almanac as a basis. This software will also output times when a receiver has a false lock and times when an ephemeris is sent late.

(Future reports will include all 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 ten NSTB 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. Two GPS/GLONASS receivers have been added to the NSYB 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 of this report provides an example of how future WAAS data analysis will be presented. The data in this report is data collected during the WAAS Stability Test. The requirements were taken from the WAAS specification (FAA-E-2892B).

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 Nonprecision 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

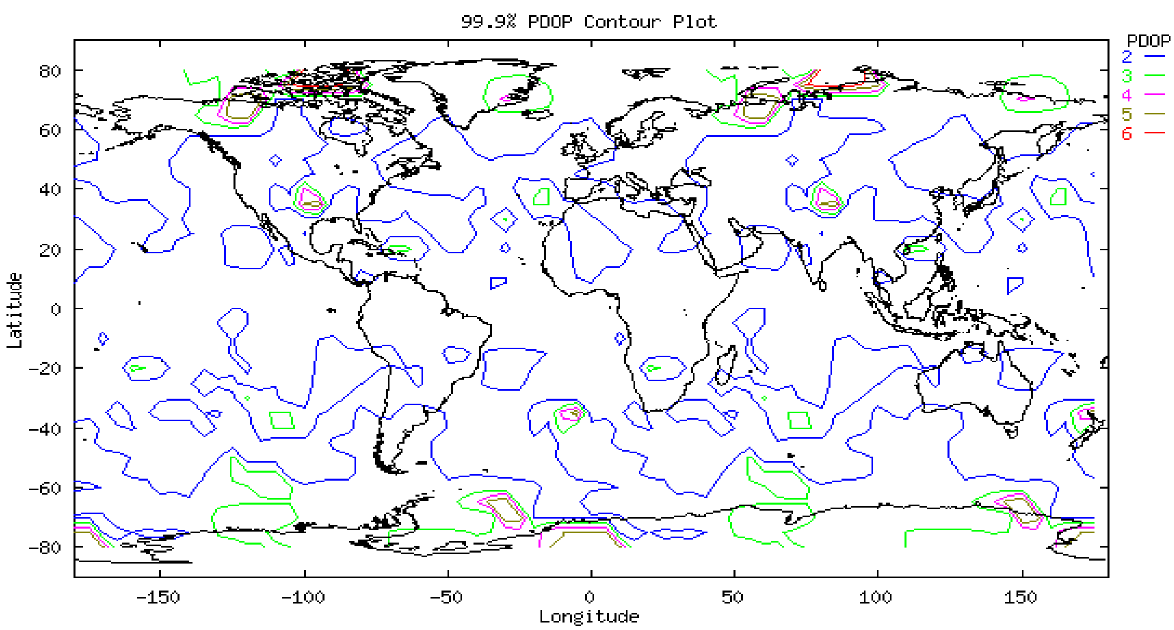
Almanacs for GPS weeks 6-18 used for this coverage portion of the report were obtained from the Coast Guard web site (www.navcen.uscg.mil). Using these almanacs, an SPS coverage area program developed by ACT-360 was used to calculate the PDOP at every 5° point between longitudes of 180W to 180E and 80S and 80N at one-minute intervals. This gives a total of 1440 samples for each of the 2376 grid points in the coverage area. Table 2-1 provides the global averages and worst-case availability over a 24-hour period for each week. Table 2-1 also gives the global 99.9% PDOP value for each of the thirteen GPS Weeks. The PDOP was 3.26 or better 99.9% for each of the 24-hour intervals.

The GPS coverage performance evaluated met the specifications stated in the SPS 1999.

Table 2-1 Coverage Statistics

GPS Week	Global 99.9% PDOP Value*	Global Average* (Spec: ≥ 99.9%)	Worst-Case Point (Spec: ≥ 96.9%)
6	3.21	99.999%	99.722%
7	3.22	99.998%	99.653%
8	3.25	99.996%	99.444%
9	3.25	99.996%	99.444%
10	3.26	99.997%	99.514%
11	3.25	99.998%	99.514%
12	3.17	99.997%	99.583%
13	3.17	99.997%	99.583%
14	3.14	99.995%	99.444%
15	3.14	99.995%	99.444%
16	3.13	99.992%	99.375%
17	3.14	99.993%	99.375%
18	3.16	99.996%	99.444%

Figure 2-1 SPS Coverage (24-Hour Period: 13 December 1999)



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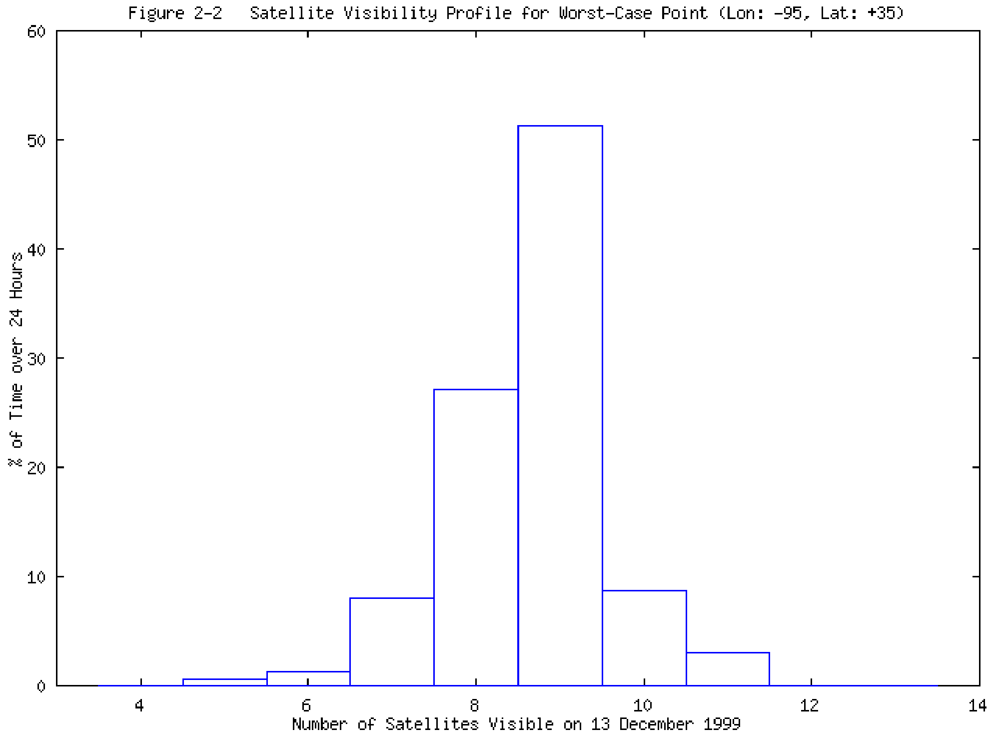


Figure 2-2 Satellite Visibility Profile for Worst-Case Point (Lon: -95, Lat: +35)
% of Time over 24 Hours
0
10
20
30
40
50
60
4
6
8
10
12
14
Number of Satellites Visible on 13 December 1999

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 1999, there were a total of seventeen reported outages. Sixteen of these outages were maintenance activities and were reported in advance. One was an unscheduled outage. 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#	SVN/PRN	Type	Start Date	Start Time	End Date	End Time	Total Unscheduled	Total Scheduled	Total
164*	25/25	S	30-Sep	20:00	1-Oct	4:18		4.30	4.30
165	38/8	S	1-Oct	17:29	2-Oct	5:02		11.55	11.55
169	29/29	S	18-Oct	13:53	19-Oct	5:34		15.68	15.68
173	27/27	S	28-Oct	23:33	29-Oct	7:31		7.97	7.97
174	35/5	S	4-Nov	21:01	5-Nov	5:16		8.25	8.25
185	17/17	S	23-Nov	10:39	23-Nov	18:45		8.10	8.10
190	43/13	S	29-Nov	21:50	30-Nov	6:04		8.23	8.23
191	14/14	S	30-Nov	8:42	30-Nov	14:46		6.07	6.07
192	37/7	S	1-Dec	15:28	1-Dec	18:49		3.35	3.35
194	24/24	S	2-Dec	12:26	2-Dec	15:41		3.25	3.25
196	30/30	S	6-Dec	14:29	6-Dec	22:43		8.23	8.23
197	13/2	S	8-Dec	21:51	9-Dec	2:19		4.47	4.47
202	40/10	S	14-Dec	6:51	14-Dec	14:43		7.87	7.87
203	43/13	S	15-Dec	2:58	15-Dec	6:56		3.97	3.97
207	37/7	S	15-Dec	20:27	16-Dec	5:30		9.05	9.05
208	26/26	S	17-Dec	5:58	17-Dec	14:54		8.93	8.93
166**	19/19	U	22-Sep	17:15	4-Oct	17:27	89.45		286.20
Total Actual Unscheduled and Scheduled Downtime and Total Actual Downtime							**89.45**	**119.27**	**208.72**

Type: S = Scheduled U = Unscheduled

* **Note**: Only 4.3 hours of this outage occurred during this quarter. The September portion of the outage was reported in PAN Report #27.
** **Note**: Only 89.45 hours of this outage occurred during this quarter. The September portion of the outage was mistakenly NOT included in PAN Report #27. The September portion will be included in cumulative statistics in this report.

