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 #49
April 30, 2005
Reporting Period: 1 January – 31 March 2005

Submitted by

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EXECUTIVE SUMMARY

The GPS Product Team (AND 730) has tasked the Navigation Branch (ACB 430) 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 twenty-one NSTB and Wide Area Augmentation System (WAAS) Reference Stations. This analysis verifies the GPS SPS performance as compared to the performance parameters stated in the SPS Specification Annex A.

This report, Report #49, includes data collected from 1 January through 31 March 2005. The next quarterly report will be issued 31 July 2005.

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

Coverage performance was based on Position Dilution of Precision (PDOP). Utilizing the weekly almanac posted on the US Coast Guard navigation web site, the coverage for every 5^o grid point between 180W to 180E and 80S and 80N was calculated for every minute over a 24-hour period for each of the weeks covered in the reporting period. For this reporting period, the coverage based on PDOP less than six for the CONUS was 99.306% or better.

Availability was verified by reviewing the “Notice: Advisory to Navstar Users” (NANU) reports issued between 1 January and 31 March 2005 and by calculating the satellite availability from the data obtained from the twenty-one sites. A total of thirteen outages were reported in the NANU’s. Twelve outages were scheduled while one was unscheduled. The quarterly availabilities for all sites was 100%. Each of these availabilities is within the SPS value of 99.85%. These availability percentages were calculated using DOP data collected at one-second intervals.

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

Position accuracies were verified by calculating the 95% and 99.99% values of horizontal and vertical errors. Range performance was verified for each satellite using the data collected from the Billings WAAS site. The data was collected in one-second samples. All of the satellites met the range error specifications. The maximum range error recorded was 28.801 meters on Satellite PRN 16. The SPS specification states that the range error should never exceed 150 meters. The maximum range rate error recorded was 1.12424 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 11.23 Millimeters/second^2 on Satellite PRN 4. The SPS specification states that the range acceleration error should never exceed 19 Millimeters/second^2.

The GLONASS/GPS performance section has been permanently removed from this report.

From the analysis performed on data collected between 1 January and 31 March 2005, 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 and WAAS for IFR operations and is developing Local Area Augmentation (LAAS), which is an additional GPS augmentation system. 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 twenty-one National Satellite Test Bed (NSTB) and WAAS reference station locations:

- Billings, MT
- Cold Bay, AK
- Juneau, AK
- Albuquerque, NM
- Anchorage, AK
- Boston, MA
- Washington, D.C.
- Honolulu, HI
- Houston, TX
- Mauna Loa, HI
- Bangor, ME
- Kansas City, KS
- Los Angeles, CA
- Salt Lake City, UT
- Miami, FL
- Minneapolis, MI
- Oakland, CA
- Cleveland, OH
- Seattle, WA
- San Juan, PR
- Atlanta, GA

(Future reports will include all WAAS sites but a database that can handle all that data needs to be developed. ACB 430 is in the process of setting up an Oracle database for this purpose.)

The analysis of the data is divided into the four performance categories stated in the Standard Positioning Service Performance Specification (SPS) Annex A (June 2, 1995). These categories are:

- Coverage Performance
- Satellite Availability Performance
- Service Reliability Standard
- Positioning, Ranging and Timing Accuracy Standard.

The results were then compared to the performance parameters stated in the SPS.

1.2 Summary of Performance Requirements and Metrics

Table 1-1 lists the performance parameters from the SPS and identifies those parameters verified in this report.

Appendix E Table 1.2 contains the performance parameters evaluated for the WAAS in this report.

1.3 Report Overview

Section 2 of this report summarizes the results obtained from the coverage calculation program called SPS_CoverageArea developed by ACB 430. 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 twenty-one NSTB/WAAS sites.

Section 4 summarizes service reliability performance. It will be reported at the end of the first year of this analysis because the SPS standard is based a measurement interval of one year. Data for the quarter is provided for completeness.

Section 5 provides the position and repeatable accuracies based on data collected on a daily basis at one-second intervals. This section also provides the statistics on the range error, range error rate and range acceleration error for each satellite. The overall average, maximum, minimum and standard deviations of the range rates and accelerations are tabulated for each satellite.

In Section 6, the data collected during solar storms is analyzed to determine the effects, if any, of GPS SPS performance.

Appendix A provides a summary of all the results as compared to the SPS specification.

Appendix B provides the geomagnetic data used for Section 6.

Appendix C provides a PAN Problem Report.

Appendix D provides a glossary of terms used in this PAN report. This glossary was obtained directly from the GPS SPS specification document.

Table 1-1 SPS Performance Requirements

Coverage Standard	**Conditions and Constraints**	**Evaluated in This Report**
≥ 99.9% global average	• Probability of 4 or more satellites in view over any 24 hour interval, averaged over the globe • 4 satellites must provide PDOP of 6 or less • 5° mask angle with no obscura • Standard is predicated on 24 operational satellites, as the constellation is defined in the almanac	✓
≥ 96.9% at worst-case point	• Probability of 4 or more satellites in view over any 24 hour interval, for the worst-case point on the globe • 4 satellites must provide PDOP of 6 or less • 5° mask angle with no obscura • Standard is predicated on 24 operational satellites, as the constellation is defined in the almanac	✓
Satellite Availability Standard	**Conditions and Constraints**	
≥ 99.85% global average	• Conditioned on coverage standard • Standard based on a typical 24 hour interval, averaged over the globe • Typical 24 hour interval defined using averaging period of 30 days	✓
≥ 99.16% single point average	• Conditioned on coverage standard • Standard based on a typical 24 hour interval, for the worst-case point on the globe • Typical 24 hour interval defined using averaging period of 30 days	✓
≥ 95.87% global average on worst-case day	• Conditioned on coverage standard • Standard represents a worst-case 24 hour interval, averaged over the globe	✓
≥ 83.92% at worst-case point on worst-case day	• Conditioned on coverage standard • Standard based on a worst-case 24 hour interval, for the worst-case point on the globe	✓
Service Availability Standard	**Conditions and Constraints**	
≥ 99.97% global average	• Conditioned on coverage and service availability standards • 500 meter NTE predictable horizontal error reliability threshold • Standard based on a measurement interval of one year; average of daily values over the globe • Standard predicated on a maximum of 18 hours of major service failure behavior over the sample interval	✓
≥ 99.79% single point average	• Conditioned on coverage and service availability standards • 500 meter Not-to-Exceed (NTE) predictable horizontal error reliability threshold • Standard based on a measurement interval of one year; average of daily values from the worst-case point on the globe • Standard based on a maximum of 18 hours of major service failure behavior over the sample interval	✓

