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

Submitted To

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

Report #26
July 30, 1999
Reporting Period 1 April – 30 June 1999

Submitted by

William J. Hughes Technical Center
NSTB/WAAS T&E Team
ACT 360
Atlantic City International Airport, NJ 08405

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: Bangor, Dayton, Elko, Gander, Honolulu, Seattle, Sitka and Winnipeg. This analysis verifies the GPS SPS performance as compared to the performance parameters stated in the SPS Specification Annex A.

This report, Report #25, includes data collected from 12 December 1998 through 31 March 1999. The next quarterly report will be issued at the end of July 1999.

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

Coverage performance was based on Position Dilution of Precision (PDOP). Utilizing the weekly almanac posted on the US Coast Guard navigation web site, the coverage for every 5^{o} grid point between 180W to 40E 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 100%.

Availability was verified by reviewing the “Notice: Advisory to Navstar Users” (NANU) reports issued between 12 December 1998 through 31 March 1999 and by calculating the satellite availability from the data obtained from the eight NSTB sites. A total of twenty satellite outages were reported in the NANUs. Eighteen of the outages were scheduled and two were unscheduled. Between 12 December 1998 through 31 March 1999, the availability for Bangor, Dayton, Elko, Gander, Honolulu, Seattle, Sitka and Winnipeg was 100%, 100%, 99.999%, 100%, 99.999%, 100%, 99.999% and 99.992%, respectively. Each of these availabilities are within the SPS value of 99.85%. These availability percentages were calculated using DOP data collected at one-second intervals.

Satellite outages caused the PDOP to exceed six. This increase in PDOP occurred five different times. To aid in determining the cause of these increases ACT-360 monitors satellite and receiver activity. There are times when a satellite stops transmitting a signal for a few seconds. Although this does not cause any position or range problems, the PDOP may exceed 6 during this time. Three of the occurrences were due to this type of outage. The other two increases were due to NANU forecasted maintenance actions that made a satellite unavailable. One important observation made was that even though a receiver was tracking five other satellites, the satellite geometry was not good enough to keep the PDOP below six.

A Solar Storm Activity section has been added to the PAN report. For the time period of this report, seven days showed significant solar activity. The data for these days met all GPS Standard Positioning Service (SPS) specifications. However, the PDOP did go above six due to a satellite outage during the same time of the storm. One issue that was raised during the analysis of solar activity effects was the importance of having at least two receivers at each site and preferably different receivers. Some of the NSTB sites have been reduced to only one receiver. This makes the elimination of receiver-caused problems difficult. Replacement of some receivers is planned.

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 eight sites was 28.49 m, 48.50 m, 58.92 m and 107.65 m, respectively.

Range performance was verified for each satellite using the data collected from the NSTB Dayton site. The data was collected in one-second samples. All of the satellites met the range error specifications. The maximum range error recorded was 148.32 meters on satellite 14. The SPS specification states that the range error should never exceed 150 meters. The Range Rate Error exceeded the SPS specification of two meters twice. Satellites 9 and 13 had maximum Range Rate Errors of 2.05 meters/second and 2.39 meters/second, respectively. The Range Acceleration Error exceeded the SPS specification of 19 millimeters/second^2 twice. Satellites 13 and 22 had maximum Range Acceleration Errors of 21.5 millimeters and 27.6 millimeters/second^2, respectively.

From the analysis performed on data collected between 12 December 1998 through 31 March 1999, the GPS performance met all SPS requirements that were evaluated except for the Range Rate Error and Range Acceleration Error Maximums.

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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. Knowledge gained from ground-based radionavigational aides to space-based radionavigation aids. 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:

- Bangor, ME
- Dayton, OH
- Elko, NV
- Gander, NFLD (Canada)
- Honolulu, HI
- Seattle, WA
- Sitka, AK
- Winnipeg, MAN (Canada)

The Millenium in Gander went down on 28 December 1998. Data for Gander was put into the PAN statistics again in the last week in March. To replace the data from Gander, the data from the Millenium in Bangor was collected and analyzed for the PAN report starting 2 February 1999. The Millenium in Seattle went down on 20 February 1999. On 8 March 1999, the data from the GSV receiver in Seattle was added to the PAN analysis.

Also during this reporting period, Dayton went to a single thread. (i.e. The Ashtech receiver was removed to be placed at another international NSTB TRS site.) This may cause a problem when attempting to investigate a problem. To narrow the cause of a problem, the analysis of data collected from a receiver at the same site can aid in determining a problem with a particular receiver and eliminate an SPS GPS cause of the problem.

(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 40 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 eight 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.

Appendix C of this report provides an example of how future WAAS data analysis will be presented. This data in this report is NSTB data. All data collected for this section was stored in a newly developed Oracle database. This database is still under development and will eventually be used to store data from all NSTB and WAAS sites. The requirements were taken from the WAAS specification (FAA-E-2892B).

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 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 1003 - 1016 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. Eight out of the fourteen days had Availabilities of 100%. The six days that gave less than 100% availability were in Weeks 1006, 1007, 1013, 1014, 1015 and 1016. Table 2-1 also gives the global 99.9% PDOP value for each of the 14 GPS Weeks. The PDOP was 5.02 or better 99.9% for each of the 24-hour intervals.

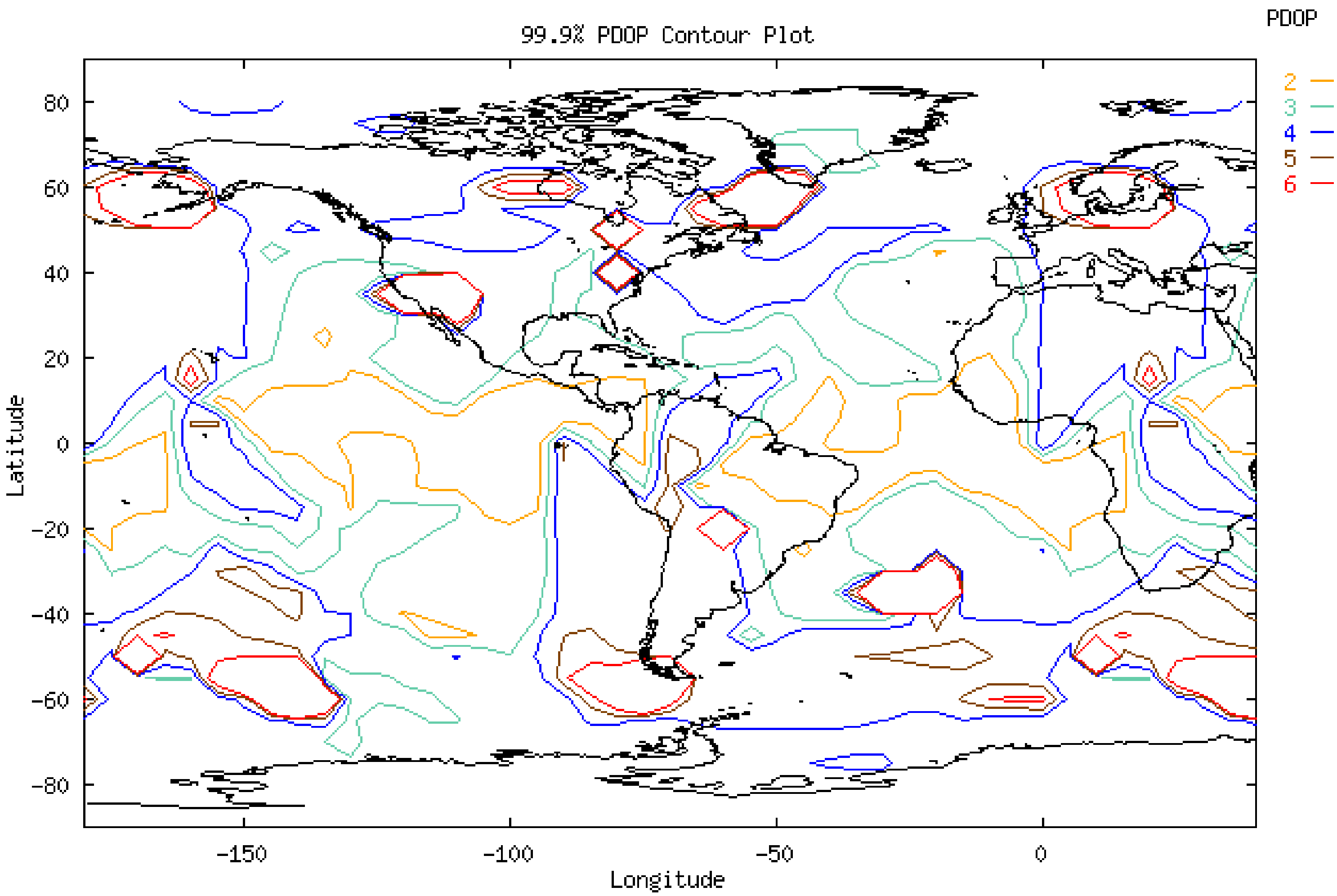
The SPS program also produces a contour plot of the coverage area. Since the contour plots for each of the fourteen days are similar, the day with the worst worst-case point and the highest 99.9% PDOP was selected as the contour plot shown in this report. Figures 2-1 and 2-2 are the contour plot and satellite visibility plot for GPS Week 1007. The contour plot shows that the highest PDOP was between 4 and 5 99.9% of the time. Figure 2-2 shows that there were never less than 5 satellites visible at any time during the 24-hour interval. At least 8 or more satellites were visible 88.4% of the time.

Table 2-1 Coverage Statistics

GPS Week	Global 99.9% PDOP Value*	Global Average* (Spec: ≥ 99.9%)	Worst-Case Point (Spec: ≥ 96.9%)
1003	3.31	100%	100%
1004	3.29	100%	100%
1005	3.29	100%	100%
1006	3.71	99.994%	98.958%
1007	5.02	99.963%	98.264%
1008	3.24	100%	99.931%
1009	3.23	100%	99.861%
1010	3.22	100%	99.861%
1011	3.22	100%	99.861%
1012	3.30	100%	99.792%
1013	4.04	99.977%	98.819%
1014	4.02	99.977%	98.889%
1015	4.03	99.978%	98.889%
1016	4.03	99.979%	98.889%

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

Figure 2-1 SPS Coverage (24-Hour Period: 28 April 1999)



Developed by FAA William J. Hughes Technical Center

Figure 2-2 Satellite Visibility Profile for Worst-Case Point (Lon: +10, Lat: +60)