Table 3-2 NANUs Forecasted To Affect Satellite Availability

NANU#	SVN/PRN	Type	Start Date	Start Time	End Date	End Time	Total	Comments
162	25/25	F	30-Sep	19:30	1-Oct	7:30	12.00	See Nanu 164
163	38/8	F	1-Oct	16:45	2-Oct	4:45	12.00	See Nanu 165
167	29/29	F	18-Oct	13:30	19-Oct	1:30	12.00	See Nanu 168
168	29/29	F/Extented	19-Oct	1:30	N/A	N/A	N/A	See Nanu 169
170	27/27	F	28-Oct	16:00	29-Oct	4:00	12.00	See Nanu 171
171	27/27	F/Rescheduled	28-Oct	23:15	29-Oct	11:15	12.00	See Nanu 173
172	35/5	F	4-Nov	20:45	5-Nov	8:45	12.00	See Nanu 174
175	43/13	F	9-Nov	21:00	10-Nov	5:00	8.00	See Nanu 179
176	40/10	F	10-Nov	14:00	11-Nov	2:00	12.00	See Nanu 178
177	36/6	F	12-Nov	4:30	12-Nov	13:00	8.50	See Nanu 180
179	43/13	F/Rescheduled	11-Nov	21:00	12-Nov	5:00	8.00	See Nanu 181
182	26/26	F	22-Nov	14:00	23-Nov	2:00	12.00	See Nanu 184
183	17/17	F	23-Nov	9:30	23-Nov	21:30	12.00	See Nanu 185
186	43/13	F	29-Nov	21:30	30-Nov	6:30	9.00	See Nanu 190
187	14/14	F	30-Nov	8:30	30-Nov	20:30	12.00	See Nanu 191
188	37/7	F	1-Dec	15:00	1-Dec	22:00	7.00	See Nanu 192
189	24/24	F	2-Dec	12:00	3-Dec	0:00	12.00	See Nanu 194
193	30/30	F	6-Dec	14:00	7-Dec	2:00	12.00	See Nanu 196
195	13/2	F	8-Dec	20:00	9-Dec	8:00	12.00	See Nanu 197
198	40/10	F	14-Dec	6:30	14-Dec	17:00	10.50	See Nanu 202
199	43/13	F	15-Dec	2:30	15-Dec	14:30	12.00	See Nanu 203
200	37/7	F	15-Dec	20:00	16-Dec	8:00	12.00	See Nanu 207
201	26/26	F	17-Dec	6:00	17-Dec	22:00	16.00	See Nanu 204
204	26/26	F/Rescheduled	17-Dec	6:00	17-Dec	22:00	16.00	See Nanu 205
206	26/26	F/Rescheduled	17-Dec	5:00	17-Dec	22:00	17.00	See Nanu 208
Total Forecasted Downtime							**280.00**	

Type: F = Forecasted

Table 3-3 *NANUs Canceled*

NANU#	SVN/PRN	Type	Start Date	Start Time	Comments
178	40/10	C	10-Nov	14:00	See Nanu 176
180	36/6	C	12-Nov	4:30	See Nanu 177
181	43/13	C	11-Nov	21:00	See Nanu 179
184	26/26	C	22-Nov	14:00	See Nanu 182
205	26/26	C	17-Dec	6:00	See Nanu 204

Type: C = Cancelled

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. A plot of satellite Mean Time To Repair (MTTR) has been included in Figures 3-1.

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 October–31 December 1999	12 December 1998– 31 December 1999
Total Forecast Downtime (hrs):	280.00	1336.22
Total Actual Downtime (hrs):	208.72	2067.96
Total Actual Scheduled Downtime (hrs):	119.27	598.07
Total Actual Unscheduled Downtime (hrs):	89.45	1469.89
Total Satellite Observed MTTR (hrs):	12.28	24.33
Scheduled Satellite Observed MTTR (hrs):	7.45	8.54
UnScheduled Satellite Observed MTTR (hrs):	89.45	97.99
# Total Satellite Outages:	17	85*
# Scheduled Satellite Outages:	16	70*
# Unscheduled Satellite Outages:	1	15
Percent Operational -- Scheduled Downtime:	99.80%	99.76%
Percent Operational -- All Downtime:	99.65%	99.17%

* **Note:** NANU 164 was already part of the cumulative statistics since it was part of PAN Report #27.

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 ten NSTB 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 – 30 December 1999.

Table 3-5 PDOP Statistics

NSTB Site	Min PDOP	Max PDOP	VDOP at Max PDOP	Mean PDOP	99.99% PDOP	99.99% VDOP	Number of Samples
Anderson	1.29	5.93	5.75	1.92	3.70	3.26	7493341
Atlantic City	1.28	6.26	5.69	1.94	3.97	3.56	7409113
Dayton	1.27	5.69	3.97	1.85	3.65	3.08	7492683
Elko	1.25	5.98	5.31	1.91	3.92	3.44	5185916
Gander	1.22	5.99	5.79	1.89	4.37	3.86	7483714
Great Falls	1.31	5.99	5.42	2.22	5.58	5.21	7477295
Seattle	1.21	5.94	5.60	1.89	3.63	3.02	7483238

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

Whenever the PDOP goes above six, regardless of whether or not the SPS performance was 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 (NANUs) messages are used to verify that satellite outages did occur. (See Section 3.1 for more details about NANUs 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.

- A PDOP calculation program developed by Intermetrics was used to verify that certain satellite outage do cause the PDOP to go above six.

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

All of the times that the PDOP went above six are 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
Atlantic City	1040/2	6.26	319	NANU 202, 10	77253	99.5971%
Worst-Case Point on Worst-Case Day = 99.5971 % (SPS Spec. ≥ 83.92%)						

Global Average on Worst-Case Day (Week_1040Day_2, 14 December 1999) = 99.94%
(SPS Spec. ≥ 95.87%)

Table 3-7 PDOP > 6 Statistics

NSTB Site	Total Number of Seconds of PDOP Monitoring	Total Seconds with PDOP > 6	Overall % Availability
Anderson	7493341	0	100
Atlantic City	7409113	319	99.9957
Dayton	7492683	0	100
Elko	5185916	0	100
Gander	7483714	0	100
Great Falls	7477295	0	100
Seattle	7483238	0	100
Worst Single Point Average = 99.9957% (SPS Spec. ≥ 99.16%)			

Global Average over Reporting Period = 99.99% (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 99.9% horizontal errors reported by a receiver at each of the ten NSTB 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 Site	Number of Samples This Quarter	Maximum Horizontal Error (meters)
Anderson	7493341	168
Atlantic City	7409113	241
Dayton	7492683	144
Elko	5185916	162
Gander	7483714	206
Great Falls	7477295	248
Seattle	7483238	154

None of the horizontal error exceeded the 500 meter threshold for this quarter. Also, since it has been a year of monitoring the maximum horizontal error, the performance can be compared against the SPS specification. Since the maximum horizontal error never exceeded 500 meters this year, the Service Reliability met SPS specification requirements for this past year.

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 1999 at the ten NSTB selected locations.

Table 5-1 provides the 95% and 99.99% horizontal and vertical error accuracies which were all within the specified limits.

Table 5-1 Horizontal & Vertical Accuracy Statistics

NSTB Site	95% Horizontal (meters)	95% Vertical (meters)	99.99% Horizontal (meters)	99.99% Vertical (meters)
Anderson	44.8	77.6	87.0	168.0
Atlantic City	44.7	76.4	90.7	173.0
Dayton	44.0	74.9	92.3	156.0
Elko	46.5	75.6	101.0	165.0
Gander	45.5	75.0	113.0	168.0
Great Falls	52.7	88.8	127.0	216.0
Seattle	45.4	73.5	95.5	160.0

Figures 5-1 and 5-2 are the combined histograms of the vertical and horizontal errors for all seven NSTB sites from 1 October to 31 December 1999.

Figure 5-1 Combined Vertical Error Histogram

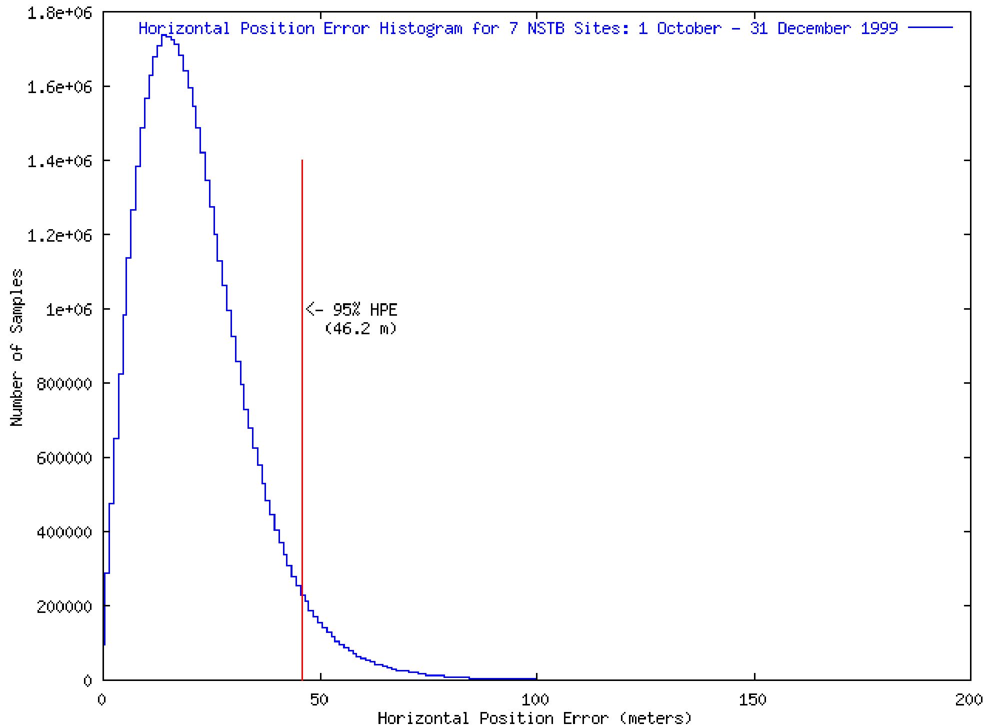
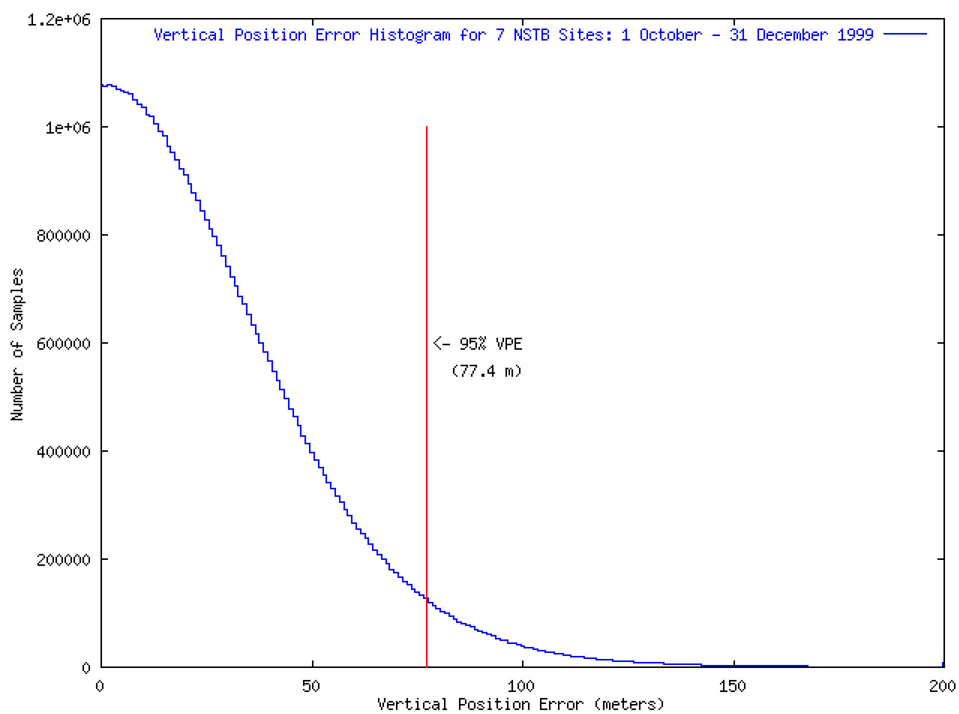