Accuracy Standard	Conditions and Constraints	
Predictable Accuracy ≤ 100 m horz. error 95% of time ≤ 156 m vert. error 95% of time ≤ 300 m horz. error 99.99% of time ≤ 500 m vert. error 99.99% of time	• Conditioned on coverage, service availability and service reliability standards • Standard based on a measurement interval of 24 hours, for any point on the globe	✓
<u>Repeatable Accuracy</u> ≤ 141 m horz. error 95% of time ≤ 221 m vert. error 95% of time	• Conditioned on coverage, service availability and service reliability standards • Standard based on a measurement interval of 24 hours, for any point on the globe	✓
<u>Relative Accuracy</u> ≤ 1.0 m horz. error 95% of time ≤ 1.5 m vert. error 95% of time	• Conditioned on coverage, service availability and service reliability standards • Standard based on a measurement interval of 24 hours, for any point on the globe • Standard presumes that the receivers base their position solutions on the same satellites, with position solutions computed at approximately the same time	Future Reports
<u>Time Transfer Accuracy</u> ≤ 340 nanoseconds time transfer error 95% of time	• Conditioned on coverage, service availability and service reliability standards • Standard based upon SPS receiver time as computed using the output of the position solution • Standard based on a measurement interval of 24 hours, for any point on the globe • Standard is defined with respect to Universal Coordinated Time, as it is maintained by the United States Naval Observatory	✓
<u>Range Domain Accuracy</u> ≤ 150 m NTE range error ≤ 2 m/s NTE range rate error ≤ 8 mm/s^2 range acceleration error 95% of time ≤ 19 mm/s^2 NTE range acceleration error	• Conditioned on satellite indicating healthy status • Standard based on a measurement interval of 24 hours, for any point on the globe • Standard restricted to range domain errors allocated to space/control segments • Standards are not constellation values -- each satellite is required to meet the standards • Assessment requires minimum of four hours of data over the 24 hour period for a satellite in order to evaluate that satellite against the standard	✓

2.0 Coverage Performance

Coverage: *The percentage of time over a specified time interval that a sufficient number of satellites are above a specified mask angle and provide an acceptable position solution geometry at any point on or near the Earth.*

Dilution of Precision (DOP): *A Root Mean Square (RMS) measure of the effects that any given position solution geometry has on position errors. Geometry effects may be assessed in the local horizontal (HDOP), local vertical (VDOP), three-dimensional position (PDOP), or time (TDOP) for example.*

Coverage Standard	Conditions and Constraints
≥ 99.9% global average	• Probability of 4 or more satellites in view over any 24 hour interval, averaged over the globe • 4 satellites must provide PDOP of 6 or less • 5° mask angle with no obscura • Standard is predicated on 24 operational satellites, as the constellation is defined in the almanac
≥ 96.9% at worst-case point	• Probability of 4 or more satellites in view over any 24 hour interval, for the worst-case point on the globe • 4 satellites must provide PDOP of 6 or less • 5° mask angle with no obscura • Standard is predicated on 24 operational satellites, as the constellation is defined in the almanac

Almanacs for GPS weeks 228-240 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 ACB 430 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 3.23359 or better 99.9% of the time for each of the 24-hour intervals.

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

Table 2-1 Coverage Statistics

GPS Week	Global 99.9% PDOP Value*	Global Average* (Spec: ≥ 99.9%)	Worst-Case Point (Spec: ≥ 96.9%)
280	3.29427	99.997	99.306
281	2.97214	99.997	99.306
282	2.96584	99.997	99.375
283	2.93713	99.997	99.306
284	2.92121	99.997	99.375
285	2.89780	99.997	99.306
286	2.87048	99.998	99.444
287	2.92362	100	99.792
288	2.91536	100	99.792
289	2.90329	100	100
290	2.89388	100	100
291	2.89473	100	100
292	2.89487	100	100

Figure 2-1 SPS Coverage (24-Hour Period: 3 January 2005)