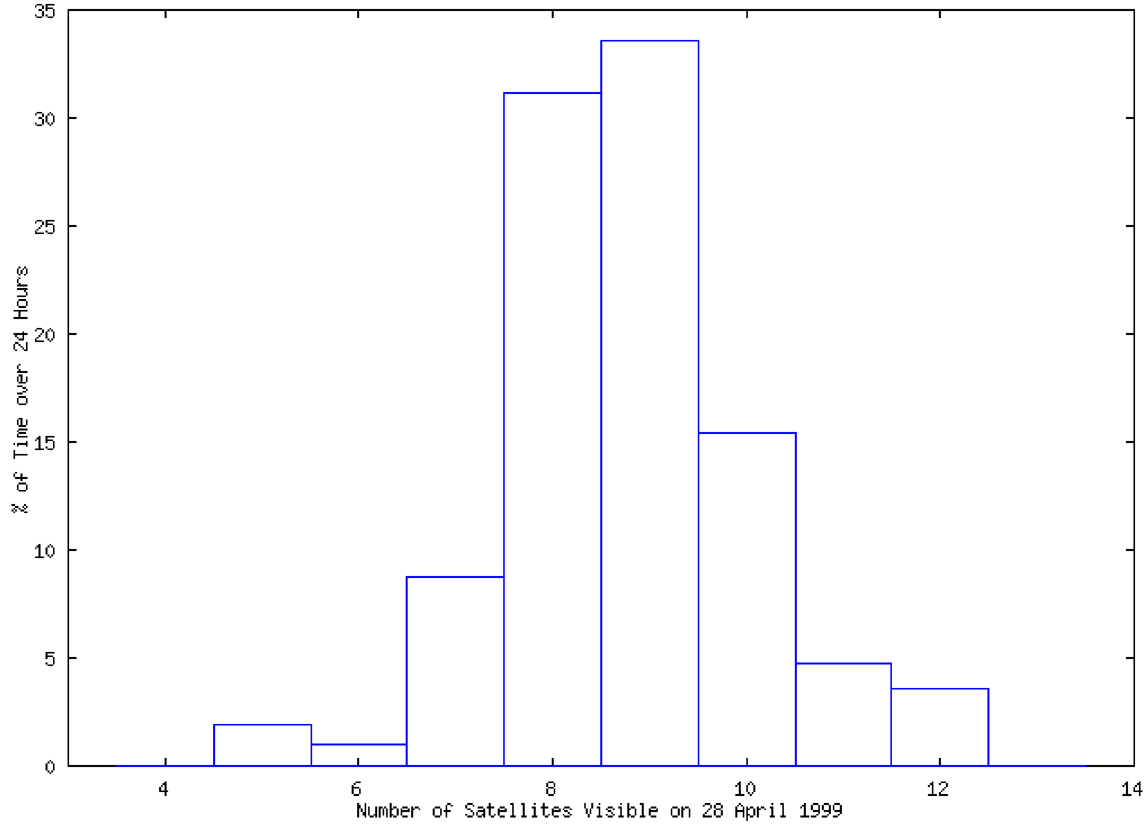
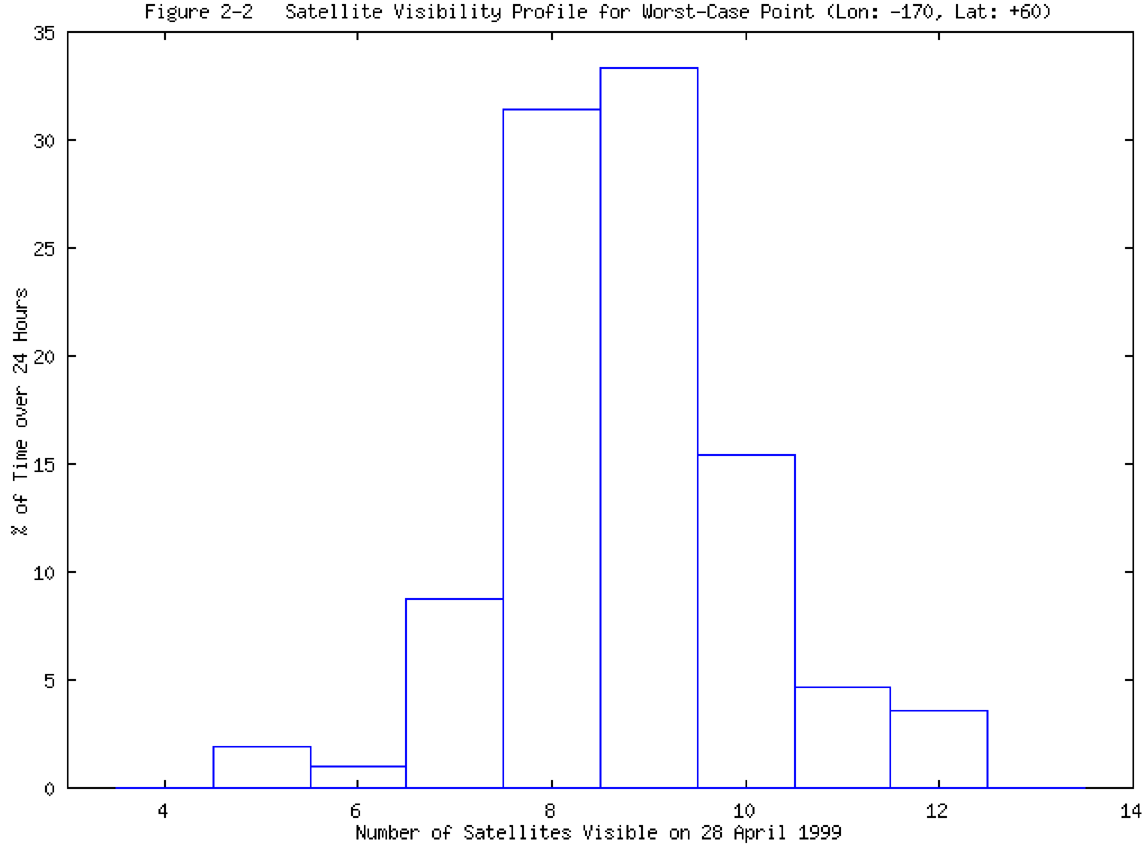


Figure 2-2 Satellite Visibility Profile for Worst-Case Point (Lon: -170, Lat: +60)



3.0 Satellite 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 from 12 December 1998 through 31 March 1999, there were a total of 20 reported outages. Eighteen of these outages were maintenance activities and were reported in advance. Two 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#	SVN/PRN	TYPE	START DATE	START TIME	END DATE	END TIME	TOTAL UNSCHED	TOTAL SCHED	TOTAL
010	15/15	U	20-Jan	19:00	20-Jan	19:20	0.33		0.33
013	43/13	U	29-Jan	17:27	29-Jan	18:35	1.13		1.13
172	19/19	S	13-Dec	13:58	13-Dec	19:52		5.90	5.90
174	37/7	S	14-Dec	17:22	15-Dec	0:02		6.67	6.67
175	21/21	S	15-Dec	6:42	15-Dec	14:21		7.65	7.65
178	19/19	S	16-Dec	14:04	16-Dec	21:15		7.18	7.18
182	29/29	S	18-Dec	5:36	18-Dec	11:24		5.80	5.80
188	40/10	S	28-Dec	19:36	28-Dec	21:26		1.83	1.83
001	43/13	S	9-Jan	14:53	9-Jan	16:35		1.70	1.70
005	26/26	S	11-Jan	21:38	12-Jan	5:52		8.23	8.23
006	22/22	S	12-Jan	13:45	12-Jan	15:42		1.95	1.95
007	24/24	S	13-Jan	18:00	13-Jan	21:14		3.23	3.23
008	31/31	S	14-Jan	9:50	14-Jan	12:43		2.88	2.88
015	32/1	S	30-Jan	16:30	30-Jan	23:40		7.17	7.17
019	43/13	S	11-Feb	10:38	12-Feb	23:41		25.05	25.05
020	36/6	S	16-Feb	0:55	16-Feb	5:02		4.12	4.12
022	26/26	S	19-Feb	17:29	19-Feb	23:36		6.12	6.12
024	18/18	S	1-Mar	13:32	1-Mar	21:57		8.42	8.42
027	24/24	S	16-Mar	3:59	16-Mar	11:53		7.90	7.90
033	19/19	S	24-Mar	12:47	24-Mar	19:35		6.80	6.80
Total Outage Hours for the Period							**1.46**	**118.06**	**119.52**

Type: S = Scheduled U = Unscheduled

Table 3-2 NANUs Forecasted To Affect Satellite Availability

NANU#	SVN/PRN	TYPE	START DATE	START TIME	END DATE	END TIME	TOTAL	COMMENTS
177	19/19	F/EXTEN.	16-Dec	14:04	N/A	N/A		SEE NANU 173
018	43/13	F/EXTEN.	11-Feb	10:38	N/A	N/A		SEE NANU 014
179	19/19	F/RESCHEDULED	16-Dec	14:04	16-Dec	21:15		SEE NANU 173
026	19/19	F/RESCHEDULED	25-Mar	12:00	26-Mar	0		SEE NANU 025
032	19/19	F/RESCHEDULED	24-Mar	12:00	24-Mar	0:00		SEE NANU 025
162	21/21	F	15-Dec	5:00	15-Dec	17:00	12.00	MAINTENANCE
163	29/29	F	18-Dec	5:00	18-Dec	17:00	12.00	MAINTENANCE
164	37/7	F	14-Dec	17:00	15-Dec	5:00	12.00	MAINTENANCE
170	19/19	F	13-Dec	13:30	13-Dec	20:30	7.00	MAINTENANCE
173	19/19	F	16-Dec	13:30	16-Dec	20:30	7.00	MAINTENANCE
176	40/10	F	28-Dec	19:30	29-Dec	7:30	12.00	MAINTENANCE
180	43/13	F	22-Dec	13:00	23-Dec	6:00	17.00	MAINTENANCE
184	24/24	F	5-Jan	6:00	6-Jan	6:00	24.00	MAINTENANCE
185	31/31	F	7-Jan	10:00	7-Jan	22:00	12.00	MAINTENANCE
186	26/26	F	11-Jan	21:30	12-Jan	9:30	12.00	MAINTENANCE
187	22/22	F	12-Jan	13:00	12-Jan	17:00	4.00	MAINTENANCE
189	43/13	F	9-Jan	12:00	10-Jan	4:30	16.50	MAINTENANCE
192	24/24	F	13-Jan	17:30	14-Jan	5:30	12.00	MAINTENANCE
193	31/31	F	14-Jan	9:30	14-Jan	21:30	12.00	MAINTENANCE
004	43/13	F	16-Jan	12:00	17-Jan	4:00	16.00	MAINTENANCE
011	32/1	F	30-Jan	16:00	31-Jan	4:00	12.00	FORECASTED
014	43/13	F	11-Feb	9:30	12-Feb	22:00	36.50	MAINTENANCE
016	36/6	F	16-Feb	0:00	16-Feb	12:00	12.00	FORECASTED
017	26/26	F	19-Feb	17:00	20-Feb	5:00	12.00	UNUSABLE
021	18/18	F	3-Mar	12:45	2-Mar	0:45		UNUSABLE
023	24/24	F	16-Mar	3:30	16-Mar	15:30	12.00	UNUSABLE
025	19/19	F	19-Mar	6:30	19-Mar	18:30	12.00	UNUSABLE
Total Forecasted Outage for the Period							**284**	

Type: F = Forecasted

Table 3-3 *NANUs Canceled*

NANU#	SVN/PRN	TYPE	START DATE	START TIME	COMMENTS
181	19/19	C	16-Dec	14:04	SEE NANU 179
183	43/13	C	22-Dec	13:00	SEE NANU 180
190	24/24	C	5-Jan	18:00	SEE NANU 184
191	31/31	C	7-Jan	10:00	SEE NANU 185
009	43/13	C	16-Jan	12:00	SEE NANU 004

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.

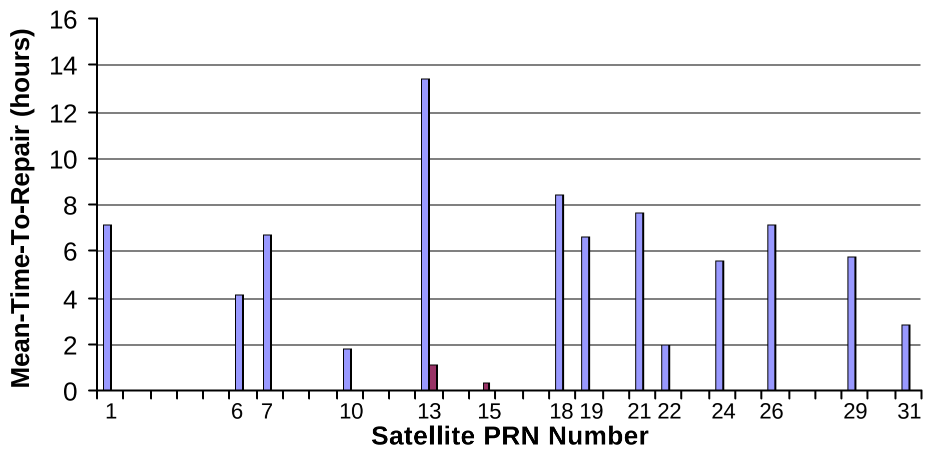
Schedule downtime was forecasted in advance via NANUs. All other downtime reported via NANU was considered unscheduled.