Figure 5-2 Combined Horizonatal Error Histogram



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	34.9	110.0
Atlantic City	35.9	111.0
Dayton	35.2	106.0
Elko	36.6	107.0
Gander	36.8	107.0
Great Falls	41.2	133.0
Seattle	34.5	99.9

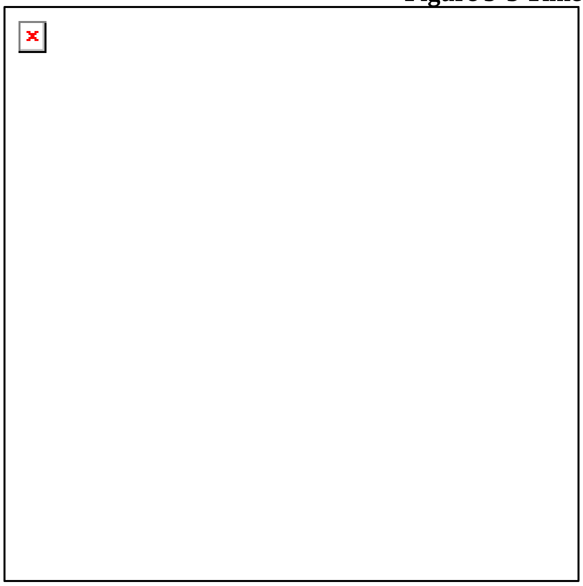
5.3 Relative Accuracy

To be included in future reports.

5.4 Time Transfer Accuracy

The GPS time error data between 1 October and 31 December 1999 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 through 31 December 1999. The Millenium at Elko was used to collect range measurement. Future PAN reports will contain statistics from all NSTB sites.

A weighted average filter was used for the calculation of the range rate error range acceleration error. All Range Domain SPS specifications were met.

Table 5-3 Range Error Statistics (meters)

PRN	Range Error Mean	Range Error RMS	1 s	95% Range Error	Max Range Error (SPS Spec. ≤ 150 m)	Samples
1	2.407	18.19	17.33	56.24	109.43	1577837
2	5.149	19.25	17.68	60.37	114.14	1725249
3	1.813	17.78	17.17	53.28	110.21	1870117
4	3.975	18.98	17.80	53.23	115.87	1653656
5	4.144	19.20	17.66	51.50	139.59	1734067
PRN	**Range Error Mean**	**Range Error RMS**	**1 s**	**95% Range Error**	**Max Range Error (SPS Spec. ≤ 150 m)**	**Samples**
6	3.509	19.11	18.04	73.72	125.61	1617861
7	4.968	19.40	17.86	56.91	118.38	1720988
8	3.764	18.53	17.57	55.15	120.19	1896038
9	3.531	18.41	17.27	60.85	133.23	1843885
10	4.069	18.95	17.58	79.33	131.81	1550809
13	2.868	18.12	17.36	45.61	108.66	1849904
14	2.095	18.35	17.74	52.40	110.37	1748628
15	2.429	7.84	6.63	21.80	72.72	1896282

16	2.748	18.33	17.55	50.04	112.91	1868247
17	3.925	18.59	17.42	49.88	112.85	1441975
18	2.724	18.47	17.83	48.26	124.05	1731010
19	3.975	18.79	17.78	48.41	116.34	1593066
21	3.353	18.53	17.65	48.65	110.96	1574539
22	3.532	18.23	17.32	54.63	117.87	1547263
23	2.734	18.58	17.77	46.15	144.32	1624393
24	4.616	20.00	18.23	56.72	118.02	1581126
25	2.679	18.67	17.97	59.64	108.22	1561285
26	3.092	18.47	17.34	55.84	127.48	1659808
27	4.812	18.79	17.44	50.24	139.42	1501268
29	2.745	18.65	17.94	56.65	120.09	1625651
30	3.443	18.77	17.79	52.25	119.44	1679783
31	2.762	17.72	16.98	56.44	105.38	1553922

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

PRN	Range Rate Error Mean	Range Rate Error RMS	Range Rate Error 1s	95% Range Rate Error	Max Range Rate Error (SPS Spec. ≤ 2 m)	Samples
1	-0.00003	0.14293	0.14293	0.27999	0.87775	1577837
2	-0.00001	0.14349	0.14349	0.28016	1.03621	1725249
3	-0.00019	0.14205	0.14205	0.27818	1.25568	1870117
4	-0.00008	0.14312	0.14311	0.27879	1.86398	1653656
5	-0.00005	0.14906	0.14905	0.29251	0.86622	1734067
6	0.00045	0.14758	0.14758	0.28827	1.24885	1617861
7	-0.0002	0.14544	0.14543	0.28389	0.91379	1720988
8	0.00011	0.14582	0.14582	0.28422	1.01449	1896038
9	-0.00022	0.14236	0.14235	0.27863	1.79645	1843885
10	0.00033	0.14088	0.14087	0.2755	1.12083	1550809
13	-0.00009	0.14542	0.14542	0.28466	0.88936	1849904
14	-0.00042	0.14867	0.14866	0.29085	0.93929	1748628
15	0.00027	0.02051	0.02048	0.0404	1.32574	1896282
16	-0.00013	0.14583	0.14582	0.28649	1.27641	1868247
17	0.00012	0.14301	0.143	0.28172	0.97459	1441975
18	0.00045	0.14781	0.1478	0.28869	0.93402	1731010
19	0.00011	0.14537	0.14537	0.28376	0.95564	1593066
21	-0.00001	0.14596	0.14596	0.28412	0.90865	1574539
22	0.00002	0.14293	0.14293	0.28116	1.37584	1547263
PRN	Range Rate Error Mean	Range Rate Error RMS	Range Rate Error 1s	95% Range Rate Error	Max Range Rate Error (SPS Spec. ≤ 2 m)	Samples
23	-0.00004	0.14547	0.14547	0.28576	0.98068	1624393
24	0.00014	0.14898	0.14898	0.2918	1.18903	1581126
25	-0.00023	0.14725	0.14725	0.28866	0.85547	1561285
26	0.00055	0.14333	0.14332	0.28089	1.39967	1659808
27	0.00027	0.14232	0.14231	0.27936	0.88985	1501268
29	-0.0004	0.14853	0.14853	0.29114	0.90026	1625651
30	-0.00053	0.14653	0.14652	0.28507	1.0339	1679783

31	0.00041	0.13981	0.1398	0.27387	1.73682	1553922

Table 5-5 Range Acceleration Error Statistics (m/s^2)

PRN	Range Acceleration Error Mean	Range Acceleration Error RMS	Range Acceleration 1s	% ≤ 0.008 (SPS Spec. 95% of Time)	Max Range Acceleration Error (SPS Spec. ≤ 0.019 m/s2)	Samples
1	0.00000	0.00108	0.00108	100	0.00716	1577837
2	0.00000	0.00108	0.00108	100	0.00887	1725249
3	0.00000	0.00108	0.00108	100	0.01228	1870111
4	0.00000	0.0011	0.0011	100	0.0172	1653650
5	0.00000	0.00111	0.00111	100	0.00739	1734067
6	0.00000	0.0011	0.0011	100	0.0091	1617856
7	0.00000	0.00111	0.00111	100	0.00959	1720984
8	0.00000	0.0011	0.0011	100	0.00946	1896038
9	0.00000	0.00108	0.00108	100	0.01785	1843881
10	0.00000	0.00107	0.00107	99.99	0.01056	1550795
13	0.00000	0.00111	0.00111	100	0.00767	1849904
14	0.00000	0.00112	0.00112	100	0.00834	1748626
15	0.00000	0.00013	0.00013	99.99	0.01303	1896262
16	0.00000	0.0011	0.0011	100	0.01166	1868241
17	0.00000	0.00107	0.00107	100	0.00678	1441975
18	0.00000	0.00111	0.00111	100	0.00762	1731010
19	0.00000	0.0011	0.0011	100	0.0074	1593066
21	0.00000	0.00111	0.00111	100	0.00708	1574539
22	0.00000	0.00108	0.00108	100	0.01109	1547263
23	-0.00001	0.00109	0.00109	100	0.00804	1624393
24	-0.00001	0.00113	0.00113	100	0.01054	1581119
25	0.00000	0.00111	0.00111	100	0.00731	1561285
26	0.00001	0.00109	0.00109	99.99	0.01214	1659770
27	0.00000	0.00108	0.00108	100	0.00672	1501268
29	0.00000	0.00112	0.00112	100	0.00742	1625651
30	0.00000	0.00109	0.00109	100	0.00800	1679783
31	0.00000	0.00106	0.00106	100	0.01834	1553918

Figures 5-4, 5-5 and 5-6 are graphical representations of the distributions of the minimum and 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 23 with an error of 144.32 meters. Satellite 15 had the lowest maximum range error of 72.72 meters.