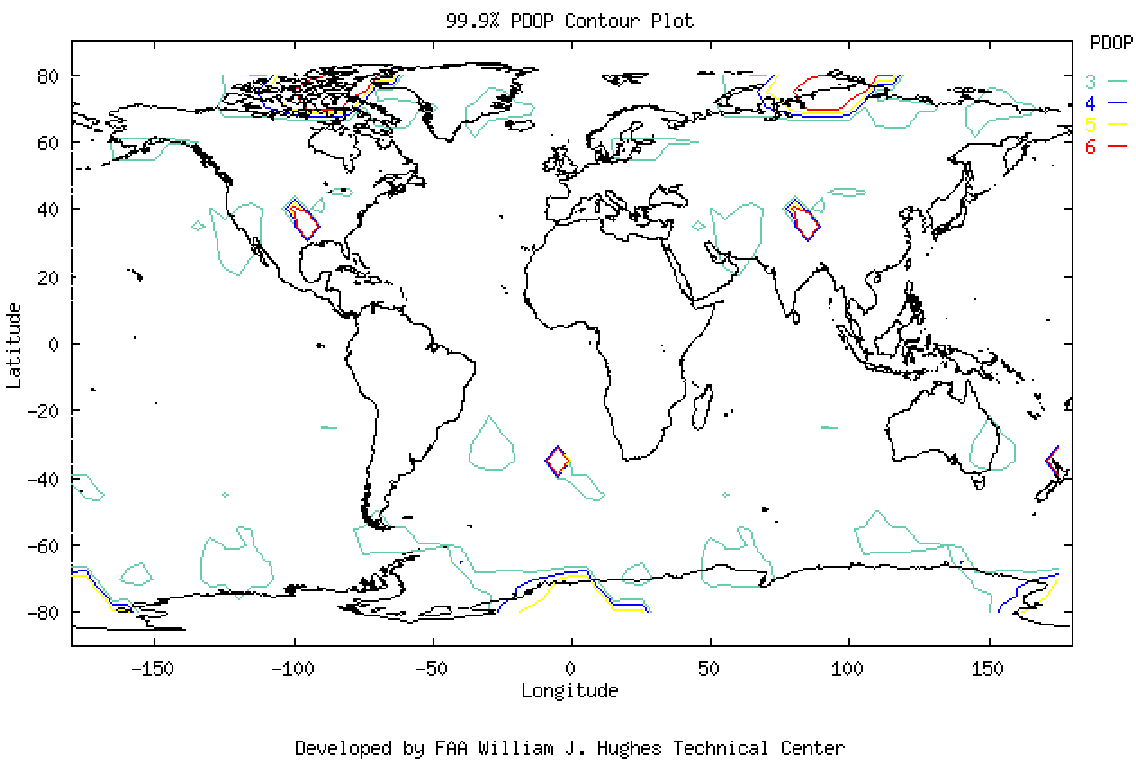
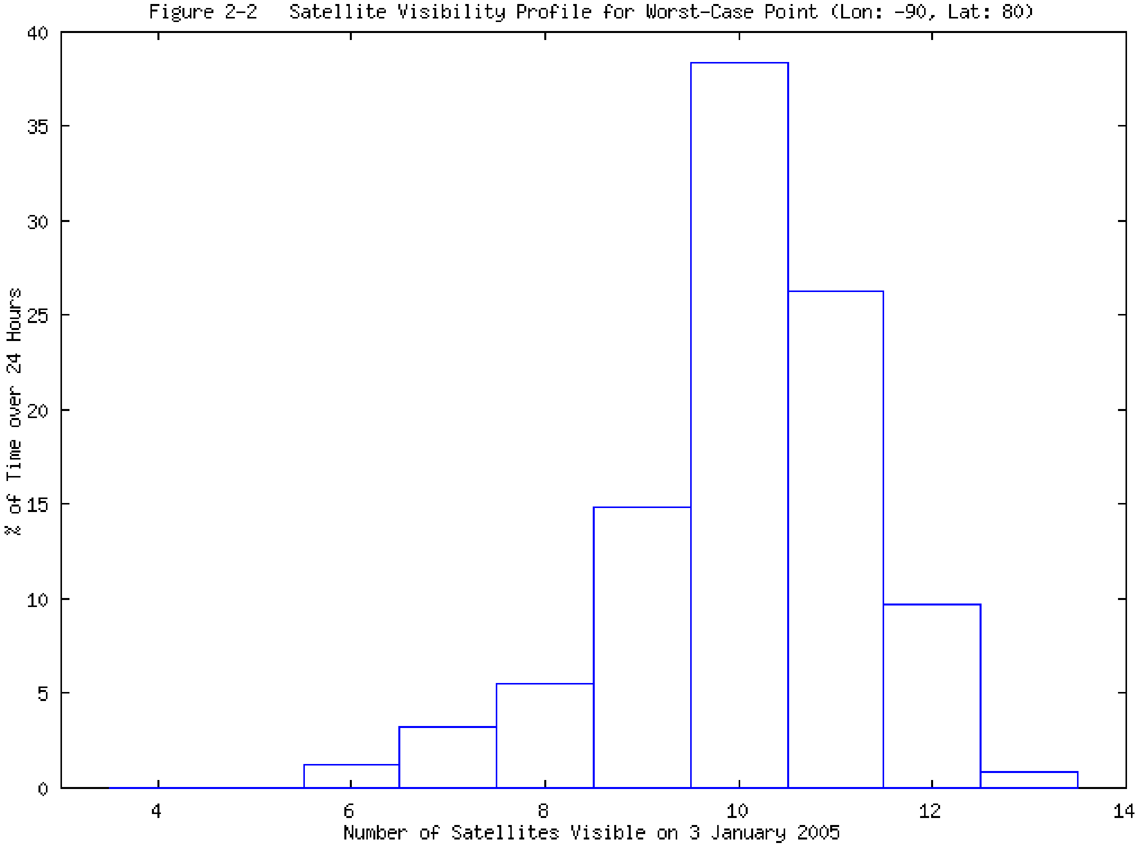


Figure 2-2 Satellite Visibility Profile for Worst-Case Point (Lon: -90, Lat: 80)



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 (NANU's). During this reporting period, 1 January through 31 March 2005, there were a total of twelve reported outages. Eleven of these outages were maintenance activities and were reported in advance. One was an unscheduled outage. A complete listing of outage NANU's for the reporting period is provided in Table 3-1. A complete listing of the forecasted outage NANU's for the reporting period can be found in Table 3-2. Canceled outage NANU's are provided in Table 3-3.

Table 3-1 NANUs Affecting Satellite Availability

NANU #	PRN	Type	Start Date	Start Time	End Date	End Time	Total Unscheduled	Total Scheduled	Total
5	8	S-FCSTSUMM	6-Jan	7:37	6-Jan	14:43		7.10	7.10
6	2	U-UNUSABLE	1-Jan	0:00	7-Jan	22:32	166.53		166.53
9	4	S-FCSTSUMM	18-Jan	18:45	19-Jan	3:57		9.20	9.20
10	13	S-FCSTSUMM	20-Jan	5:33	20-Jan	10:52		5.31	5.31
15	27	S-FCSTSUMM	28-Jan	16:20	28-Jan	20:30		4.17	4.17
17	17	S-FCSTSUMM	3-Feb	14:41	3-Feb	19:54		5.22	5.22
18	26	S-FCSTSUMM	8-Feb	21:28	9-Feb	0:56		3.47	3.47
21	30	S-FCSTSUMM	17-Feb	15:21	17-Feb	21:38		6.28	6.28
24	10	S-FCSTSUMM	24-Feb	17:32	24-Feb	18:30		0.97	0.97
27	24	S-FCSTSUMM	9-Mar	15:59	9-Mar	19:00		3.02	3.02
28	24	S-FCSTSUMM	15-Mar	13:10	16-Mar	2:42		13.53	13.53
32	26	S-FCSTSUMM	29-Mar	2:09	29-Mar	10:08		7.98	7.98
36	13	S-FCSTSUMM	31-Mar	15:46	31-Mar	19:15		3.48	3.48
Total Actual Unscheduled and Scheduled Downtime and Total Actual Downtime							**166.53**	**69.73**	**236.26**
Type:	S = Scheduled		U = Unscheduled						