The "Percent Operational" was calculated based on the ratio of total actual operating hours to total available operating hours.

Table 3-4 GPS Block II/IIA Satellite RMA Data: 12 December 1998 – 31 March 1999

Satellite Reliability/Maintainability/Availability (RMA) Parameter	Actual
Total Forecast Downtime (hrs):	284.00
Total Actual Downtime (hrs):	119.52
Total Actual Scheduled Downtime (hrs):	118.06
Total Actual Unscheduled Downtime (hrs):	1.46
Total Satellite Observed MTTR (hrs):	5.98
Scheduled Satellite Observed MTTR (hrs):	6.56
UnScheduled Satellite Observed MTTR (hrs):	0.73
# Unscheduled Satellite Outages:	2
# Scheduled Satellite Outages:	18
# Total Satellite Outages:	20
Percent Operational -- Scheduled Downtime:	99.83%
Percent Operational -- All Downtime:	99.83%

Figure 3-1 Mean-Time-To-Repair



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 eight 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 12 December 1998 through 31 March 1999.

Table 3-5 DOP Statistics*

NSTB Site	Min	Max	Mean
Bangor			
PDOP			
HDOP			
VDOP			
Dayton			

PDOP			
HDOP			
VDOP			
Elko			
PDOP			
HDOP			
VDOP			
Gander			
PDOP			
HDOP			
VDOP			
Honolulu			
PDOP			
HDOP			
VDOP			
Seattle			
PDOP			
HDOP			
VDOP			
NSTB Site	**Min**	**Max**	**Mean**
Sitka			
PDOP			
HDOP			
VDOP			
Winnipeg			
PDOP			
HDOP			
VDOP			

*Note: The HDOP and VDOP values are at the values obtained at the maximum PDOP and not necessarily the maximum HDOP and VDOP of the entire analysis period.

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 eight 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.

The increase in PDOP to above six in Honolulu was caused by a satellite outage. ACT-360 has developed software to detect satellite outages. In Week 990 Day 1, the satellite monitoring software detected a 5-6 second outage on satellite PRN 18. This means that none of the receivers in the NSTB network tracked Satellite 18 during these seconds. Although the receiver was still tracking 5 other satellites (PRN 7, 14, 15, 16 and 19), the geometry of the remaining satellites caused the PDOP to go above six.

The increase in PDOP to above six in Sitka was also caused by a satellite outage and was detected by the satellite monitoring software. Satellite 17 was unavailable for about six seconds. This means that none of the receivers in the NSTB network tracked Satellite 18 during these seconds. In this case, the Millenium receiver was tracking eight other satellites (PRN 3, 6, 10, 13, 19, 22, 23 and 26).

The increases in Week 996 Day 5 and Week 1003 Day 3 in Winnipeg were due to a 5-6 second outage of Satellite 18 that were also detected by the satellite monitoring software. The receiver was tracking five other satellites in both cases. The other two increases were due to forecasted maintenance actions on Satellite 18 (NANU 1999024 and NANU 1999033). Solar storms were occurring in Week 999 Day 1. These storms may have also contributed to the increases in PDOP by causing other satellites to be dropped or not tracked. The data from the co-located GSV receiver in Winnipeg was processed for Week 1002 Day 3. The GSV receiver was tracking the same satellites as the Millenium (i.e. PRN 3, 14, 16, 18, 22, 31) and also had PDOPs that exceeded six.

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	Number of Samples	Availability on days when PDOP > 6
Atlantic City	1013/5	12.69	181	86033	99.7896%
Bangor	1007/0	6.76	9	85530	
Bangor	1013/5	19.67	198	86019	
Elko	1005/5	19.56	8	85646	
Elko	1016/2	6.13	579	79106	
Honolulu	1005/5	13.45	26	64869	
Honolulu	1006/4	7.42	151	86107	
Honolulu	1006/5	6.56	159	86246	
Honolulu	1006/6	6.59	169	86261	
Honolulu	1007/0	7.56	181	86174	
Honolulu	1007/1	7.64	191	84844	
Honolulu	1014/2	16.29	310	86004	
Seattle	1016/2	6.63	314	79384	
Sitka	1011/5	7.24	24	85621	
Winnipeg	1005/5	11.23	12	85646	
Winnipeg	1012/1	7.60	19	85592	
Winnipeg	1014/0	8.16	12	86154	
Winnipeg	1014/2	8.04	635	86276	
Worst-Case Point on Worst-Case Day = 99.56126% (SPS Spec. ≥ 83.92%)					

Global Average on Worst-Case Day (Week_999Day_1, 1 March) = 99.92634%
(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
Bangor			
Dayton			
Elko			
Gander			
Honolulu			
Seattle			
Sitka			
Winnipeg			
Worst Single Point Average = 99.99199% (SPS Spec. ≥ 99.16%)			

Global Average over Reporting Period = 100% (SPS Spec. > 99.85%)

4.0 Service Reliability Standard

Service Reliability: *Given coverage and service availability, the percentage of time over a specified time interval that the instantaneous predictable horizontal error is maintained within a specified threshold at any point on or near the Earth.*

Service Reliability Standard	Conditions and Constraints
≥ 99.97% global average	• Conditioned on coverage and service availability standards • 500 meter NTE predictable horizontal error reliability threshold • Standard based on a measurement interval of one year; average of daily values over the globe • Standard predicated on a maximum of 18 hours of major service failure behavior over the sample interval
≥ 99.79% single point average	• Conditioned on coverage and service availability standards • 500 meter Not-to-Exceed (NTE) predictable horizontal error reliability threshold • Standard based on a measurement interval of one year; average of daily values from the worst-case point on the globe • Standard based on a maximum of 18 hours of major service failure behavior over the sample interval

Table 4-1 has the 99.9% horizontal errors reported by a receiver at each of the eight 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	99.9% Horizontal Error (m)
Bangor		
Dayton		
Elko		
Gander		
Honolulu		
Seattle		
Sitka		
Winnipeg		

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 12 December 1998 through 31 March 1999 at the eight 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 (m)	95% Vertical (m)	99.99% Horizontal (m)	99.99% Vertical (m)
Bangor	33.86	55.58	74.82	124.03
Dayton	24.55	41.98	51.58	89.50
Elko	24.35	40.99	49.80	84.45
Gander	41.70	68.80	77.00	143.00
Honolulu	23.07	43.46	42.17	98.11
Seattle	31.80	53.37	61.47	106.29
Sitka	23.96	42.27	51.68	104.94
Winnipeg	24.65	41.58	62.87	110.88
Average	28.49	48.50	58.92	107.65

Figures 5-1 and 5-2 are the combined histograms of the vertical and horizontal errors for all eight NSTB sites from 12 December 1998 through 31 March 1999.

Figure 5-1 Combined Vertical Error Histogram

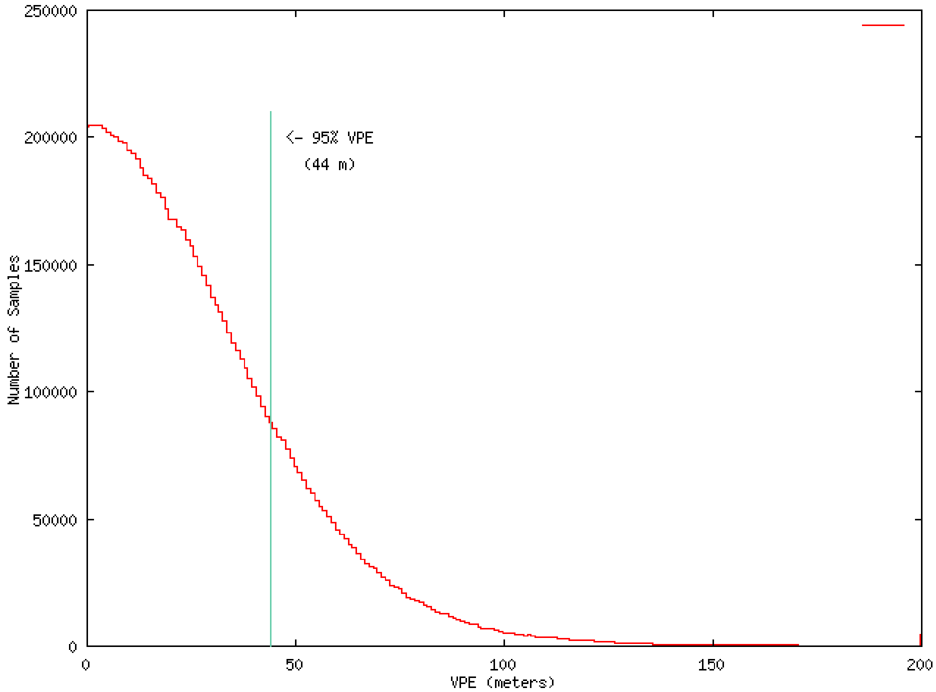
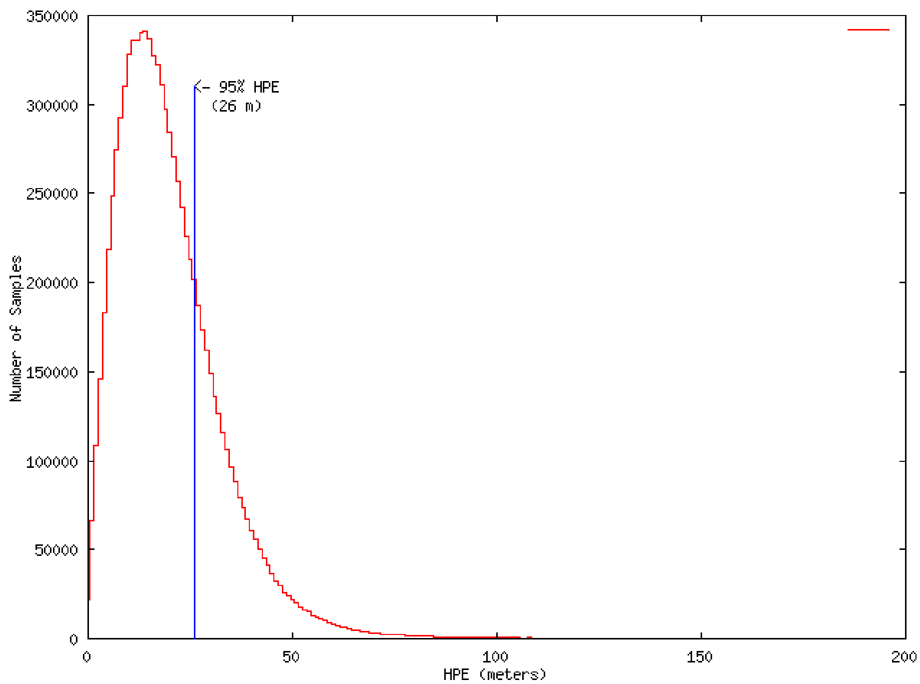


Figure 5-2 Combined Horizontal Error Histogram



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)
Bangor	26.04	77.71
Dayton	19.01	58.61
Elko	19.21	55.94
Gander	32.60	94.20
Honolulu	17.52	58.61
Seattle	24.28	75.02
Sitka	19.21	59.80
Winnipeg	20.49	58.51
Average	22.30	67.30

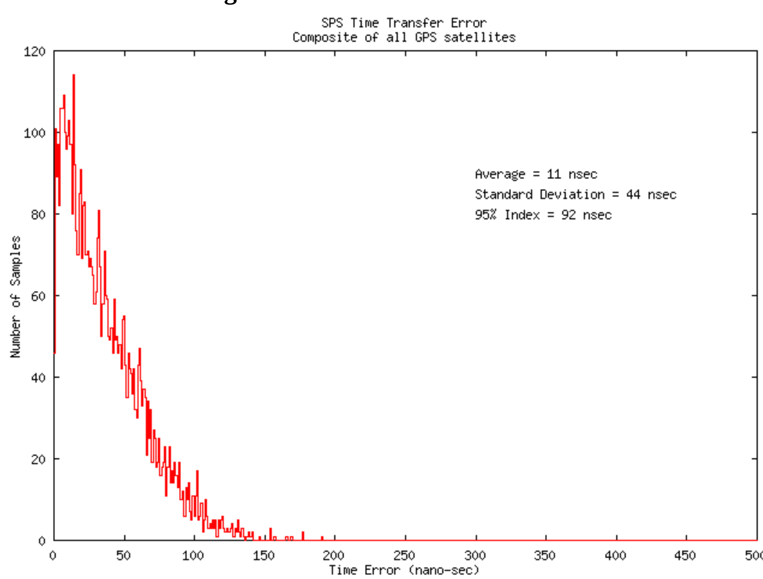
5.3 Relative Accuracy

To be included in next report.