Figure 5-4 Distribution of Daily Max Range Errors

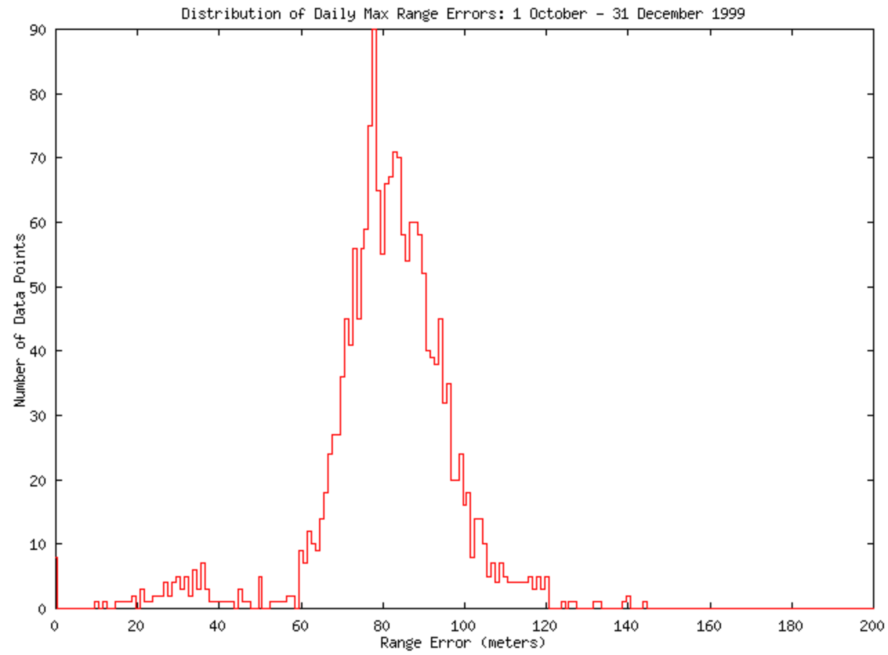


Figure 5-5 Distribution of Daily Max Range Rate Errors

Figure 5-6 Distribution of Daily Max Acceleration Rate Errors

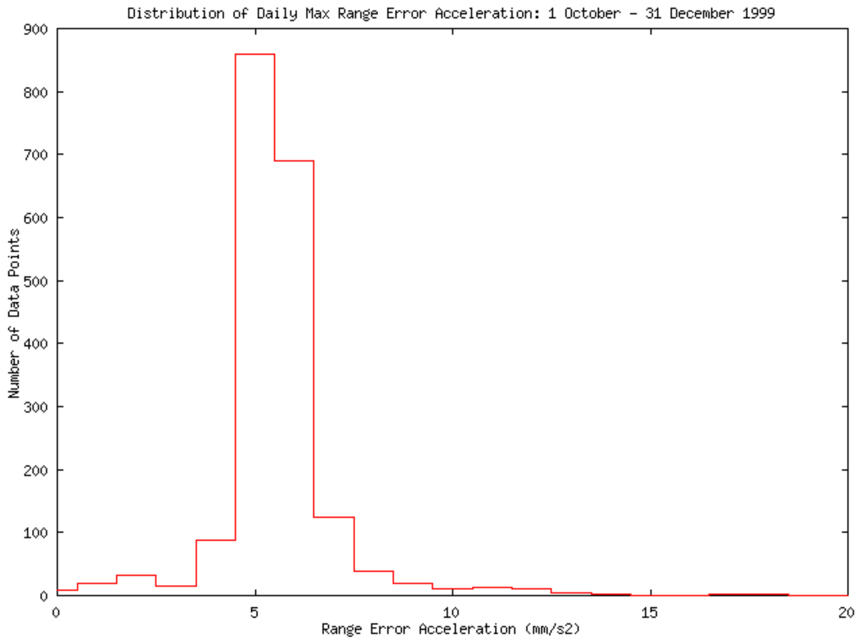

Distribution of Daily Max Range Error Acceleration: 1 October - 31 December 1999
Number of Data Points
Range Error Acceleration (mm/s2)
0
100
200
300
400
500
600
700
800
900
0
5
10
15
20

Figure 5-7 Maximum Range Error Per Satellite

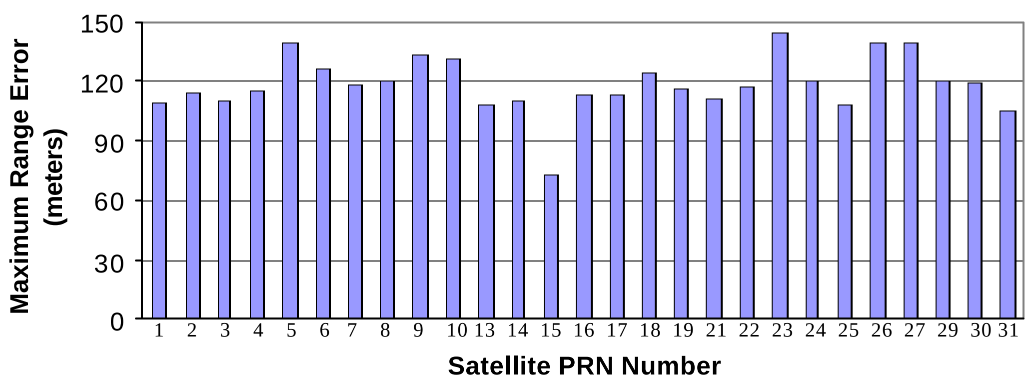


Figure 5-8 Maximum Range Rate Error Per Satellite

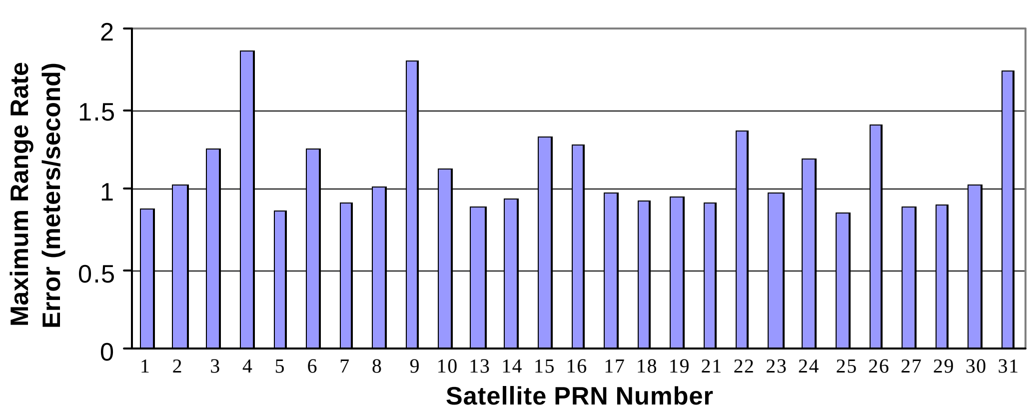
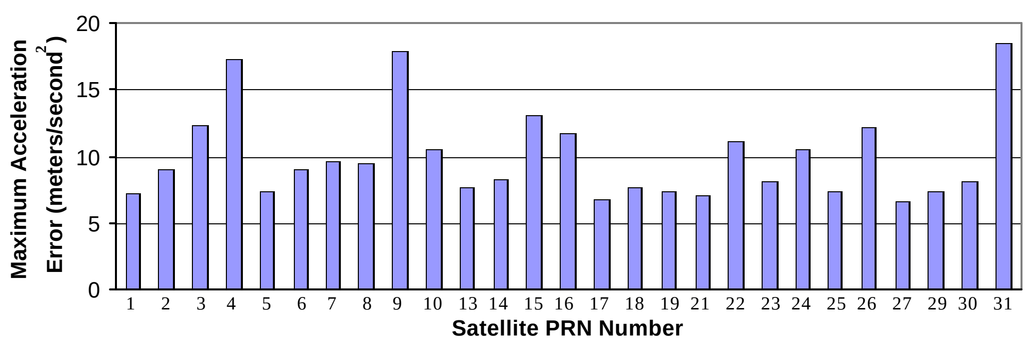


Figure 5-9 Maximum Range Acceleration Error Per Satellite



6.0 Solar Storms

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

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

The aurora is understood to be 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 a 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.

The disturbance of the geomagnetic field may also be measured by an instrument called a magnetometer. 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 10-13 October 1999