Table 3-2 NANUs Forecasted to Affect Satellite Availability

NANU #	PRN	Type	Start Date	Start Time	End Date	End Time	Total	Comments
2004149	8	FCSTDV	6-Jan	7:15	6-Jan	19:15	CANC	See NANU 2
2004150	8	FCSTDV	6-Jan	7:15	6-Jan	19:15	CANC	See NANU 1
4	8	FCSTDV	6-Jan	7:15	6-Jan	19:15	12	See NANU 5
7	4	FCSTDV	18-Jan	18:30	19-Jan	6:30	12	See NANU 9
8	13	FCSTDV	20-Jan	4:45	20-Jan	16:45	12	See NANU 10
11	27	FCSTMX	28-Jan	15:30	29-Jan	3:30	12	See NANU 15
12	17	FCSTMX	1-Feb	14:00	2-Feb	2:00	RESCD	See NANU 13
13	17	FCSTRESCD	3-Feb	14:00	4-Feb	2:00	12	See NANU 17
16	26	FCSTMX	8-Feb	21:00	9-Feb	9:00	12	See NANU 18
19	30	FCSTMX	17-Feb	15:00	18-Feb	3:00	12	See NANU 21
20	10	FCSTMX	24-Feb	17:15	25-Feb	5:15	12	See NANU 24
25	24	FCSTMX	9-Mar	15:$5	10-Mar	3:45	12	See NANU 27
26	24	FCSTDV	15-Mar	12:45	16-Mar	12:45	24	See NANU 28
29	26	FCSTDV	28-Mar	1:45	28-Mar	13:45	RESCD	See NANU 30
30	26	FCSTRESCD	29-Mar	1:45	29-Mar	13:45	12	See NANU 32
31	13	FCSTMX	31-Mar	13:00	1-Apr	1:00	12	See NANU 36
					Total Forecast Downtime		**156**	

Table 3-3 NANUs Canceled

NANU#	PRN	Type	Start Date	Start Time	Comments
1	8	FCSTCANC	6-Jan	7:15	See NANU 2004150
2	8	FCSTCANC	6-Jan	7:15	See NANU 2004149

Satellite Reliability, Maintainability, and Availability (RMA) data is being collected based on published "Notice: Advisory to Navstar Users" messages (NANU's). This data has been summarized in Table 3-4. The "Total Satellite Observed MTTR" was calculated by taking the average downtime of all satellite outage occurrences. Schedule downtime was forecasted in advance via NANU's. All other downtime reported via NANU was considered unscheduled. The "Percent Operational" was calculated based on the ratio of total actual operating hours to total available operating hours for every satellite.

Table 3-4 GPS Block II/IIA Satellite RMA Data

Satellite Reliability/Maintainability/Availability (RMA) Parameter	1 January - 31 Mar. 2005	1 October, 1999- 31 Mar. 2005
Total Forecast Downtime (hrs):	156.00	5033.73
Total Actual Downtime (hrs):	236.26	11451.70
Total Actual Scheduled Downtime (hrs):	69.73	2825.16
Total Actual Unscheduled Downtime (hrs):	166.53	8626.54
Total Satellite Observed MTTR (hrs):	18.17	31.72
Scheduled Satellite Observed MTTR (hrs):	5.81	10.91
Unscheduled Satellite Observed MTTR (hrs):	166.53	84.57
# Total Satellite Outages:	13	361
# Scheduled Satellite Outages:	12	259
# Unscheduled Satellite Outages:	1	102
Percent Operational -- Scheduled Downtime:	99.89	99.78
Percent Operational -- All Downtime:	99.98	99.11

NANU 3 announced NANU 2004151 was renamed to 2005001 due to an internal network error.
NANU 14 stated that PRN31 will remain unhealthy unless operational need requires it set healthy.
NANU 22 announced that PRN17 will be decommissioned.
NANU 23 announced that PRN17 was decommissioned on February 23, 2005 at 22:00Z.

3.2 Service Availability

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

To verify availability, the data collected from receivers at the nine NSTB/WAAS sites was reduced to calculate DOP information and reported in Tables 3-5 to 3-7. The data was collected at one-second intervals between 1 January and 31 March 2005.

Table 3-5 PDOP Statistics

NSTB/WAAS Site	Min PDOP	Max PDOP	VDOP at Max PDOP	Mean PDOP	99.99% PDOP	99.99% VDOP	Number of Samples
Bangor	1.519	6.000	5.549	2.389	5.965	5.715	7568323
Mauna Loa	1.225	5.645	5.465	1.775	3.890	3.635	7355469
Billings	1.182	4.280	3.757	1.762	3.139	2.714	6966603
Cold Bay	1.152	4.707	4.416	1.697	4.559	4.217	7574957
Juneau	1.236	5.998	5.544	1.780	4.280	3.921	7520188
Albuquerque	1.234	4.201	3.781	1.734	3.733	3.159	7251909
Anchorage	1.148	5.598	5.289	1.728	3.619	3.313	7598138
Boston	1.173	4.092	3.003	1.726	3.430	2.872	7592092
Washington, D.C.	1.122	4.107	3.666	1.733	3.979	3.417	7598664
Honolulu	1.164	4.218	3.932	1.724	3.881	3.661	7585451
Houston	1.157	4.039	33.354	1.738	3.417	3.168	7582734
Kansas City	1.198	4.112	3.607	1.778	3.935	3.501	7587273
Los Angeles	1.182	4.955	4.688	1.757	4.148	3.915	7590505
Salt Lake City	1.190	5.661	5.478	1.755	4.172	3.909	7101862
Miami	1.208	3.871	3.605	1.773	3.752	3.482	7595938
Minneapolis	1.152	3.874	3.321	1.746	3.779	3.195	7590213
Oakland	1.174	4.898	4.556	1.740	4.361	4.009	7585725
Cleveland	1.108	5.811	5.005	1.750	4.249	3.671	7367469
Seattle	1.195	3.389	2.995	1.750	3.284	2.888	7588604
San Juan	1.198	4.028	3.866	1.726	3.906	3.740	7589755
Atlanta	1.224	4.169	3.665	1.746	4.112	3.611	7589984