5.4 Time Transfer Accuracy

The GPS time error data between 12 December and 31 March 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 5-15) 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 5-15. 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 12 December 1998 through 31 March 1999. The data was collected from the Dayton NSTB site. Future PAN reports will contain statistics from all NSTB sites.

A weighted average filter was used for the calculation of the range acceleration error. The range acceleration errors were below the specified 8mm/s^2 at least 99.998% of the time.

Table 5-3 Range Error Statistics (meters)

PRN	Mean	RMS	1 s	95%	Max	Samples
1	4.58	17.59	14.87	48.54	131.49	2266484
2	7.18	18.28	15.43	53.56	143.72	2110171
3	4.73	17.42	15.16	52.37	131.26	2339219
4	5.12	17.24	15.23	55.08	117.84	2102100
5	4.91	17.54	15.37	45.14	138.14	2414818
6	4.13	17.34	15.05	50.23	138.83	2244879
7	7.18	18.21	15.42	50.94	133.24	2251329
8	4.23	17.29	15.23	47.05	123.56	2276196
9	3.59	17.39	15.51	49.53	129.30	2494577
10	6.73	17.75	15.24	42.48	136.76	1968039
13	2.75	17.17	15.34	55.07	121.72	2511955
14	5.03	17.59	15.27	45.25	148.32	2481218
15	5.43	8.10	3.77	14.32	69.28	2470739
16	5.89	17.83	15.49	46.88	122.25	2507185
17	5.57	17.78	15.15	46.15	135.64	1978955
18	5.05	17.79	15.46	50.81	124.25	2216237
19	6.70	18.14	15.05	51.52	139.38	1891690
21	5.38	17.61	14.94	46.60	136.18	2087354
22	4.94	17.41	14.74	51.15	125.60	1807893
23	5.53	17.58	14.87	51.14	133.00	2288317
24	6.71	17.65	15.24	42.65	127.15	2276097
25	3.71	17.46	14.91	47.87	121.34	1947525
26	4.37	17.30	15.06	46.27	132.18	1928048
27	5.92	17.75	15.20	44.75	127.56	1728204
29	3.57	17.14	14.77	45.55	124.28	2269808
30	2.91	17.31	15.18	49.67	120.63	2105623
31	4.98	17.46	14.82	55.33	144.65	1702268

Table 5-4 Range Rate Error Statistics (m/s)

PRN	Mean	RMS	1 s	95%	Max	Samples
1	-0.00005	0.13069	0.13069	0.25523	0.91455	2266484
2	0.00023	0.12967	0.12966	0.25228	0.92334	2110171
3	0.00018	0.12958	0.12957	0.25347	1.29191	2339219
4	-0.00011	0.13008	0.13007	0.25435	1.44548	2102100
5	-0.00018	0.13155	0.13155	0.25709	1.03017	2414818
6	0.00006	0.13079	0.13078	0.25653	0.90134	2244879

PRN	Mean	RMS	1 s	95%	Max	Samples
7	0.00005	0.13127	0.13126	0.25620	0.96348	2251329
8	0.00024	0.13010	0.13010	0.25570	1.28826	2276196
9	-0.00005	0.13111	0.13111	0.25672	2.05660	2494577
10	-0.00011	0.13122	0.13122	0.25761	1.47961	1968039
13	0.00032	0.13059	0.13059	0.25602	2.39440	2511955
14	0.00024	0.12973	0.12972	0.25441	1.37703	2481218
15	0.00000	0.00744	0.00743	0.01091	1.32962	2470739
16	0.00011	0.13165	0.13164	0.25850	1.83726	2507185
17	-0.00004	0.13083	0.13083	0.25760	0.87882	1978955
18	0.00028	0.13097	0.13096	0.25706	1.03883	2216237
19	0.00036	0.12919	0.12919	0.25179	0.96345	1891690
21	-0.00012	0.13141	0.13141	0.25759	0.91460	2087354
22	-0.00017	0.12982	0.12981	0.25431	2.71132	1807893
23	-0.00027	0.13013	0.13013	0.25430	0.82579	2288317
24	-0.00007	0.13037	0.13037	0.25660	1.35729	2276097
25	-0.00013	0.13231	0.13230	0.25960	0.90616	1947525
26	-0.00002	0.13057	0.13056	0.25664	1.68012	1928048
27	0.00021	0.12854	0.12854	0.25078	1.01754	1728204
29	-0.00012	0.12968	0.12968	0.25419	0.90594	2269808
30	-0.00001	0.13047	0.13046	0.25634	0.93185	2105623
31	-0.00005	0.12892	0.12892	0.25196	0.95135	1702268

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

PRN	Mean	RMS	1 s	% < .008	Max	Samples
1	-0.00001	0.00102	0.00102	1.00000	0.00703	2266484
2	0.00000	0.00101	0.00101	1.00000	0.00708	2110171
3	0.00000	0.00100	0.00100	1.00000	0.01243	2339219
4	0.00000	0.00103	0.00103	1.00000	0.01351	2102100
5	0.00000	0.00104	0.00104	1.00000	0.01304	2414818
6	0.00000	0.00104	0.00104	1.00000	0.00678	2244879
7	0.00000	0.00103	0.00103	1.00000	0.00736	2251329
8	0.00000	0.00102	0.00102	0.99999	0.01293	2276196
9	0.00000	0.00103	0.00103	0.99998	0.01725	2494577
10	0.00000	0.00103	0.00103	1.00000	0.01461	1968039
13	0.00001	0.00103	0.00103	0.99999	0.02149	2511955
14	0.00000	0.00101	0.00101	0.99999	0.01152	2481218
15	0.00000	0.00014	0.00014	0.99999	0.01333	2470739
16	0.00001	0.00103	0.00103	0.99999	0.01854	2507185
17	0.00000	0.00103	0.00103	1.00000	0.00721	1978955
18	0.00001	0.00104	0.00104	1.00000	0.01065	2216237
19	-0.00001	0.00100	0.00100	1.00000	0.00794	1891690
21	0.00000	0.00102	0.00102	1.00000	0.00778	2087354
22	0.00001	0.00101	0.00101	0.99999	0.02756	1807893
23	0.00000	0.00102	0.00102	1.00000	0.00693	2288317
24	0.00000	0.00101	0.00101	1.00000	0.01301	2276097
25	0.00000	0.00104	0.00104	1.00000	0.00700	1947525
26	0.00000	0.00102	0.00102	1.00000	0.01602	1928048

PRN	Mean	RMS	1 s	% < .008	Max	Samples
27	0.00001	0.00101	0.00101	1.00000	0.00787	1728204
29	0.00000	0.00102	0.00102	1.00000	0.00744	2269808
30	0.00000	0.00102	0.00102	1.00000	0.00912	2105623
31	-0.00001	0.00101	0.00101	1.00000	0.01051	1702268

Figures 5-16, 5-17 and 5-18 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 14 with an error of 148.32 meters. Satellite 15 had the lowest maximum range error of 69.28 meters.

Figure 5-4 Distribution of Daily Max Range Errors: 12 Dec. 1998 – 31 March 1999

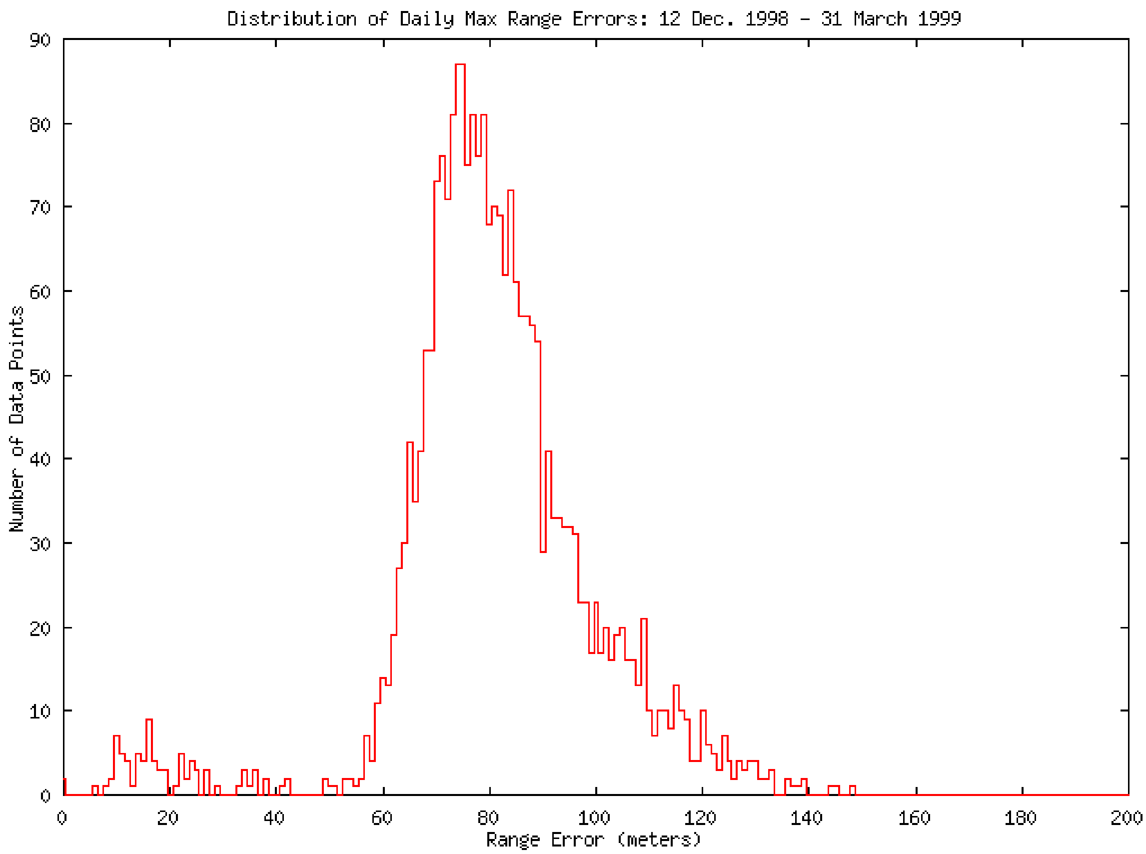


Figure 5-5 Distribution of Daily Max Range Rate Errors: 12 Dec. 1998 – 31 March 1999