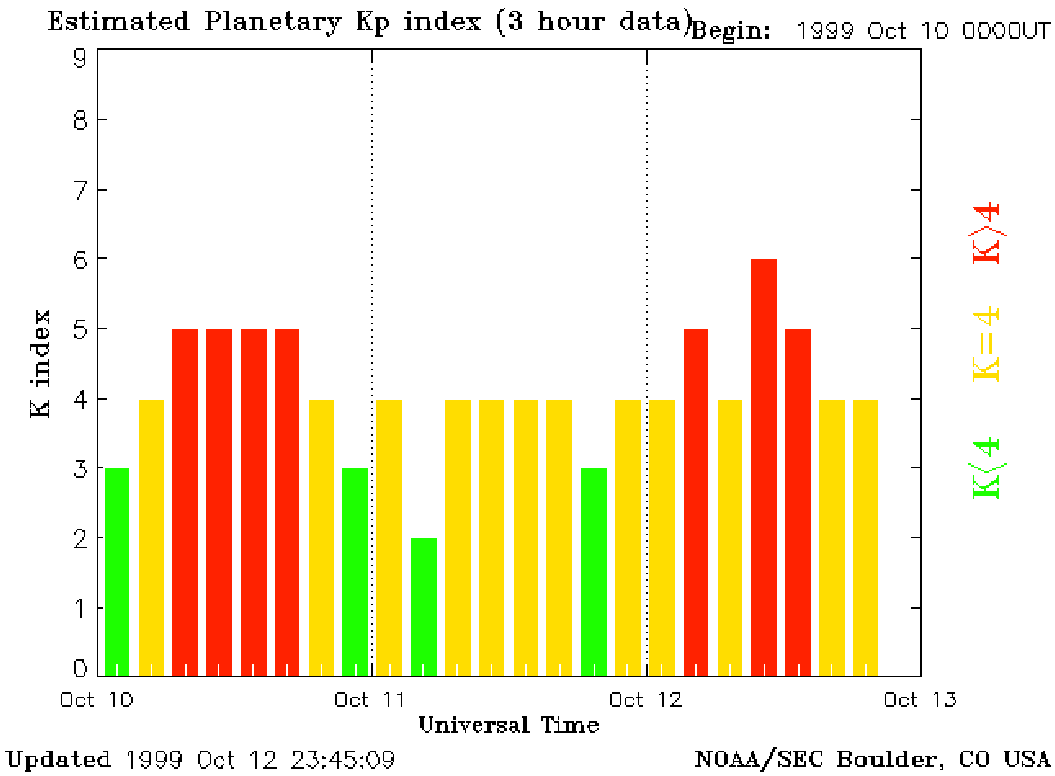


Figure 6-2 K-Index for 22-25 October 1999

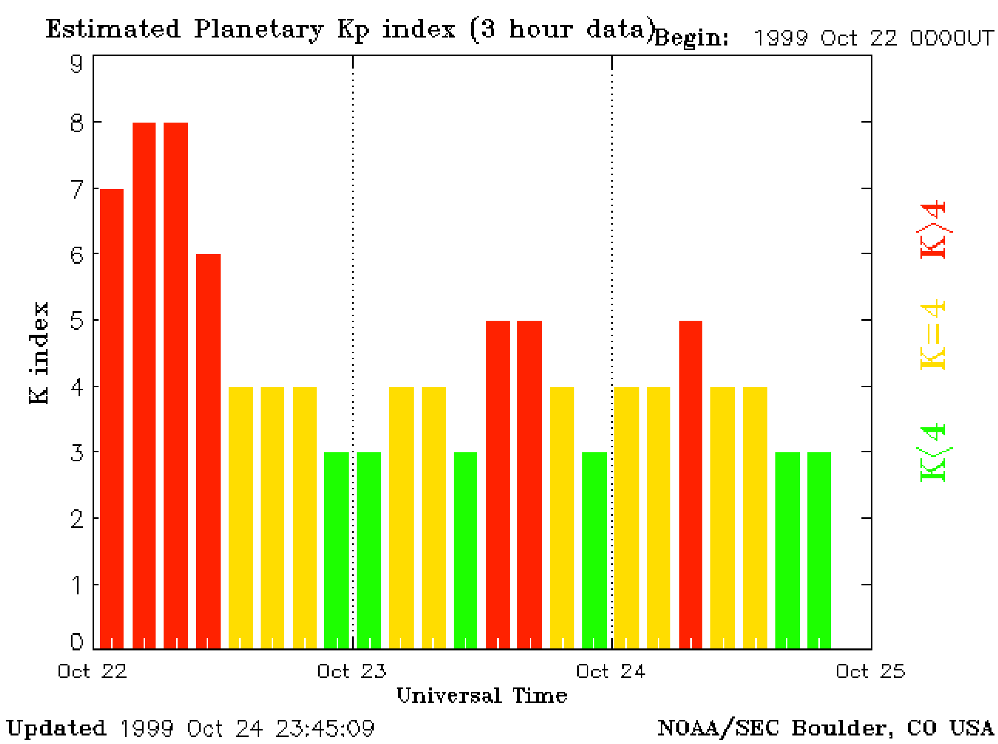
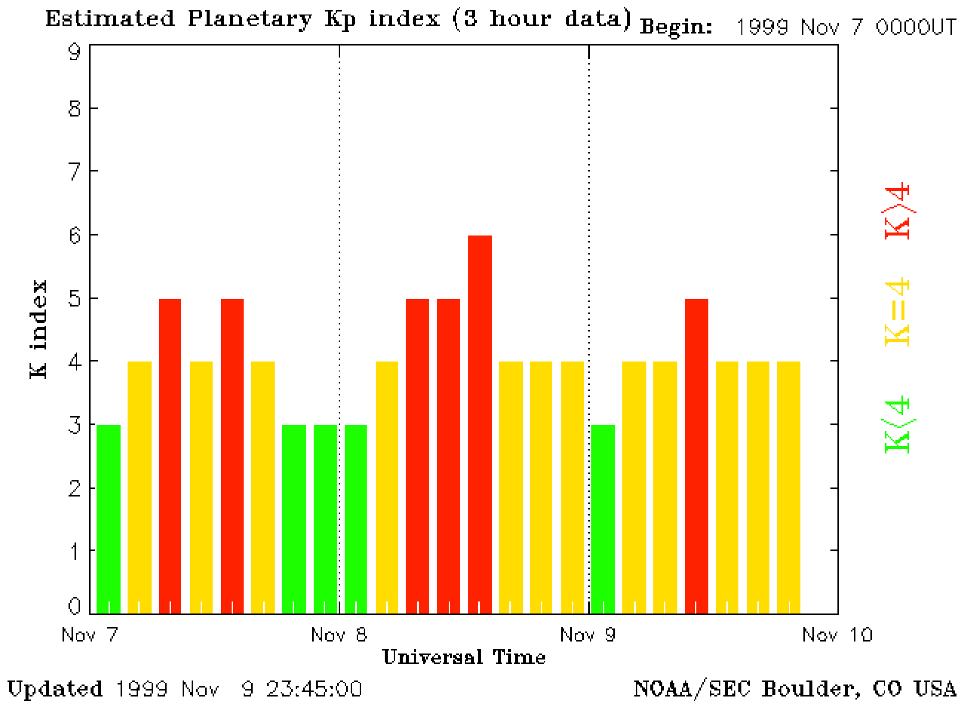


Figure 6-3 K-Index for 7-10 November 1999



Tables 6-1 and 6-2 show the PDOP and position accuracy information, respectively, for the days corresponding to Figures 6-1 and 6-2. The PDOPs and position accuracies show no significant differences between the days with storms and the days with no storms. 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	95%	95% VDOP
Anderson					
10-12-99	1.30	3.43	1.90	2.64	2.32
10-22-99	1.31	3.57	1.89	2.66	2.34
11-8-99	1.32	3.48	1.89	2.55	2.23
Atlantic City					
10-12-99	1.40	4.63	1.92	2.87	2.54
10-22-99	1.39	5.58	1.92	2.90	2.57
11-8-99	1.44	4.08	1.81	2.49	2.11
Dayton					
10-12-99	1.33	4.03	1.82	2.29	1.97
10-22-99	1.33	3.23	1.81	2.27	1.95
11-8-99	1.33	4.75	1.82	2.29	2.01
Elko					
10-12-99	1.29	5.57	1.89	2.80	2.42
10-22-99	1.29	5.32	1.88	2.80	2.41

NSTB Site	Min	Max	Mean	95%	95% VDOP
Gander					
10-12-99	1.29	5.67	1.85	2.69	2.21
10-22-99	1.29	5.46	1.84	2.59	2.14
11-8-99	1.25	3.68	1.85	2.56	2.12
Great Falls					
10-12-99	1.39	5.85	2.19	3.31	2.75
10-22-99	1.39	5.82	2.19	3.24	2.74
11-8-99	1.36	5.69	2.10	2.95	2.51
Seattle					
10-12-99	1.31	4.26	1.86	2.62	2.21
10-22-99	1.31	3.35	1.86	2.56	2.19
11-8-99	1.29	3.35	1.81	2.43	2.06

Table 6-2 Horizontal & Vertical Accuracy Statistics*

NSTB Site	95% Horizontal (m)	95% Vertical (m)	99.99% Horizontal (m)	99.99% Vertical (m)
Anderson				
10-12-99	43.9	77.7	74.7	145.0
10-22-99	44.6	84.4	72.5	144.0
11-8-99	43.1	73.1	98.6	162.0
Atlantic City				
10-12-99	44.2	77.4	85.1	153.0
10-22-99	42.5	84.0	74.4	170.0
11-8-99	44.7	68.4	86.5	181.0
Dayton				
10-12-99	43.7	71.4	80.4	150.0
10-22-99	42.7	75.9	67.5	155.0
11-8-99	43.0	70.4	97.2	219.0
Elko				
10-12-99	45.5	69.5	95.0	196.0
10-22-99	47.4	79.7	94.6	158.0
Gander				
10-12-99	44.5	79.6	88.7	158.0
10-22-99	45.5	81.5	116.0	176.0
11-8-99	47.0	64.7	125.0	189.0
Great Falls				
10-12-99	50.6	90.9	120.0	245.0
10-22-99	56.3	93.7	160.0	220.0
11-8-99	49.8	80.4	112.0	223.0
Seattle				
10-12-99	43.5	70.8	92	178.0
10-22-99	47.7	73.7	86.3	164.0
11-8-99	41.3	68.0	97.7	168.0

7.0 GLONASS/GPS Performance

7.1 Introduction

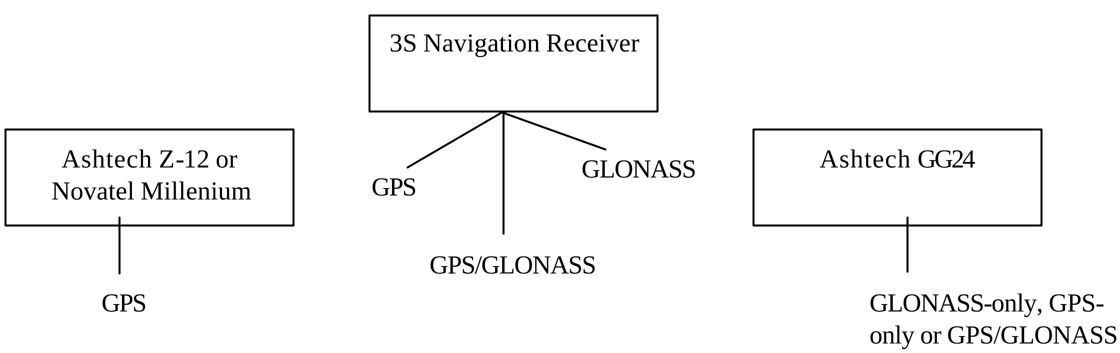
This section is new to the PAN report. In April 1999, ACT-360 was tasked to monitor, analyze and characterize GLONASS and GPS/GLONASS system performance. The objective of this task is to evaluate the ability of GLONASS to provide navigation by itself and with SPS GPS and to assess the incremental benefit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

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.

Two GPS/GLONASS receivers were purchased and placed in the ACT-360 NSTB laboratory. The 3S Navigation R-100/30T receiver provides the three solutions (GPS, GLONASS and blended) simultaneously. The Ashtech GG24 provides the three solutions but only one at a time. With these two receivers in addition to the Ashtech Z-12 and the Novatel Millenium that are already in the NSTB laboratory, any performance due to a receiver problem can be eliminated.

Figure 7-1 Receiver with Corresponding Solutions



Analysis will include the comparison of the different solutions obtained from all three. The GPS/GLONASS receiver solutions will be compared to the Z-12 or Millenium 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

Data will also be provided at an NSTB website. Graphical representation of the previous day's performance data (e.g. position accuracies, availabilities, satellite visibility) will be made available at the website.

7.3 Quarter Results

For this quarter, data collected from the Ashtech GG24 receiver and the Ashtech Z-12 will be analyzed and compared. Tables 7-1 and 7-2 provide PDOP and Position Accuracy statistics for the two Ashtech receivers from 1 October through 31 December 1999. The statistics are cumulative.