Tables 3-6 and 3-7 show the statistics related to maximum PDOP and PDOP greater than six, respectively. Table 3-6 shows the PDOP statistics for the worst-case point on the worst-case day.
NOTE: Global in this report refers to the twenty-one sites used. Although future reports will have all additional sites, a true global availability cannot be determined since there aren't reference stations around the world. Whenever the

PDOP goes above six and an SPS requirement is not met, an investigation is performed to determine what caused the PDOP to go above six. The following is a list of programs/procedures used during times of high PDOP:

- Notice of Advisory to Navstar Users (NANU's) messages are used to verify that satellite outages did occur. (See Section 3.1 for more details about NANU's for this quarter.)
- A satellite outage detection program developed by ACB 430 verifies satellite outages that are not verified through a NANU. For example, a satellite outage can occur for just a few seconds during an upload. This satellite detection program monitors all the receivers and keeps track of what satellites the receiver should be tracking versus what satellites the receiver is actually tracking. At least six receivers need to be tracking the satellite prior to the outage and no receiver can be tracking the satellite for the program to detect an outage. This program is also being enhanced so that false locks and late ephemeris problems can also be detected. This program will also output flags from the receivers so that problems with the receiver or TRS software, if any, can be tracked more easily.
- Data from co-located receivers is analyzed for times that the PDOP goes above six. This helps in determining whether the problem is due to the environment.

The instance of worst performance where the PDOP went above six is reported in Table 3-6. The column labeled "NANU/SOD" reports whether the outage was detected via a NANU or the Satellite Outage Detection (SOD) program along with the Satellite PRN number that had the outage.

Table 3-6 Maximum PDOP Statistics

Site	GPS Week/ Day	Max PDOP	Number of Seconds of Whole Day PDOP > 6	NANU/SOD, Satellite PRN Number	Number of Samples	Availability on days when PDOP > 6
None						
Worst-Case Point on Worst-Case Day = 100% (SPS Spec. ≥ 83.92%)						

Global Average on Worst-Case Day = 100% (SPS Spec. ≥ 95.87%)

Table 3-7 PDOP > 6 Statistics

Site	Total Number of Seconds of PDOP Monitoring	Total Seconds with PDOP > 6	Overall % Availability
Bangor	7568323	0	100%
Mauna Loa	7355469	0	100%
Billings	6966603	0	100%
Cold Bay	7574957	0	100%
Juneau	7520188	0	100%
Albuquerque	7251909	0	100%
Anchorage	7598138	0	100%
Boston	7592092	0	100%
Washington, D.C.	7598664	0	100%
Honolulu	7585451	0	100%
Houston	7582734	0	100%
Kansas City	7587273	0	100%
Los Angeles	7590505	0	100%
Salt Lake City	7101862	0	100%
Miami	7595938	0	100%
Minneapolis	7590213	0	100%
Oakland	7585725	0	100%
Cleveland	7367469	0	100%
Seattle	7588604	0	100%
San Juan	7589755	0	100%
Atlanta	7589984	0	100%
Worst Single Point Average = 100% (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 99.99% horizontal errors reported by a receiver at each of the twenty-one NSTB/WAAS sites. This will be evaluated against the SPS specification at the end of the year.

Table 4-1 Service Reliability Based on Horizontal Error

Site	Number of Samples This Quarter	Maximum Horizontal Error (Meters)
Bangor	7568323	14.80
Mauna Loa	7355469	13.10
Billings	6966603	6.50
Cold Bay	7574957	6.54
Juneau	7520188	6.50
Albuquerque	7251909	6.26
Anchorage	7598138	6.48
Boston	7592092	7.75
Washington, D.C.	7598664	6.46
Honolulu	7585451	12.70
Houston	7582734	5.32
Kansas City	7587273	6.07
Los Angeles	7590505	7.63
Salt Lake City	7101862	5.75
Miami	7595938	6.92
Minneapolis	7590213	8.77
Oakland	7585725	7.63
Cleveland	7367469	7.26
Seattle	7588604	7.10
San Juan	7589755	11.50
Atlanta	7589984	5.65

5.0 Accuracy Characteristics

Accuracy: *Given coverage, service availability and service reliability, the percentage of time over a specified time interval that the difference between the measured and expected user position or time is within a specified threshold at any point on or near the Earth.*

Accuracy Standard	Conditions and Constraints
Predictable Accuracy ≤ 100 meters horizontal error 95% of time ≤ 156 meters vertical error 95% of time ≤ 300 meters horizontal error 99.99% of time ≤ 500 meters vertical error 99.99% of time	• Conditioned on coverage, service availability and service reliability standards • Standard based on a measurement interval of 24 hours, for any point on the globe
Repeatable Accuracy ≤ 141 meters horizontal error 95% of time ≤ 221 meters vertical error 95% of time	• Conditioned on coverage, service availability and service reliability standards • Standard based on a measurement interval of 24 hours, for any point on the globe
Relative Accuracy ≤ 1.0 meters horizontal error 95% of time ≤ 1.5 meters vertical error 95% of time	• Conditioned on coverage, service availability and service reliability standards • Standard based on a measurement interval of 24 hours, for any point on the globe • Standard presumes that the receivers base their position solutions on the same satellites, with position solutions computed at approximately the same time
Time Transfer Accuracy ≤ 340 nanoseconds time transfer error 95% of time	• Conditioned on coverage, service availability and service reliability standards • Standard based upon SPS receiver time as computed using the output of the position solution • Standard based on a measurement interval of 24 hours, for any point on the globe • Standard is defined with respect to Universal Coordinated Time, as it is maintained by the United States Naval Observatory
Range Domain Accuracy ≤ 150 meters NTE range error ≤ 2 meters/second NTE range rate error ≤ 8 millimeters/second^2 range acceleration error 95% of time ≤ 19 millimeters/second^2 NTE range acceleration error	• Conditioned on satellite indicating healthy status • Standard based on a measurement interval of 24 hours, for any point on the globe • Standard restricted to range domain errors allocated to space/control segments • Standards are not constellation values -- each satellite is required to meet the standards • Assessment requires minimum of four hours of data over the 24 hour period for a satellite in order to evaluate that satellite against the standard

5.1 Position Accuracies

The data used for this section was collected for every second between 1 January through 31 March 2005 at the NSTB and WAAS selected locations.

Table 5-1 provides the 95% and 99.99% horizontal and vertical error accuracies for the quarter.