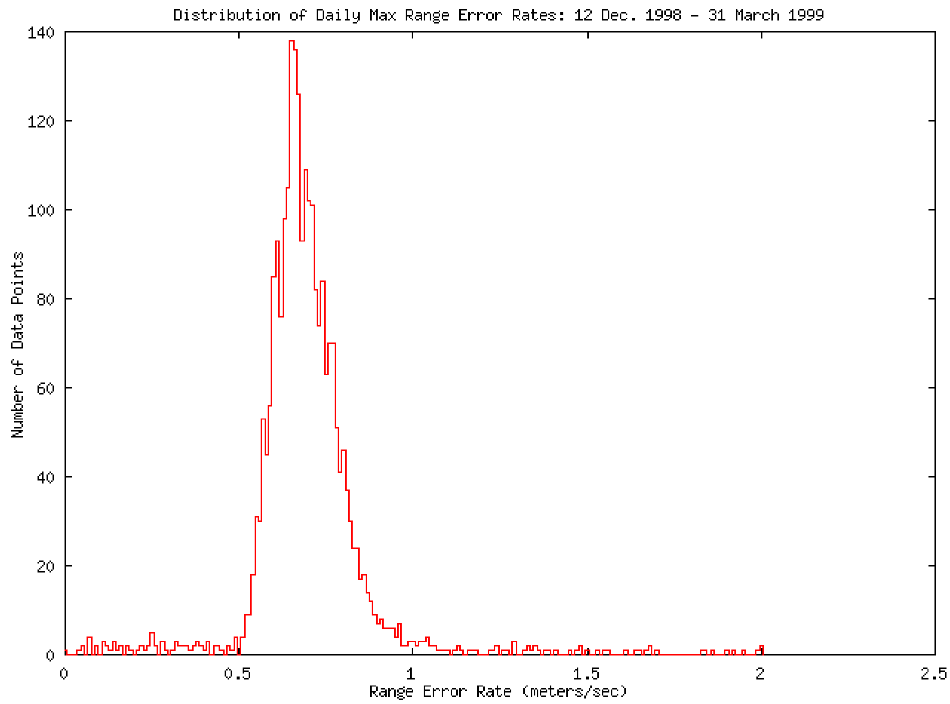


Figure 5-6 Distribution of Daily Max Acceleration Rate Errors: 12 Dec. 1998 – 31 March 1999

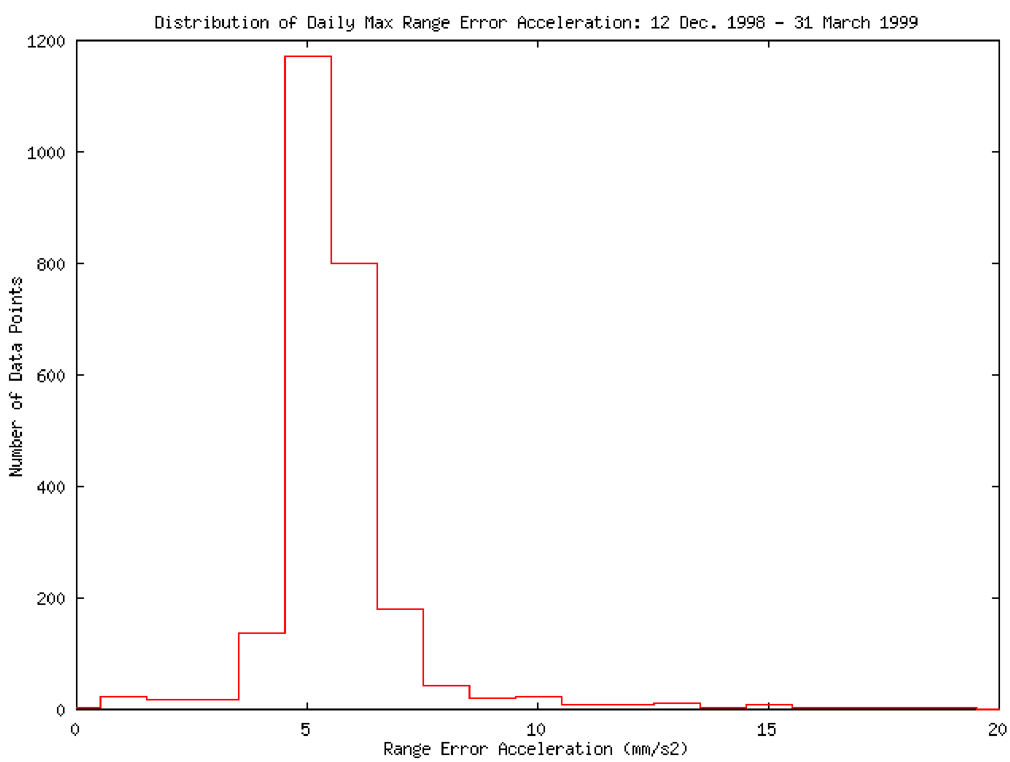


Figure 5-7 Maximum Range Error Per Satellite

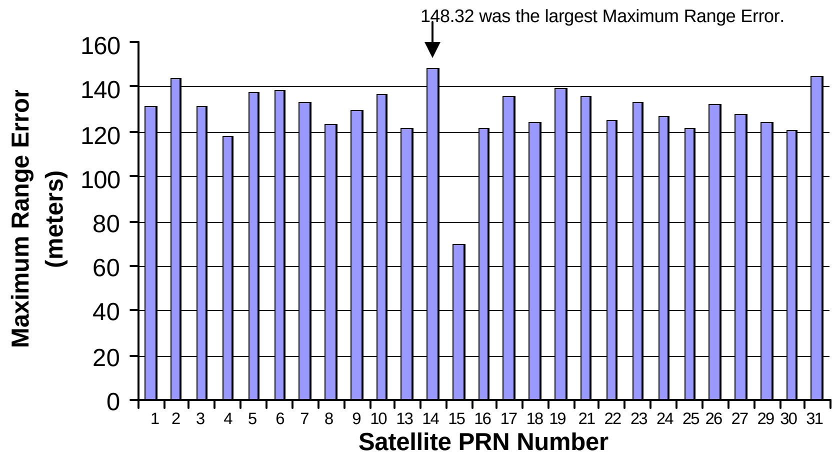


Figure 5-8 Maximum Range Rate Errors Per Satellite

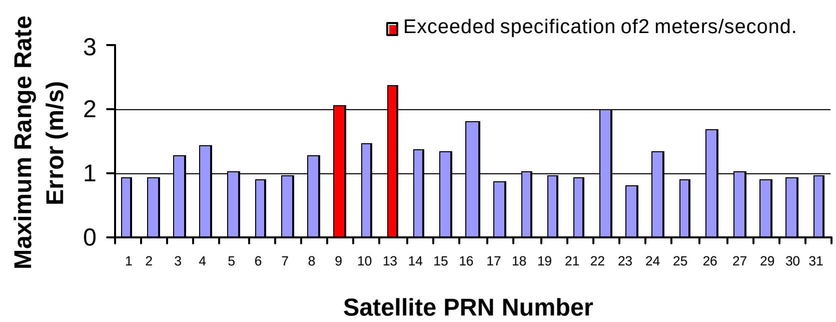
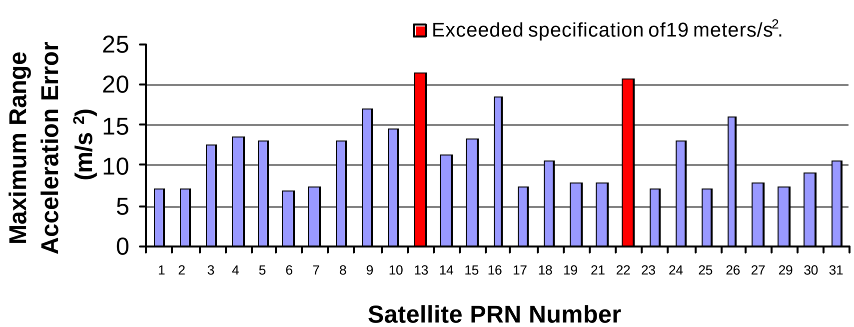


Figure 5-9 Maximum Range Acceleration Error Per Satellite



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. For this reporting period, storm activity was reported in January, February and March.

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.

Fredericksburg, College, and Estimated Planetary A and K Indices:
The daily 24-hour A index and eight 3-hourly K indices from the Fredericksburg (middle-latitude) and College (high-latitude) stations monitoring Earth's magnetic field. The estimated planetary 24 hour A index and eight 3-hourly K indices are derived in real time from a network of western hemisphere ground-based magnetometers. K indices range from 0 (very quiet) to 9 (extremely disturbed). A indices range from 0 (very quiet) to 400 (extremely disturbed). An index of 30 or greater indicates local geomagnetic storm conditions.

Figures 6-1 through 6-4 show the K-index for four different time periods. Solar storms with K indices of 5 or greater occurred on 13-14 January, 17-19 February and 2-3 March with the storms in February having the highest K indices. Figure 6-4 show the K-indices for time periods of no solar storms. (See Appendix B for the actual geomagnetic data for this reporting period.)