Table 7-1 PDOP Statistics for Two Solutions

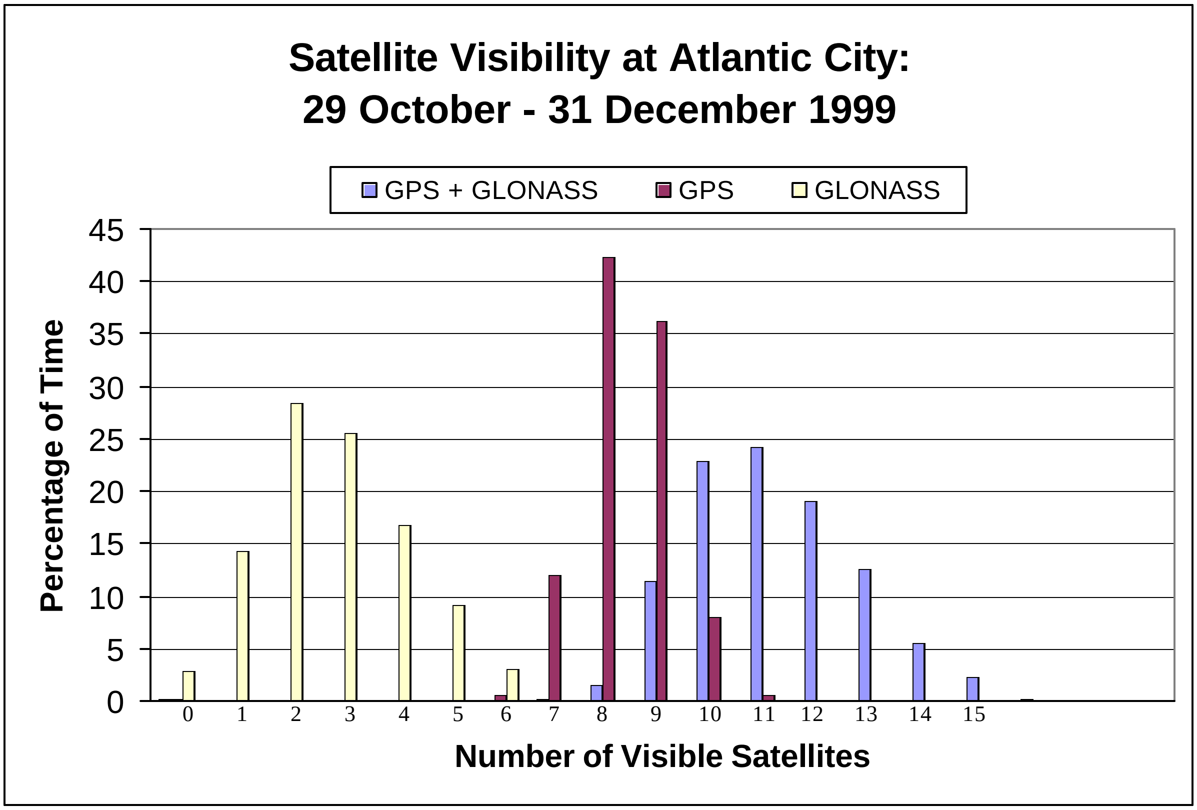
Receiver	Solution	Maximum PDOP	Minimum PDOP	Mean PDOP	95% PDOP	Number of Samples
Ashtech GG24	GPS/GLONASS	4.3	1.1	1.6	2.18	5215667
Novatel Millenium	GPS-only	6.3	1.3	1.7	1.9	7409113

Table 7-2 Position Accuracy Statistics for Two Solutions

Receiver	Solution	95% Horizontal (m)	95% Vertical (m)	99.99% Horizontal (m)	99.99% Vertical (m)	Number of Samples
Ashtech GG24	GPS/GLONASS	32.8	74.4	70.5	148.0	5215667
Novatel Millenium	GPS-only	44.7	76.4	90.7	173.0	7409113

Table 7-3 shows the PDOP and Position Accuracy statistics broken down by the number of GLONASS satellites tracked. Figure 7-2 provides the satellite visibility from 29 October through 31 December 1999.

Figure 7-2 Satellite Visibility Based on GG24 Data



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

Figure 7-3 Horizontal Position Error Histograms for GPS/GLONASS and GPS-Only Solutions

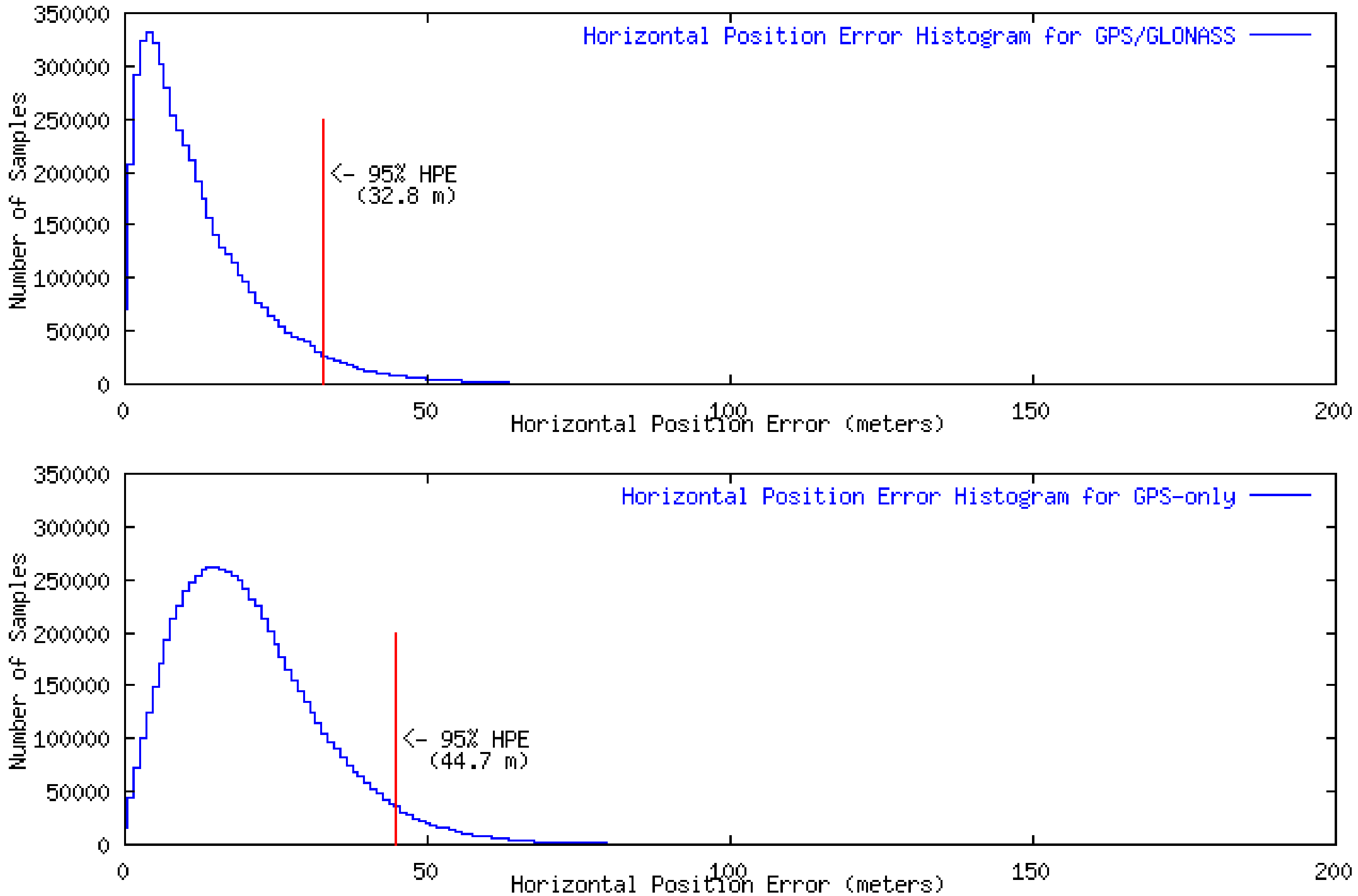
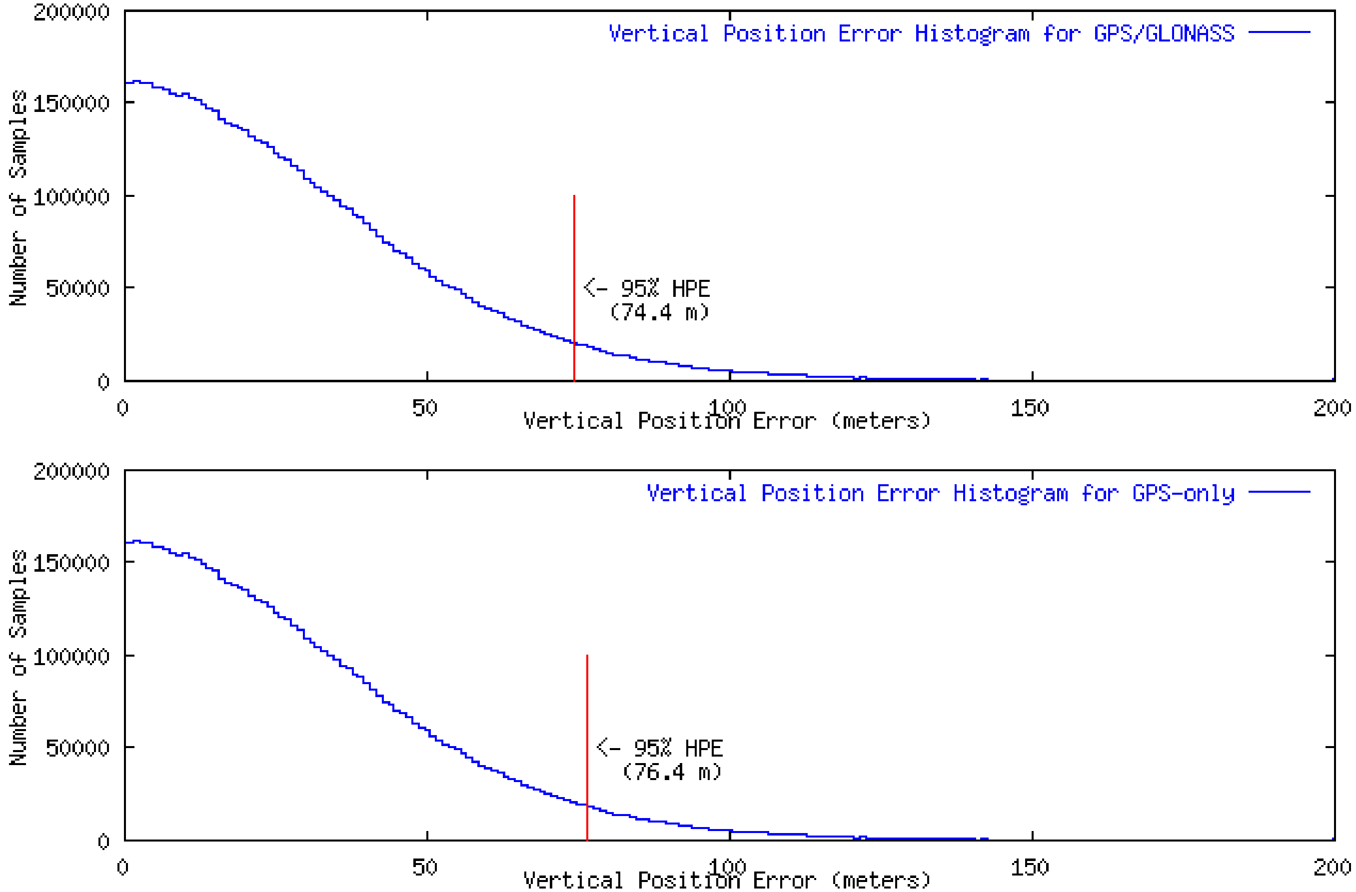