Table 5-1 Horizontal & Vertical Accuracy Statistics for the Quarter

Site	95% Horizontal (Meters)	95% Vertical (Meters)	99.99% Horizontal (Meters)	99.99% Vertical (Meters)
Bangor	3.416	5.856	9.949	16.944
Mauna Loa	6.948	6.328	12.551	17.371
Billings	2.864	4.902	6.247	10.612
Cold Bay	2.572	5.552	6.090	10.874
Juneau	2.575	5.208	5.420	11.259
Albuquerque	2.794	4.936	6.019	9.513
Anchorage	2.513	5.551	6.210	11.152
Boston	2.881	4.881	6.611	9.430
Washington, D.C.	2.885	5.123	6.179	10.073
Honolulu	6.379	5.822	12.487	14.129
Houston	2.799	5.166	5.050	10.557
Kansas City	2.882	5.192	5.768	10.609
Los Angeles	2.844	5.324	7.127	12.398
Salt Lake City	2.872	4.967	5.357	9.325
Miami	3.026	5.630	6.284	12.085
Minneapolis	2.865	4.996	8.028	10.134
Oakland	2.748	5.264	6.652	10.560
Cleveland	2.943	4.880	7.112	10.413
Seattle	2.885	5.066	6.708	10.658
San Juan	3.729	5.620	10.649	18.342
Atlanta	2.893	5.320	5.021	10.939

Figures 5-1 and 5-2 are the combined histograms of the vertical and horizontal errors for all twenty-one NSTB and WAAS sites from 1 January to 31 March 2005.

Figure 5-1 Combined Vertical Error Histogram

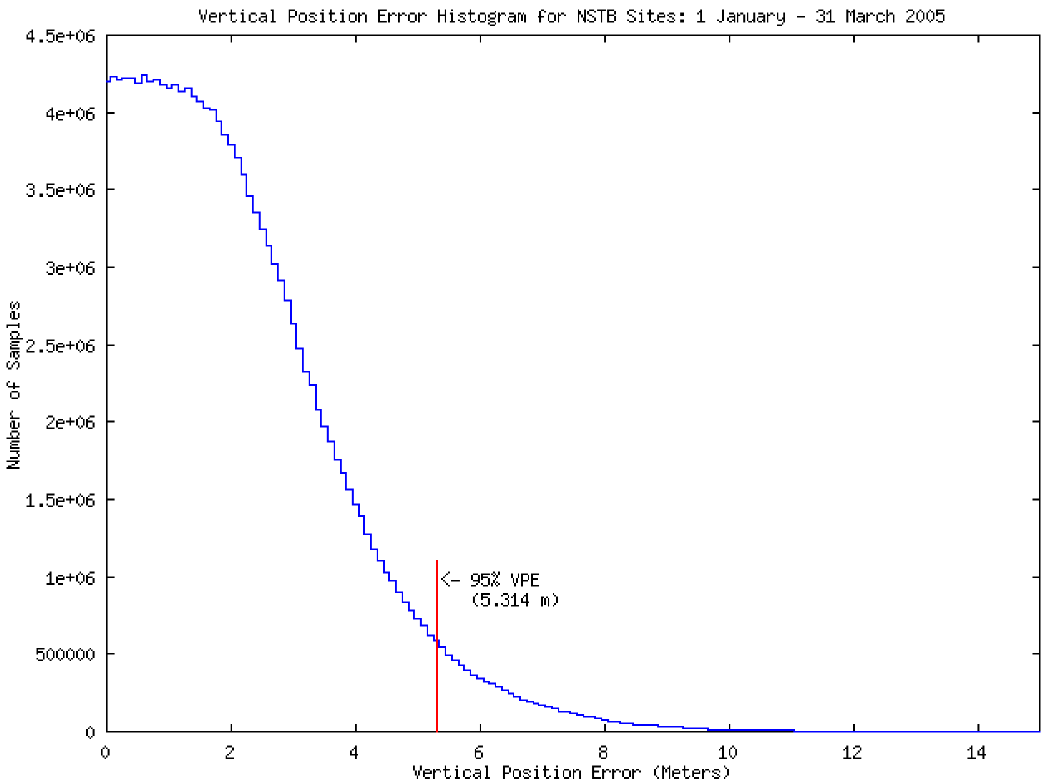
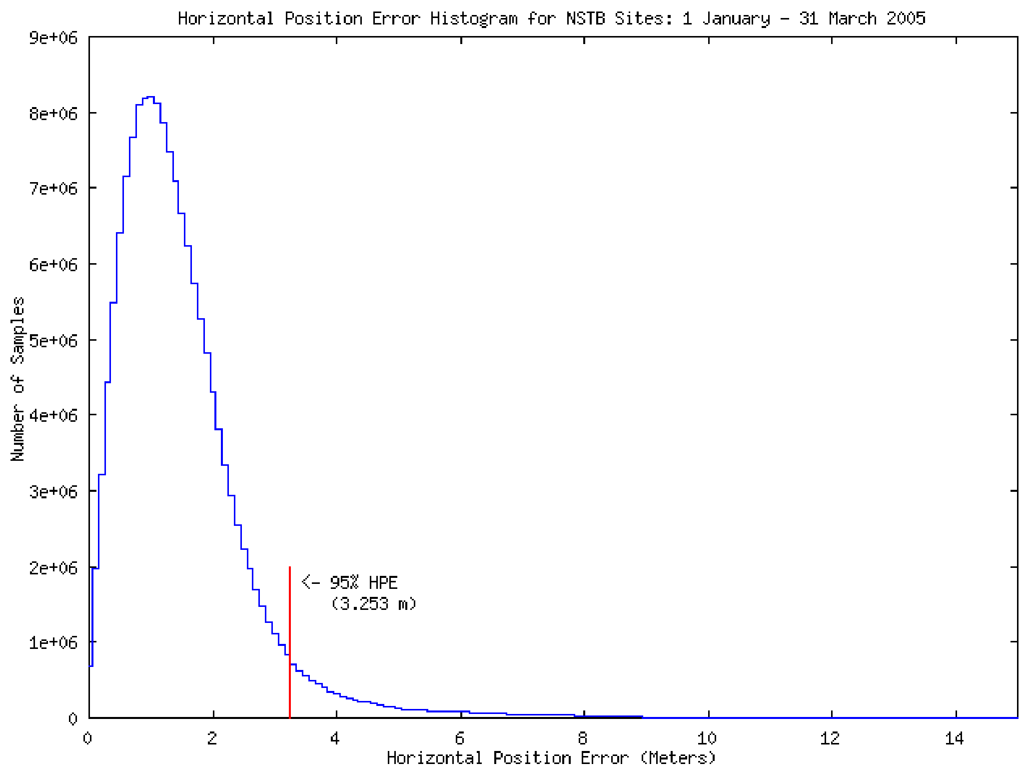