Figure 6-1 K-Index for 15-18 April 1999

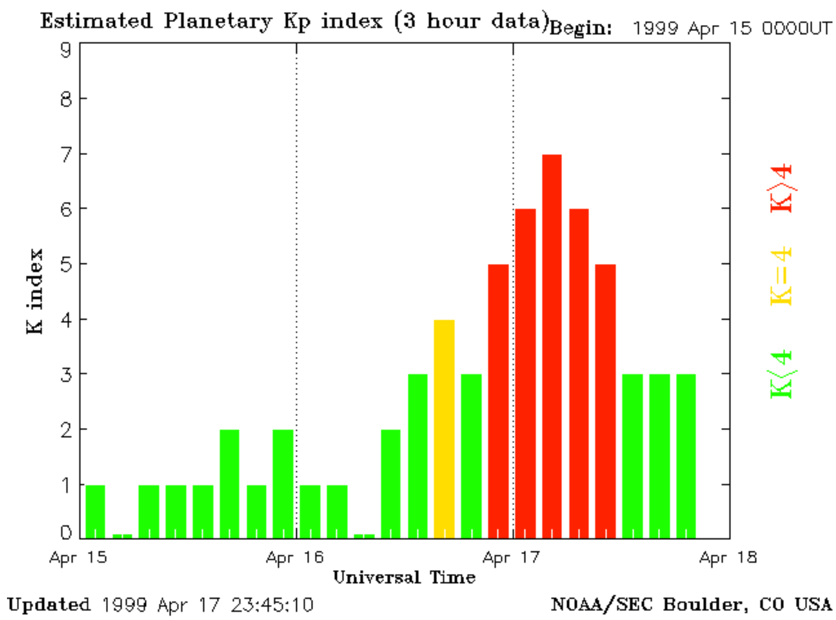


Figure 6-2 K-Index for 28 April – 1 May 1999

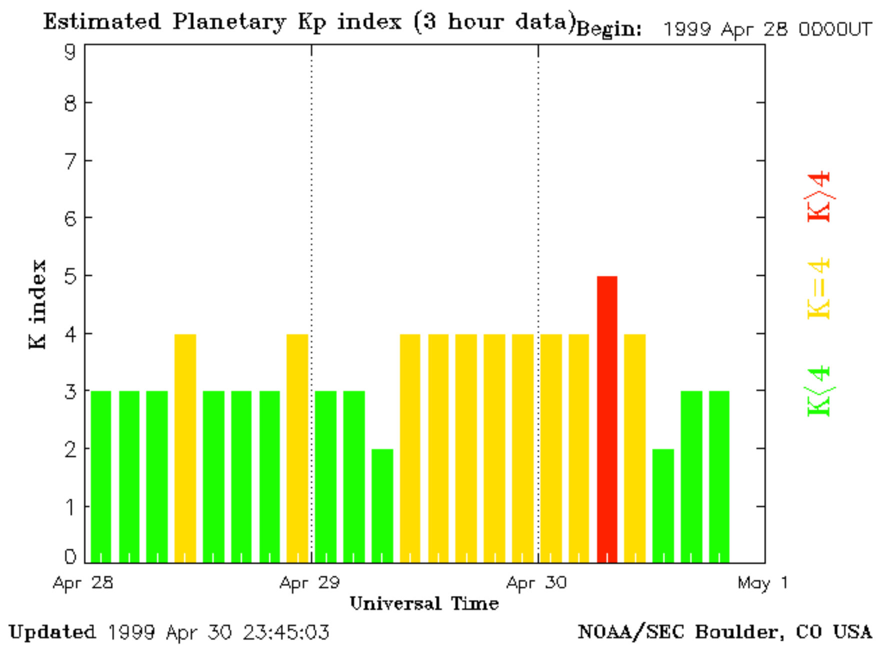


Figure 6-2 K-Index for 11-14 May 1999

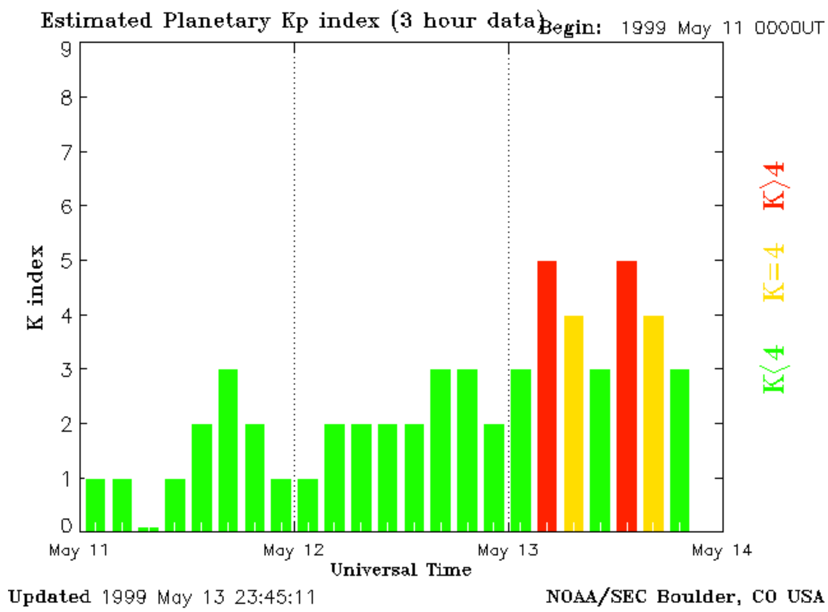


Figure 6-2 K-Index for 16-19 May 1999

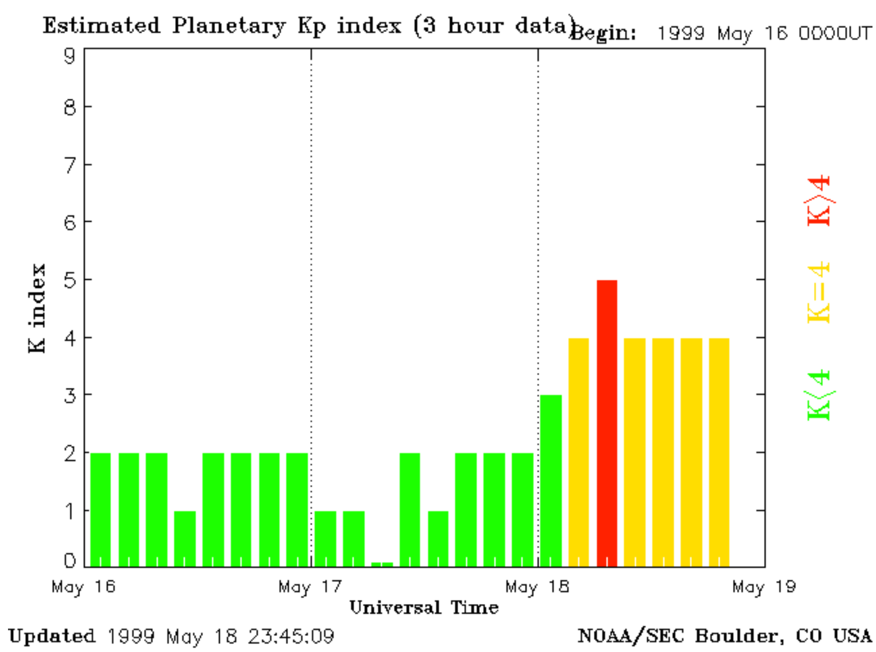
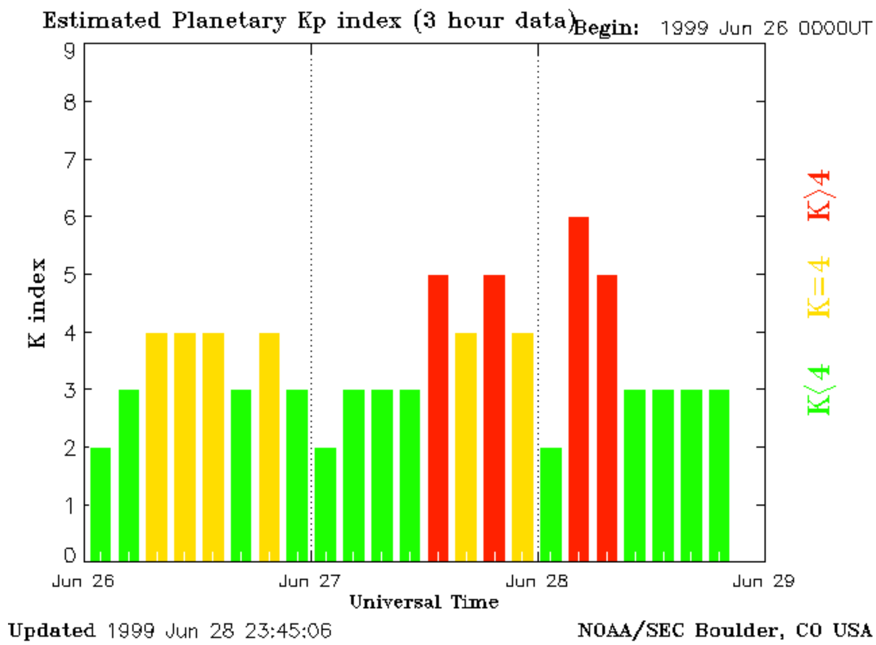


Figure 6-2 K-Index for 25-29 June 1999



Tables 6-1 and 6-2 show the PDOP and position accuracy information, respectively, for the days corresponding to Figures 6-1 through 6-4. The PDOPs and position accuracies show no significant differences between the days with storms and the days with no storms with the exception of 10 February at Sitka and 1 March at Winnipeg. The PDOP on these days exceed six. Since no solar storms were reported on 10 February, the PDOP increase at Sitka cannot be attributed to Solar storms. Although there were solar storms on 1 March, a satellite outage also occurred. This outage in conjunction with the storm may have caused the increase in PDOP at Winnipeg. The rows shaded green were days with no solar storms. The purple-shaded cells are when the PDOP exceed six. (Even when the PDOP did go above six, the GPS SPS performance still met the availability requirements.)

Table 6-1 PDOP Statistics

NSTB Site	Min	Max	Mean
Bangor			
Dayton			
Elko			
Honolulu			

NSTB Site	Min	Max	Mean
Seattle*			
Sitka			
Winnipeg			

***Note**: The Millenium receiver was not operational on the dates not shown.

Table 6-2 Horizontal & Vertical Accuracy Statistics

NSTB Site	95% Horizontal (m)	95% Vertical (m)	99.99% Horizontal (m)	99.99% Vertical (m)
Bangor				
Dayton				

NSTB Site	95% Horizontal (m)	95% Vertical (m)	99.99% Horizontal (m)	99.99% Vertical (m)
Elko				
Honolulu				
Seattle*				
Sitka				
Winnipeg				

***Note**: The Millenium receiver was not operational on the dates not shown.

APPENDICES A – D

Appendix A Performance Summary

Coverage Standard	***Conditions and Constraints***	***Measured Performance***
≥ 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	99.999952%
≥ 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	99.931% availability Max PDOP was 4.17
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	100%
≥ 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	99.99199%
≥ 95.87% global average on worst-case day	• Conditioned on coverage standard • Standard represents a worst-case 24 hour interval, averaged over the globe	99.92634%
≥ 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	99.56126%
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	Future Reports

≥ 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	Future Reports
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	28.49 m horz. error 95% of time 48.50 m vert. error 95% of time 58.92 m horz. error 99.99% of time 107.65 m vert. error 99.99% of time
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	22.30 m horz. error 95% of time 67.30 m vert. error 95% of time
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	92 ns 95% of the time
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	148.32 m NTE range error 2.39 m/s NTE range rate error less than 8 mm/sec2 at least 95% of the time 27.6 mm NTE range acceleration error

Appendix B Geomagnetic Data

:Product: Daily Geomagnetic Data quar_DGD.txt
:Issued: 0328 UT 09 Mar 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 04 01	14	5 5 2 1 1 0 1 1	15	5 5 2 2 1 1 1 1	14	5 5 2 2 2 2 1 1
1999 04 02	7	1 3 1 1 2 2 3 2	10	2 2 3 2 4 2 2 1	10	1 3 3 2 3 3 3 2
1999 04 03	12	2 2 3 2 3 3 3 3	8	2 2 2 3 3 2 2 1	8	2 2 3 2 2 2 3 3
1999 04 04	8	3 2 1 2 2 2 3 2	16	2 2 3 4 5 3 2 2	13	3 2 4 2 3 2 3 3
1999 04 05	9	2 2 4 3 2 2 1 0	17	2 2 4 5 4 3 2 1	11	2 2 4 4 3 2 1 1
1999 04 06	6	3 2 2 0 1 1 2 1	8	2 2 3 1 3 2 1 1	9	3 4 2 1 1 2 2 2
1999 04 07	10	4 3 2 2 2 1 2 2	-1	-1-1-1-1-1-1-1-1	9	3 3 2 2 2 2 2 2
1999 04 08	10	1 2 2 2 2 4 3 2	-1	-1-1-1-1-1-1-1-1	9	1 1 2 2 2 4 3 2
1999 04 09	6	2 2 1 2 2 2 2 0	-1	-1-1-1-1-1-1-1-1	5	2 2 1 1 2 2 1 1
1999 04 10	9	2 2 3 1 2 3 2 3	-1	-1-1-1-1-1-1-1-1	11	2 2 3 2 3 3 3 3
1999 04 11	10	3 3 3 3 2 2 1 1	-1	-1-1-1-1-1-1-1-1	9	3 3 3 3 2 2 2 1
1999 04 12	6	3 1 1 3 1 1 1 1	-1	2 1 0 1 3 1 1 2	7	3 1 2 3 3 3 1 1
1999 04 13	2	0 0 1 1 1 1 1 1	4	0 0 0 3 1 2 1 1	5	1 0 1 1 2 1 1 1
1999 04 14	6	1 1 3 2 1 1 2 2	6	1 1 3 3 1 2 1 0	7	2 0 3 3 1 2 2 2
1999 04 15	2	1 0 1 1 0 1 1 1	3	1 0 0 1 0 1 1 3	4	1 0 1 1 1 2 1 2
1999 04 16	13	1 2 0 2 3 2 3 5	8	1 1 0 1 3 3 2 3	14	1 1 0 2 3 4 3 5
1999 04 17	30	6 6 4 4 2 1 2 2	38	5 6 5 6 3 2 3 2	47	6 7 6 5 3 3 3 3
1999 04 18	5	2 2 0 2 2 1 2 1	8	2 2 0 1 4 2 2 1	6	2 2 1 2 3 2 2 1
1999 04 19	10	0 1 2 4 2 2 3 3	-1	-1 1 3 6 5 4 2 3	13	0 1 3 4 3 3 3 3
1999 04 20	15	4 2 3 3 3 3 3 2	41	3 4 4 6 6 6 3 1	21	4 4 4 4 4 4 3 2
1999 04 21	9	2 2 3 2 2 3 2 1	25	3 2 3 5 5 5 3 1	12	2 1 3 4 3 3 3 2
1999 04 22	2	2 1 1 0 0 0 1 1	-1	2-1 0-1 0 1 2 1	4	1 1 1 0 0 2 2 1