Figure 7-4 Vertical Position Error Histograms for GPS/GLONASS and GPS-Only Solutions



APPENDICES A – D

Appendix A Performance Summary

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	99.992%
• Probability of 4 or more satellites in view over any 24 hour interval, for the worst-case point on the globe • 4 satellites must provide PDOP of 6 or less • 5° mask angle with no obscura • Standard is predicated on 24 operational satellites, as the constellation is defined in the almanac	≥ 96.9% at worst-case point	99.375% availability 99.9% PDOP was 3.13
Conditions and Constraints	***Satellite Availability Standard***	
• 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	99.99%
• 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	99.99%
• Conditioned on coverage standard • Standard represents a worst-case 24 hour interval, averaged over the globe	≥ 95.87% global average on worst-case day	99.34%
• Conditioned on coverage standard • Standard based on a worst-case 24 hour interval, for the worst-case point on the globe	≥ 83.92% at worst-case point on worst-case day	99.59%
Conditions and Constraints	***Service Availability Standard***	
• 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***	
• 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>Predictable Accuracy</u> ≤ 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	46 m horz. error 95% of time 77 m vert. error 95% of time 101 m horz. error 99.99% of time 172 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	36 m horz. error 95% of time 111 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	<u>Relative Accuracy</u> ≤ 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	<u>Time Transfer Accuracy</u> ≤ 340 nanoseconds time transfer error 95% of time	88 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	<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	144 m NTE range error 1.86 m/s NTE range rate error less than 8 mm/sec^2 100% of the time 18 mm NTE range acceleration error

Appendix B Geomagnetic Data

:Product: Daily Geomagnetic Data quar_DGD.txt
:Issued: 0225 UT 07 Jul 1999
#
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
#

NOTE: A value of –1 for either the A or K terms means that there is no data for that time period.

Table B-1 Current Quarter Daily Geomagnetic Data

	Middle Latitude - Fredericksburg -		High Latitude ---- College ----		Estimated --- Planetary ---	
Date	A	K-indices	A	K-indices	A	K-indices
1999 10 01	6	3 2 1 1 2 1 2 1	13	2 2 3 4 4 3 1 1	11	2 3 2 3 3 3 3 3
1999 10 02	9	2 4 3 2 2 1 2 2	19	3 4 4 4 3 4 1 2	15	3 4 4 3 3 3 2 2
1999 10 03	6	2 1 2 2 2 2 1 2	18	5 2 2 4 3 2 4 1	10	2 1 3 3 3 3 2 2
1999 10 04	9	1 2 2 2 2 2 2 4	-1	2 3 4-1-1 4 4 3	15	1 3 3 3 3 3 3 3
1999 10 05	11	2 2 2 2 3 2 2 4	19	3 3 3 3 5 4 2 2	16	3 3 3 3 4 3 3 3
1999 10 06	4	0 1 2 2 2 1 1 1	10	0 1 2 5 3 1 1 1	6	1 1 3 3 2 2 2 1
1999 10 07	5	2 2 2 1 1 0 1 2	6	3 0 2 3 1 0 1 1	6	2 2 2 1 2 2 2 1
1999 10 08	8	1 4 1 2 3 0 1 1	14	1 1 1 4 4 0 0 5	8	2 3 2 3 3 1 1 1
1999 10 09	4	0 1 1 0 1 2 2 2	4	0 0 2 2 1 1 2 1	6	0 1 2 1 2 2 3 3
1999 10 10	18	2 3 3 4 4 4 3 2	52	1 4 6 5 6 7 4 2	28	3 4 5 5 5 5 4 3
1999 10 11	18	4 2 3 3 3 4 2 4	45	4 2 6 6 5 6 3 4	23	4 2 4 4 4 4 3 4
1999 10 12	21	5 4 2 4 3 3 3 3	61	4 4 6 6 6 7 4 4	34	4 5 4 6 5 4 4 4
1999 10 13	21	5 3 5 3 3 2 3 2	35	4 2 6 5 5 4 4 3	26	4 3 5 4 4 3 3 3
1999 10 14	17	3 4 3 2 4 3 3 3	41	3 3 4 6 6 6 3 3	24	3 4 4 4 4 5 3 4
1999 10 15	17	4 4 3 3 3 3 3 2	52	4 6 6 5 6 6 3 2	24	4 4 5 4 4 4 3 3
1999 10 16	17	4 4 2 3 3 3 3 3	38	3 4 4 6 6 5 3 3	21	4 4 3 3 4 4 3 3
1999 10 17	16	4 3 4 4 3 2 1 1	58	3 4 6 7 7 5 2 2	26	4 3 5 5 5 3 1 2
1999 10 18	6	1 1 0 0 3 3 1 2	9	1 1 0 2 5 2 1 1	6	1 1 1 1 3 3 2 2
1999 10 19	5	3 2 3 0 0 0 0 0	10	1 3 4 2 4 0 0 0	7	2 2 4 1 1 2 2 1
1999 10 20	4	1 1 0 1 3 1 1 0	1	0 0 0 0 1 0 1 0	4	0 1 1 1 2 2 2 1
1999 10 21	14	3 4 2 2 2 2 3 4	13	3 3 1 2 2 3 3 4	15	3 4 2 2 2 3 3 4
1999 10 22	45	6 4 7 4 3 4 4 3	-1	5-1 6 6 5 5 5 3	87	7 8 8 6 4 4 4 3
1999 10 23	26	3 5 3 2 5 5 3 3	58	2 3 6 4 7 7 4 4	26	3 4 4 3 5 5 4 3
1999 10 24	20	4 3 5 3 2 2 3 4	46	3 4 5 7 6 4 3 3	23	4 4 5 4 4 3 3 4
1999 10 25	10	3 3 3 2 2 2 2 1	-1	3 2 4 6-1 4 5 1	18	3 3 4 4 4 3 3 1
1999 10 26	6	1 2 1 2 2 2 2 2	16	1 1 4 5 4 3 1 1	9	1 3 2 3 3 3 2 2
1999 10 27	10	2 3 2 3 3 2 2 2	40	2 3 4 6 6 6 3 3	17	2 3 3 4 4 4 2 2
1999 10 28	9	0 1 2 1 4 2 3 2	53	1 5 5 3 7 6 6 2	16	2 1 3 1 5 4 3 3
1999 10 29	9	1 2 2 2 2 3 2 3	23	5 2 2 6 4 0 2 2	10	3 2 3 3 3 2 2 2
1999 10 30	4	1 1 1 2 2 1 0 1	18	4 0 4 4 5 3 0 0	7	1 1 1 2 3 2 2 2
1999 10 31	7	2 2 2 2 1 1 2 3	17	5 1 4 4 2 2 2 2	10	2 2 3 3 3 3 2 3