Figure 5-2 Combined Horizontal Error Histogram



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

Site	95% Horizontal (m)	95% Vertical (m)
Bangor	1.590	3.717
Mauna Loa	0.838	2.750
Billings	0.804	2.661
Cold Bay	1.430	3.823
Juneau	1.225	2.974
Albuquerque	0.958	2.111
Anchorage	1.180	2.992
Boston	0.955	1.990
Washington, D.C.	1.081	1.856
Honolulu	0.977	2.467
Houston	0.910	2.442
Kansas City	1.051	2.658
Los Angeles	0.860	2.340
Salt Lake City	0.818	2.306
Miami	0.893	2.088
Minneapolis	0.998	2.177
Oakland	0.762	2.235
Cleveland	0.966	2.296
Seattle	0.848	2.595
San Juan	0.729	1.947
Atlanta	1.246	2.188

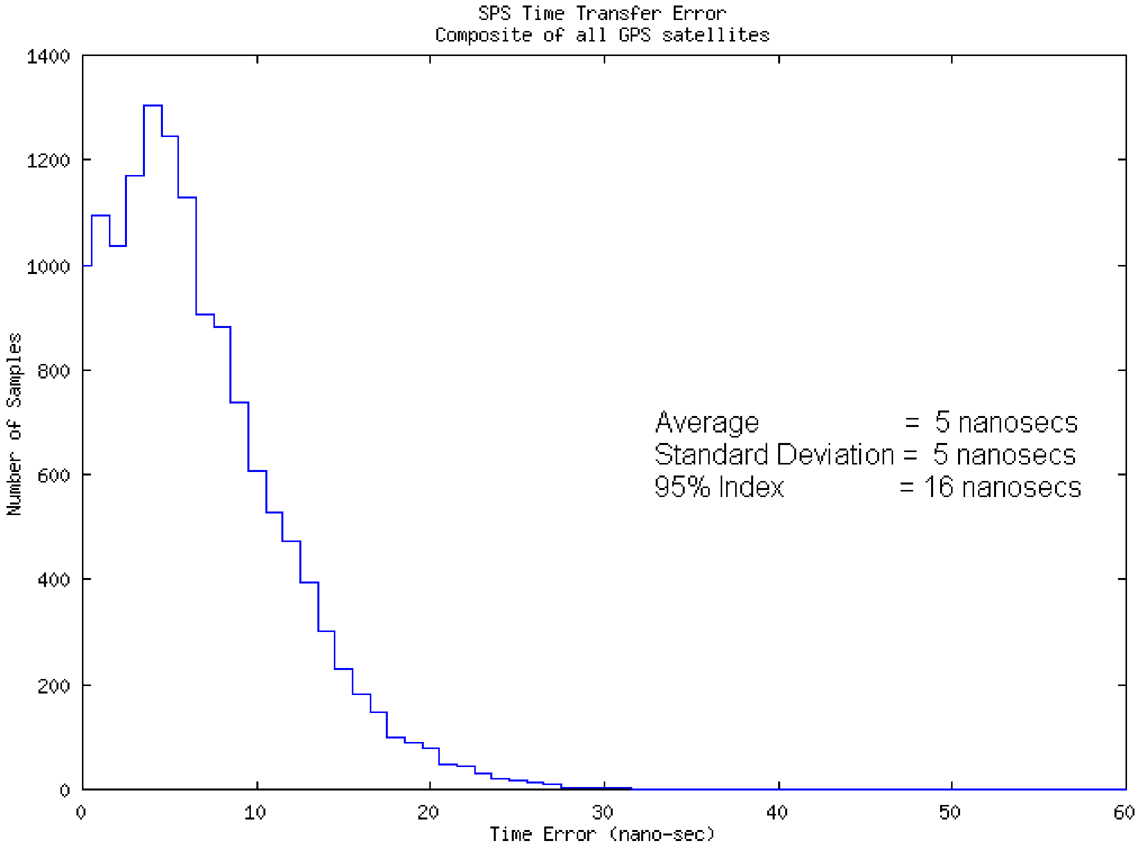
5.3 Relative Accuracy

To be included in future reports.

5.4 Time Transfer Accuracy

The GPS time error data between 1 January and 31 March 2005 was down loaded from USNO Internet site. The USNO data file contains the time difference between the USNO master clock and GPS system time for each GPS satellites during the time period. Over 10,000 samples of GPS time error are contained in the USNO data file. In order to evaluate the GPS time transfer error, the data file was used to create a histogram (Fig 5-3) to represent the distribution of GPS time error. The histogram was created by taking the absolute value of time difference between the USNO master clock and GPS system time, then creating data bins with one nanosecond precision. The number of samples in each bin was then plotted to form the histogram in Fig 5-3. The mean, standard deviation, and 95% index are within the requirements of GPS SPS time error.

Figure 5-3 Time Transfer Errors



5.5 Range Domain Accuracy

Tables 5-3 through 5-5 provide the statistical data for the range error, range rate error and the range acceleration error for each satellite. This data was collected between 1 January and 31 March 2005. The WAAS receiver at Houston was used to collect range measurement. Future PAN reports will contain statistics from all WAAS sites.