1999 04 23	4	1 1 1 1 2 2 1 1	4	1 2 1 2 2 1 0 1	5	1 0 1 1 2 2 2 1
1999 04 24	5	2 3 1 1 1 1 1 0	4	2 2 1 2 1 1 1 0	7	3 2 2 2 1 3 2 1
1999 04 25	5	0 0 2 1 2 1 2 3	5	0 0 2 4 1 1 0 1	5	1 0 1 1 2 2 1 3
1999 04 26	6	1 0 1 2 3 2 2 1	5	1 0 1 2 2 2 2 1	7	1 0 1 2 3 3 2 2
1999 04 27	9	1 1 2 2 2 2 4 2	18	1 0 4 6 2 2 3 2	14	1 1 3 3 3 4 4 4
1999 04 28	14	3 3 2 3 2 2 3 4	29	3 3 5 6 4 4 2 3	19	3 3 3 4 3 3 3 4
1999 04 29	18	2 2 2 3 3 3 4 5	34	3 3 2 6 6 5 3 3	19	3 3 2 4 4 4 4 4
1999 04 30	17	4 3 4 3 3 2 3 3	34	3 4 5 6 5 4 3 3	21	4 4 5 4 2 3 3 3
1999 05 01	15	4 4 3 2 3 2 3 2	28	4 3 5 4 5 5 2 2	19	3 4 4 3 3 3 3 3
1999 05 02	8	2 2 3 1 2 2 2 2	19	2 3 5 4 4 3 2 2	13	2 3 4 3 3 2 3 2
1999 05 03	8	3 3 2 2 2 1 2 1	12	3 3 4 3 2 2 2 1	9	3 3 2 3 2 2 2 1
1999 05 04	3	1 1 0 1 1 1 2 1	4	0 2 2 2 2 0 1 0	6	1 2 3 1 2 2 2 1
1999 05 05	6	1 0 1 1 2 2 2 3	3	1 0 0 2 0 2 2 1	7	1 0 1 2 2 3 3 3
1999 05 06	9	2 2 2 3 3 2 1 2	17	2 3 3 4 4 4 3 1	11	3 2 3 4 3 2 1 3
1999 05 07	9	3 2 2 1 2 2 3 2	11	3 2 4 3 1 2 2 1	9	3 3 2 1 2 3 3 2
1999 05 08	4	1 2 0 1 1 0 2 2	7	2 2 3 3 1 0 1 1	6	2 2 1 2 2 2 2 2
1999 05 09	4	1 1 1 2 1 1 1 2	8	2 2 1 4 3 0 1 1	6	1 2 1 2 2 2 2 2
1999 05 10	3	2 1 1 1 1 1 0 1	4	2 2 0 0 1 1 1 2	5	2 2 0 1 2 2 2 1
1999 05 11	1	0 0 0 0 0 0 1 2	1	0 0 0 0 1 1 0 0	5	1 1 0 1 2 3 2 1
1999 05 12	8	1 2 2 2 2 3 2 2	5	0 1 2 2 2 2 2 1	9	1 2 2 2 2 3 3 2
1999 05 13	17	3 4 4 2 4 2 2 3	46	3 5 5 3 7 6 3 2	24	3 5 4 3 5 4 3 3
1999 05 14	7	2 2 3 1 1 1 2 2	9	3 2 3 2 3 2 1 1	9	3 3 3 1 2 2 2 2
1999 05 15	6	2 2 1 2 2 2 1 2	6	2 2 2 2 2 2 0 1	9	2 2 2 2 2 3 2 2
1999 05 16	3	2 1 1 1 1 2 0 0	-1	2 2 1 2 0 1 0-1	6	2 2 2 1 2 2 2 2
1999 05 17	1	0 0 0 1 0 1 1 0	5	0 0 0 4 2 1 1 0	5	1 1 1 2 1 2 2 2
1999 05 18	21	4 4 3 3 4 3 4 3	32	3 4 5 4 6 4 3 3	23	3 4 5 4 4 4 4 3
1999 05 19	8	3 2 1 1 2 2 2 3	15	4 2 1 1 3 5 2 2	10	3 3 2 1 2 2 3 3
1999 05 20	4	1 2 1 1 1 1 1 2	14	3 3 2 5 2 1 2 2	10	2 3 2 3 3 2 1 3
1999 05 21	5	2 2 1 1 2 1 1 2	9	3 3 1 0 1 2 1 4	7	3 3 1 1 2 3 2 2
1999 05 22	3	0 1 1 0 2 1 1 1	-1	1-1 1 0 2 1 0 3	5	1 1 1 0 2 2 2 2
1999 05 23	8	2 1 2 3 3 2 2 1	15	2 1 1 5 5 1 2 0	10	3 2 2 4 4 2 2 1
1999 05 24	11	3 3 2 2 2 2 3 3	11	2 3 1 4 2 2 1 3	11	3 3 2 3 2 2 2 4
1999 05 25	14	4 4 3 3 2 1 2 2	23	4 5 4 4 4 3 2 1	19	5 4 4 4 3 2 2 3
1999 05 26	7	3 1 1 1 2 2 2 2	7	2 1 2 0 3 2 2 2	8	2 2 2 1 2 3 3 2
1999 05 27	7	2 2 1 1 2 1 2 3	4	2 2 1 1 1 1 1 1	10	2 3 3 2 2 3 3 3
1999 05 28	7	2 1 2 2 1 1 2 3	10	3 2 3 3 3 2 1 1	9	3 1 3 3 2 2 2 3
1999 05 29	3	2 0 0 0 2 1 1 1	3	2 1 0 0 1 2 2 0	6	2 1 0 1 2 3 3 1
1999 05 30	3	0 0 0 0 2 1 2 2	5	0 0 0 0 3 3 1 1	5	0 0 0 1 2 2 2 2
1999 05 31	2	1 0 0 0 1 0 1 2	2	1 1 0 1 1 0 0 1	4	2 1 0 1 2 2 2 2
1999 06 01	6	0 1 2 1 2 2 2 3	4	0 1 1 0 3 1 1 1	8	1 2 2 1 2 3 2 3
1999 06 02	9	3 1 1 2 2 1 2 4	4	2 2 0 1 0 0 1 3	11	3 2 0 3 2 2 2 4
1999 06 03	9	4 2 2 2 2 1 2 2	4	3 1 2 1 1 0 1 0	8	4 1 1 2 2 2 2 2
1999 06 04	8	1 2 3 1 2 2 1 3	10	1 3 3 1 4 2 1 2	8	1 2 3 2 2 3 2 3

1999 06 05	3	2 0 0 1 1 0 2 2	5	2 0 0 3 2 1 2 1	4	2 1 0 1 2 1 2 2
1999 06 06	3	2 1 1 1 1 1 1 0	2	0 1 1 0 2 1 0 0	4	1 1 1 1 2 2 1 0
1999 06 07	4	1 1 1 0 1 1 2 2	2	1 1 0 0 0 1 1 2	4	1 1 1 1 1 2 2 2
1999 06 08	12	2 3 4 2 2 3 2 2	15	2 4 3 3 3 4 1 2	15	2 3 4 3 3 4 3 2
1999 06 09	11	2 2 1 2 2 4 3 3	17	4 5 1 0 2 4 3 2	13	3 4 1 1 3 4 3 3
1999 06 10	3	2 1 1 0 1 0 1 1	4	3 1 1 1 1 1 0 0	7	3 2 2 1 2 2 3 2
1999 06 11	3	0 0 1 1 1 1 2 2	6	3 1 1 2 1 2 1 2	6	1 1 1 2 2 2 2 3
1999 06 12	5	2 3 0 0 1 1 1 2	10	5 3 1 0 1 1 1 1	7	3 3 1 1 1 2 1 2
1999 06 13	7	2 2 0 0 3 3 2 2	4	2 2 2 1 1 0 1 1	6	3 2 2 1 2 1 2 2
1999 06 14	2	1 1 1 0 0 1 0 0	3	1 1 3 1 0 0 0 0	4	1 1 2 2 1 1 1 1
1999 06 15	4	1 0 1 1 2 2 2 1	5	1 0 0 1 1 3 3 1	8	2 2 0 2 3 4 2 2
1999 06 16	5	1 0 2 2 2 1 2 2	11	1 1 2 2 5 2 2 1	7	1 1 2 3 2 2 2 2
1999 06 17	6	2 2 2 1 2 1 1 2	9	3 3 4 1 1 1 1 1	7	2 2 3 1 2 2 2 2
1999 06 18	7	1 2 1 2 2 2 2 3	7	1 3 2 1 2 1 2 2	7	1 2 2 2 2 2 2 3
1999 06 19	4	2 1 2 1 1 1 1 1	3	2 2 1 0 1 1 1 0	7	2 1 1 1 2 3 2 3
1999 06 20	2	0 0 0 1 1 2 1 0	1	1 1 0 0 0 0 0 0	4	1 1 0 1 2 2 2 1
1999 06 21	1	0 0 0 1 1 1 3 0	0	0 0 0 0 0 0 0 0	4	0 0 0 1 2 2 2 1
1999 06 22	3	0 0 1 1 1 1 1 2	1	0 0 0 1 0 0 0 1	4	1 0 1 1 1 2 2 2
1999 06 23	5	1 1 2 1 1 1 2 2	3	1 2 1 2 1 0 0 0	6	1 1 2 2 2 2 2 3
1999 06 24	4	1 1 0 1 2 2 2 1	5	1 1 2 1 3 1 1 1	6	2 1 2 2 2 2 2 2
1999 06 25	2	1 1 0 0 0 1 1 1	2	2 1 0 1 0 0 0 0	5	2 1 0 1 1 3 2 2
1999 06 26	14	1 3 3 3 3 2 4 3	27	1 3 5 5 5 4 3 3	17	2 3 4 4 4 3 4 3
1999 06 27	15	1 2 2 3 4 3 3 4	26	1 4 2 3 5 5 5 3	21	2 3 3 3 5 4 5 4
1999 06 28	22	2 6 5 3 1 2 2 2	29	2 5 6 5 4 2 2 2	26	2 6 5 3 3 3 3 3
1999 06 29	5	2 1 1 2 2 2 1 1	14	2 2 2 5 4 2 2 1	9	2 2 2 3 3 3 3 1
1999 06 30	3	1 0 1 1 0 2 1 1	1	1 0 2 0 0 0 0 0	5	1 1 1 1 2 2 2 2

Appendix C NSTB Data Compared to WAAS Requirements

NSTB Wide Area Differential GPS Performance

Background:
NSTB (WAAS) user position data was processed and collected between March 30, 1999 and April 2, 1999 (GPS Week 1003 Day 2 – 5) for two NSTB GPS receivers located at Oklahoma City and Dayton. The prototypeWAAS messages were generated using the FAATC Stel master station and transmitted over the NSTB network. A UNIX workstation connected to the NSTB network receives both TestBed Reference Station (TRS) information and the WAAS messages generated by the FAATC Stel master station. The prototype WAAS correction messages were applied to the TRS receiver pesodorange measurement data using a MOPS compliant, all in view, weighted least squares navigation solution. The resulting NSTB (WAAS) user position errors and WAAS-based protection levels (HPL & VPL) were stored in a rational database (RDB). The database was then queried to provide the statistical information (Table C-1) on Oklahoma City and Dayton GPS receivers. The distribution of Vertical Position Error (VPE) verses Vertical protection level (VPL) are shown for both receivers in Figures C-1 and C-2. These plots are separated into three zones labeled as Normal Operation (VPL < 19.2 and VPE < VPL), HMI (VPE > VPL), and Unavailable Operation (VPL > 19.2).