1999 11 01	9	2 2 2 4 2 1 2 1	-1	-1-1-1-1-1-1-1-1	10	3 2 2 4 3 2 2 1
1999 11 02	4	2 1 1 2 0 1 1 1	-1	-1-1-1-1-1-1-1-1	6	2 1 2 2 2 2 2 2
1999 11 03	4	3 0 0 0 1 2 1 1	-1	3 0-1 2 0 0 3 0	5	3 0 1 1 1 2 2 2
1999 11 04	5	2 2 1 1 2 1 1 1	2	1 1 1 2 0 0 0 0	5	1 2 1 1 1 2 2 2
1999 11 05	4	2 0 0 0 0 1 2 3	1	0 0 0 0 0 0 2 1	4	1 0 0 0 0 1 2 3
1999 11 06	5	2 1 1 1 1 2 2 1	-1	-1-1-1-1-1-1-1-1	7	2 1 1 1 1 2 3 2
1999 11 07	20	3 3 3 3 5 4 2 3	-1	-1-1-1-1-1-1-1-1	24	3 4 5 4 5 4 3 3
1999 11 08	18	2 3 4 3 4 3 4 2	-1	3 3 6 6 7 5 5-1	33	3 4 5 5 6 4 4 4
1999 11 09	23	4 4 3 4 3 3 4 4	-1	-1-1-1-1-1-1-1-1	25	3 4 4 5 4 4 4 4
1999 11 10	10	2 3 1 1 3 2 3 3	-1	-1-1-1-1-1-1-1-1	12	3 3 2 3 3 3 3 3
1999 11 11	16	3 4 4 2 3 2 3 3	-1	-1-1-1-1-1-1-1-1	23	3 4 5 4 4 3 3 3
1999 11 12	8	2 2 2 1 2 1 3 3	-1	-1-1-1-1-1-1-1-1	10	2 1 2 1 3 2 3 3
1999 11 13	20	3 3 3 3 4 3 4 4	-1	-1-1-1-1-1-1-1-1	31	2 3 4 3 5 4 5 5
1999 11 14	9	2 3 3 2 2 1 2 2	-1	-1-1-1-1-1-1-1-1	10	2 2 4 3 1 2 1 3
1999 11 15	3	1 0 2 1 1 1 1 0	-1	-1-1-1-1-1-1-1-1	6	2 0 2 2 2 2 1 0
1999 11 16	11	1 1 2 4 3 3 3 1	-1	-1-1-1-1-1-1-1-1	16	1 1 2 4 4 3 3 3
1999 11 17	8	2 1 2 2 3 2 3 1	-1	1 2 3 3 4 3 2-1	10	2 2 2 2 3 3 3 2
1999 11 18	8	2 2 2 3 2 2 2 2	19	2 2 4 4 4 4 3 3	12	2 2 3 3 3 3 3 3
1999 11 19	9	3 3 2 1 2 0 2 3	22	2 3 5 4 5 3 1 3	12	3 3 3 3 3 2 3 3
1999 11 20	7	3 3 2 2 1 1 1 1	11	3 2 2 5 2 0 2 0	9	3 3 2 2 2 2 2 2
1999 11 21	11	2 3 4 1 0 2 3 3	9	0 2 4 3 2 1 2 2	10	2 2 3 2 1 3 3 3
1999 11 22	8	3 1 2 3 3 2 0 1	30	2 0 5 6 6 3 1 1	10	3 2 2 3 4 2 1 1
1999 11 23	13	1 4 3 3 2 1 2 4	36	0 2 6 5 6 4 4 3	15	1 3 4 4 3 3 3 4
1999 11 24	14	2 2 4 5 2 1 2 1	29	2 1 5 6 5 4 3 2	19	2 3 4 5 3 3 3 1
1999 11 25	17	2 2 2 5 5 2 2 2	33	0 3 4 7 5 3 3 2	18	1 2 3 6 4 3 3 2
1999 11 26	2	0 0 1 2 2 0 0 0	4	1 1 1 3 4 0 0 0	4	1 0 2 2 2 1 1 1
1999 11 27	1	0 0 0 0 1 0 0 1	1	0 0 0 0 1 0 0 1	3	0 0 1 1 1 2 1 1
1999 11 28	7	2 2 2 2 2 2 1 2	9	0 1 3 3 3 2 2 2	7	2 2 3 2 1 3 2 2
1999 11 29	2	1 1 0 2 1 0 1 0	5	1 1 1 3 3 0 0 0	4	2 0 1 1 2 1 2 1
1999 11 30	8	2 1 2 3 3 0 2 2	14	1 1 1 5 5 0 2 1	8	2 2 2 3 3 2 2 2
1999 12 01	2	2 0 0 1 0 1 1 1	1	1 0 0 0 0 1 1 0	4	1 1 0 1 1 1 2 1
1999 12 02	3	2 1 0 0 1 1 1 2	2	0 0 0 1 1 0 1 2	4	2 0 0 1 1 1 2 2
1999 12 03	9	2 2 2 3 3 2 2 2	23	2 2 1 4 5 6 2 2	13	3 2 2 3 3 4 3 2
1999 12 04	21	4 2 3 5 4 3 3 3	60	1 2 5 7 7 6 5 3	28	4 3 4 6 5 4 3 3
1999 12 05	19	4 4 4 4 3 3 2 2	-1	-1-1-1-1-1-1-1-1	18	4 4 4 4 3 3 3 2
1999 12 06	14	2 4 3 3 3 2 3 2	42	3 3 5 5 7 4 4 3	19	2 4 4 4 4 3 3 2
1999 12 07	8	3 2 2 2 2 1 2 2	23	2 3 4 5 3 4 4 3	14	3 2 4 3 2 3 3 3
1999 12 08	9	2 2 3 1 1 3 2 3	30	3 2 6 4 4 5 4 2	13	3 2 4 3 2 3 3 3
1999 12 09	14	3 4 3 3 2 2 3 3	-1	2 3 3 5-1-1-1-1	12	3 4 3 3 2 3 3 3
1999 12 10	8	1 3 2 1 2 2 2 2	-1	-1-1-1-1-1-1-1-1	7	2 3 2 2 2 2 3 2
1999 12 11	6	1 2 2 2 3 2 0 0	12	1 2 2 4 5 2 0 0	7	1 2 3 2 3 2 1 1
1999 12 12	11	1 3 1 3 2 4 3 2	20	0 1 1 5 5 4 4 2	9	1 3 1 3 2 3 3 2
1999 12 13	26	3 4 4 6 4 4 2 1	43	3 4 6 6 6 5 2 1	26	3 4 5 5 5 4 2 1
1999 12 14	3	2 1 1 1 0 2 2 0	1	1 1 0 0 0 0 0 0	3	1 0 0 0 2 1 1 1
1999 12 15	2	0 0 0 0 0 1 2 2	1	0 0 0 0 0 0 1 1	4	0 0 0 0 1 1 1 3
1999 12 16	6	2 1 2 1 2 2 2 2	2	1 0 2 0 0 1 1 1	5	1 1 2 1 1 2 2 2
1999 12 17	8	2 3 1 2 3 2 2 1	5	1 1 0 3 3 1 1 0	5	1 2 1 1 2 2 2 1
1999 12 18	4	1 0 1 1 1 2 2 2	3	0 0 0 2 1 2 2 1	5	2 0 1 1 1 2 2 2
1999 12 19	6	1 1 1 2 3 3 1 1	6	0 1 0 2 4 2 1 0	4	1 0 0 2 2 2 1 1
1999 12 20	4	0 0 1 2 2 2 2 2	1	0 0 1 1 0 0 0 0	3	0 0 1 1 0 2 1 1
1999 12 21	1	0 0 1 0 1 0 0 0	7	0 0 1 1 0 0 0 5	2	0 0 1 1 1 1 0 1
1999 12 22	1	0 0 0 0 0 0 2 0	0	0 0 0 0 0 0 0 0	2	0 0 0 0 1 1 1 1
1999 12 23	2	0 0 0 1 1 2 0 2	-1	-1-1-1-1-1-1-1-1	5	0 0 0 1 2 2 2 1
1999 12 24	11	3 3 3 2 2 2 2 3	-1	-1-1-1-1-1-1-1-1	10	2 3 3 4 2 2 1 2
1999 12 25	10	2 2 3 2 4 2 1 1	18	1 4 3 3 5 4 1 1	10	1 2 4 2 4 3 1 2
1999 12 26	2	1 0 0 0 1 1 0 2	0	0 0 0 1 0 0 0 0	2	1 0 0 0 0 1 1 1
1999 12 27	6	4 2 1 1 0 1 1 1	-1	1 2 3-1 1-1-1-1	6	3 2 2 2 0 1 2 0
1999 12 28	8	1 3 1 1 1 1 2 4	7	0 1 1 1 3 1 1 4	7	0 3 1 1 2 2 2 2
1999 12 29	5	3 2 1 0 0 2 1 2	4	3 1 1 0 0 2 1 1	7	3 2 1 0 1 2 2 2
1999 12 30	7	1 1 1 2 1 2 3 3	8	0 1 2 3 1 1 3 3	8	2 0 2 2 2 2 3 3
1999 12 31	20	4 3 2 3 3 3 3 5	40	4 4 4 5 5 5 5 5	27	4 4 4 4 4 4 4 5

Appendix C WAAS DATA from Performance Build Testing

Background: WAAS Stability Test

The Performance Build test started 13 December 1999 and ended on 12 January 2000. Using NSTB reference station data at Anderson and Denver and the WAAS broadcast corrections transmitted from AOR-W satellite collected at Dayton, position errors were computed. Cumulative data for this time period was compiled and statistical values and plots were generated. Horizontal and vertical performance results are presented in histogram graphs. The vertical and horizontal 3d-histograms show the density of the position error versus the protection level in respective operational zones. These operational zones are defined as follow:

Operational Zone	**HPL**	**VPL**
Precision Approach (PA)	40 m	12 m
Instrument approach with vertical guidance (IPV)	40 m	20m
Non-precision approach with vertical guidance (NPV)	556 m	50 m
Unavailable	Above 556 m	Above 50 m
Alarm Condition	HPE exceeds HPL	VPE exceeds VPL

The 2-d histogram plot includes four histogram graphs of horizontal error histogram, normalized horizontal error histogram, vertical error histogram, and normalized vertical error histogram.
Statistical values of mean, standard deviation, and 95% for the overall and the individual operational zones are shown on the 3d-histogram plots. In addition, table XXX shows the statistical values of mean, standard deviation, 95%, 99%, 99.9%, and 99.99% for the overall and the individual operation area both for vertical and horizontal.

**Figure C-1 Vertical and Horizontal Histograms:
Denver 13 December 1999 – 12 January 2000**

**Figure C-2 Vertical and Horizontal Histograms:
Anderson 13 December 1999 – 12 January 2000**

Figure C-3 HPE vs HPL 3D Histogram:
Denver 13 December 1999 – 12 January 2000

Figure C-4 HPE vs HPL 3D Histogram:
Anderson 13 December 1999 – 12 January 2000

Figure C-5 VPE vs VPL 3D Histogram:
Denver 13 December 1999 – 12 January 2000

**Figure C-6 VPE vs VPL 3D Histogram:
Anderson 13 December 1999 – 12 January 2000**

The statistic table for each day shows mean, standard deviation, 95%, 99%, 99.9%, and 99.99% for the overall and the individual operation area both for vertical and horizontal.

Table C-1 Position Accuracy Statistics for WAAS Stability Test At Anderson: 13 December 1999 – 12 January 2000

Waas Requirement	Count	% of Total	Mean	Std_dev	95 index	99 index	99.9 index	99.99 index
Vertical_Total	2500185	1	-0.309	1.636	2.724	3.828	7.898	49.074
Vertical_Not_Available	6000	0.00239982	-2.273	18.738	46.921	58.368	71.272	71.272
Vertical_Alarm_Condition	0	0	0	0	0	0	0	0
Vertical_PA	1902570	0.76097167	-0.298	1.191	2.479	3.289	4.226	4.766
Vertical_SPEC	2475875	0.99027669	-0.301	1.295	2.685	3.693	4.944	5.919
Vertical_IPV	2480614	0.99217218	-0.303	1.297	2.69	3.705	4.982	5.963
Vertical_NPV	2494185	0.9976002	-0.304	1.305	2.705	3.745	5.1	6.139
Horizontal_Total	2500185	1	0.815	0.76	1.588	2.023	5.068	33.244
Horizontal_Not_Available	37	0.0000148	19.342	6.26	30.291	30.291	30.291	30.291
Horizontal_Alarm_Condition	0	0	0	0	0	0	0	0
Horizontal_PA_IPV	2495120	0.99797416	0.798	0.428	1.581	1.996	2.586	3.058
Horizontal_NPV	2500148	0.99998522	0.815	0.754	1.587	2.022	4.806	31.11

Table C-2 Position Accuracy Statistics for WAAS Stability Test At Denver: 13 December 1999 – 12 January 2000

Waas Requirement	Count	% of Total	Mean	Std_dev	95 index	99 index	99.9 index	99.99 index
Vertical_Total	2328213	1	0.499	1.53	2.434	3.401	7.76	51.363
Vertical_Not_Available	5205	0.00223562	-3.655	20.793	56.389	69.03	69.722	69.722
Vertical_Alarm_Condition	0	0	0	0	0	0	0	0
Vertical_PA	1813080	0.77874321	0.444	1.029	2.185	2.899	3.755	4.258
Vertical_SPEC	2300647	0.98816001	0.507	1.111	2.396	3.267	4.513	5.544
Vertical_IPV	2305723	0.99034023	0.508	1.113	2.4	3.273	4.535	5.551
Vertical_NPV	2323008	0.99776441	0.508	1.123	2.416	3.317	4.602	5.756
Horizontal_Total	2328213	1	0.771	0.794	1.499	2.01	5.518	33.415
Horizontal_Not_Available	93	0.00003994	23.048	1.206	25.057	25.183	25.183	25.183
Horizontal_Alarm_Condition	0	0	0	0	0	0	0	0
Horizontal_PA_IPV	2323452	0.99795508	0.753	0.408	1.493	1.977	2.706	3.241
Horizontal_NPV	2328120	0.99996006	0.77	0.778	1.499	2.009	4.934	32.965

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. The minimum signal reception and processing capabilities which must be designed into an SPS receiver in order to experience performance consistent 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 which 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 which 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 Radionavigation 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.