Accuracy:
The Precision Approach (PA) 95% vertical position accuracy for Dayton and Oklahoma City is 4.978 and 4.295 meters (Table C-1) respectively which is within the 7.6 meter requirement.

Integrity:
The PA probability of HMI for Dayton and Oklahoma City is 0.00983/sec (1.475/approach) and 0.00543/sec (0.815/approach) respectively which is greater than 4 X 10E-8/approach requirement. Although this requirement has not been meet by the NSTB (WAAS) the distribution of VPE as shown in Figure C-1 and C-2 is mostly grouped at the boarder between Normal operation and HMI zones. Since the 95% VPE in the HMI zone is low (4.424 m at Oklahoma City) and if the VPL had been slightly higher at those times then the points would not have been considered HMI, hence reducing PA probability of HMI. In this situation the NSTB (WAAS) is not sending hazardous or misleading information since the VPE in the HMI zone is small (Dayton 95% VPE = 8.507m and Oklahoma City 95% VPE = 4.424m), however there is a failure of the VPL to bound VPE at these times.
(**Note**: Data binned at 1-second samples.)

Availability:
The Precision Approach availability for Dayton and Oklahoma City is 99.85% and 99.78% respectively, which is greater than the requirement of 95%.

Table C-1 NSTB Data Compared to WAAS Requirements

Week_1005DayDay_4

Oklahoma	Count	% of Total	horz mean	horz std_dev	horz 95 index	vert mean	vert std_dev	vert 95 index
Total	86367	0.98567742	1.268	3.198	2.532	0.582	6.908	5.1
Not_Available	1237	0.0143226	6.809	14.915	20.02	0.133	23.811	49.43
HMI	800	0.0092628	10.955	23.019	64.323	19.81	58.737	155.89
Normal	84330	0.97641462	1.095	0.909	2.348	0.406	2.082	4.49

Week_1005Day_5

Oklahoma	Count	% of Total	horz mean	horz std_dev	horz 95 index	vert mean	vert std_dev	vert 95 index
Total	86368	0.95172983	3.303	60.683	3.981	4.236	179.599	5.78
Not_Available	4169	0.04827019	9.161	268.311	17.205	9.365	805.812	46.74
HMI	1714	0.01984531	90.501	51.735	147.29	186.116	112.76	308.66
Normal	80485	0.93188447	1.143	0.834	2.715	0.098	2.19	4.53

Week_1005Day_6

Oklahoma	Count	% of Total	horz mean	horz std_dev	horz 95 index	vert mean	vert std_dev	vert 95 index
Total	86367	0.94000024	5.075	16.433	23.576	1.333	25.839	39.2
Not_Available	5182	0.05999977	20.832	19.069	44.928	-10.491	40.395	100.07
HMI	4509	0.05220744	49.613	46.809	117.744	39.937	95.725	176.13
Normal	76676	0.88779277	1.39	1.94	2.555	-0.138	1.984	3.67

Week_1007Day_3

Denver	Count	% of Total	horz mean	horz std_dev	horz 95 index	vert mean	vert std_dev	vert 95 index
Total	48600	0.9274897	1.192	0.986	2.383	0.256	2.584	4.11
Not_Available	3524	0.07251029	1.793	2.747	3.897	0.279	6.704	7.96
HMI	26	0.00053498	8.794	2.938	13.545	13.981	7.52	21.71

Normal	45050	0.92695475	1.141	0.625	2.285	0.247	1.884	3.75

Figure C-1 VPE vs VPL 3D Histogram - Dayton

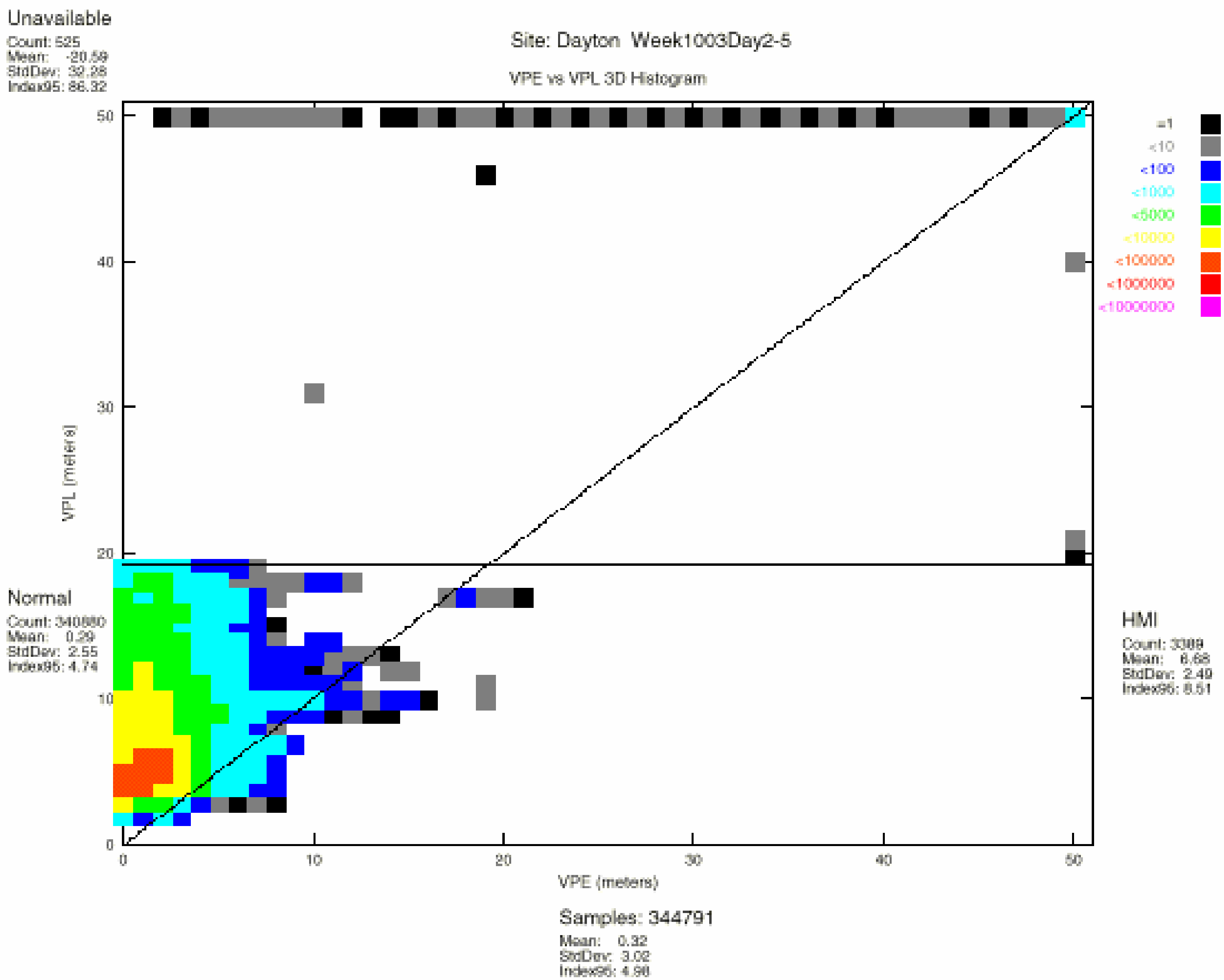
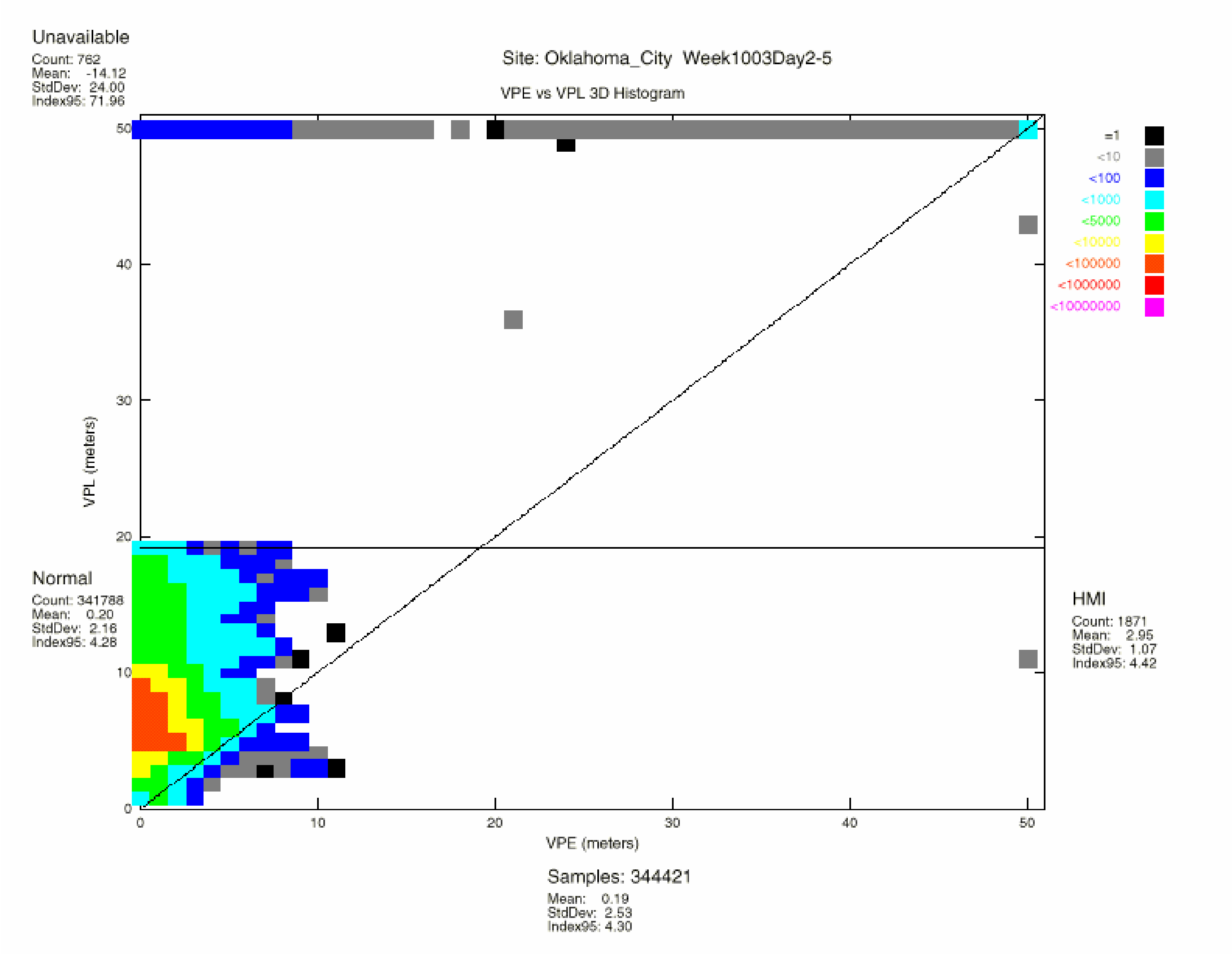


Figure C-2 VPE vs VPL 3D Histogram - Oklahoma



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.