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

Table 5-3 Range Error Statistics (meters)

PRN	Range Error Mean	Range Error RMS	1s	95% Range Error	Max Range Error (SPS Spec. ≤ 150 m)	Samples
1	4.695	5.067	1.908	7.697	13.142	1888442
2	4.347	5.190	2.836	9.566	18.578	1583026
3	4.028	4.389	1.744	6.937	12.840	2248987
4	2.445	3.384	2.340	6.176	25.319	1857178
5	3.999	4.792	2.640	8.401	15.181	1962657
6	3.655	4.498	2.622	7.954	14.365	1716945
7	3.690	4.214	2.034	7.101	13.675	1832357
8	3.370	4.083	2.305	7.455	13.644	1745286
9	2.974	3.752	2.288	6.759	14.327	2218950
10	4.858	5.465	2.504	9.018	17.903	2128497
11	4.574	4.817	1.511	6.921	10.023	2215761
13	3.518	3.749	1.296	5.519	15.438	1640015
14	5.311	5.528	1.535	7.993	11.276	1783354
15	4.963	5.503	2.376	8.906	15.344	1729734
16	4.781	5.061	1.662	7.352	28.801	2180274
17	4.566	5.311	2.713	9.145	13.336	1041799
18	5.152	5.485	1.882	8.640	12.313	1883616
19	6.538	6.692	1.428	8.807	12.877	2236983
20	4.709	4.978	1.616	7.176	12.790	1978680
21	5.638	6.114	2.365	9.784	15.109	1884831
22	5.347	5.685	1.932	8.712	12.312	1918527
23	5.975	6.100	1.231	7.965	11.200	1756622
24	3.160	4.000	2.453	7.116	27.248	2052589
25	3.924	4.373	1.930	6.914	11.883	1668145
26	3.269	3.899	2.125	7.252	12.378	2229395
27	3.278	3.685	1.682	5.957	8.897	1865832
28	4.184	4.650	2.031	7.640	16.323	1900281
29	3.823	4.296	1.960	7.483	27.771	2272677
30	2.500	3.541	2.508	6.529	26.912	2145980

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	0.00002	0.00230	0.00230	0.00300	0.18796	1888442
2	0.00003	0.00172	0.00172	0.00336	0.07419	1583026
3	0.00002	0.00237	0.00237	0.00327	0.33700	2248987
4	0	0.00557	0.00557	0.00481	1.12424	1857178
5	0.00018	0.00363	0.00362	0.00411	0.48372	1962657
6	0.00005	0.00302	0.00302	0.00364	0.19523	1716945
7	-0.00003	0.00150	0.00150	0.00284	0.25187	1832357
8	-0.00002	0.00301	0.00301	0.00346	0.22916	1745286
9	-0.00003	0.00262	0.00262	0.00334	0.26544	2218950
10	-0.00002	0.00306	0.00306	0.00377	0.25992	2128497
11	-0.00004	0.00199	0.00199	0.00325	0.20552	2215761
13	0	0.00350	0.00350	0.00323	0.69879	1640015
14	-0.00006	0.00171	0.00171	0.00287	0.20691	1783354
15	-0.00003	0.00214	0.00214	0.00317	0.22910	1729734
16	-0.00003	0.00441	0.00441	0.00346	0.91359	2180274
17	0	0.00235	0.00235	0.00331	0.31627	1041799
18	-0.00002	0.00160	0.00160	0.00311	0.10037	1883616
19	-0.00001	0.00155	0.00155	0.00297	0.08052	2236983
20	-0.00003	0.00397	0.00397	0.00346	0.32480	1978680
21	-0.00001	0.00203	0.00203	0.00330	0.20338	1884831
22	-0.00003	0.00186	0.00186	0.00372	0.16888	1918527
23	0.00001	0.00153	0.00153	0.00291	0.05480	1756622
24	-0.00011	0.00404	0.00404	0.00383	0.40854	2052589
25	0	0.00240	0.00240	0.00314	0.16691	1668145
26	-0.00006	0.00193	0.00192	0.00314	0.16547	2229395
27	0.00003	0.00160	0.00160	0.00292	0.13480	1865832
28	-0.00001	0.00220	0.00220	0.00302	0.24985	1900281
29	-0.00007	0.00357	0.00357	0.00343	0.88137	2272677
30	0.00013	0.00233	0.00233	0.00352	1.12079	2145980

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

PRN	Range Acceleration Error Mean	Range Acceleration Error RMS	Range Acceleration 1 s	% ≤ 0.008 (SPS Spec. 95% of Time)	Max Range Acceleration Error (SPS Spec. ≤ 0.019 m/s2)	Samples
1	0	0.00002	0.00002	100	0.00188	1888442
2	0	0.00001	0.00001	1000	0.00070	1583026
3	0	0.00002	0.00002	100	0.00341	2248987
4	0	0.00005	0.00005	99.999	0.01123	1857178
5	0	0.00003	0.00003	100	0.00482	1962657
6	0	0.00003	0.00003	100	0.00196	1716945
7	0	0.00001	0.00001	100	0.00253	1832357
8	0	0.00003	0.00003	100	0.00223	1745286
9	0	0.00002	0.00002	100	0.00265	2218950
10	0	0.00003	0.00003	100	0.00259	2128497
11	0	0.00002	0.00002	100	0.00204	2215761
13	0	0.00003	0.00003	100	0.00701	1640015
14	0	0.00001	0.00001	100	0.00207	1783354
15	0	0.00002	0.00002	100	0.00229	1729734
16	0	0.00004	0.00004	99.999	0.00928	2180274
17	0	0.00002	0.00002	100	0.00317	1041799
18	0	0.00001	0.00001	100	0.00100	1883616
19	0	0.00001	0.00001	100	0.00079	2236983
20	0	0.00004	0.00004	100	0.00330	1978680
21	0	0.00002	0.00002	100	0.00203	1884831
22	0	0.00002	0.00002	100	0.00169	1918527
23	0	0.00001	0.00001	100	0.00054	1756622
24	0	0.00003	0.00003	100	0.00361	2052589
25	0	0.00002	0.00002	100	0.00168	1668145
26	0	0.00002	0.00002	100	0.00164	2229395
27	0	0.00001	0.00001	100	0.00133	1865832
28	0	0.00002	0.00002	100	0.00253	1900281
29	0	0.00003	0.00003	99.999	0.00882	2272677
30	0	0.00002	0.00002	99.999	0.01117	2145980

Figures 5-4, 5-5 and 5-6 are graphical representations of the distributions of the maximum range error, range rate error and range acceleration error for all satellites. None of the range errors for any of the satellites exceeded the 150-meter SPS requirement. The highest maximum range error occurred on satellite 7 with an error of 35.011 meters. Satellite 1 had the lowest maximum range error of 9.936 meters.

Figure 5-4 Distribution of Daily Max Range Errors

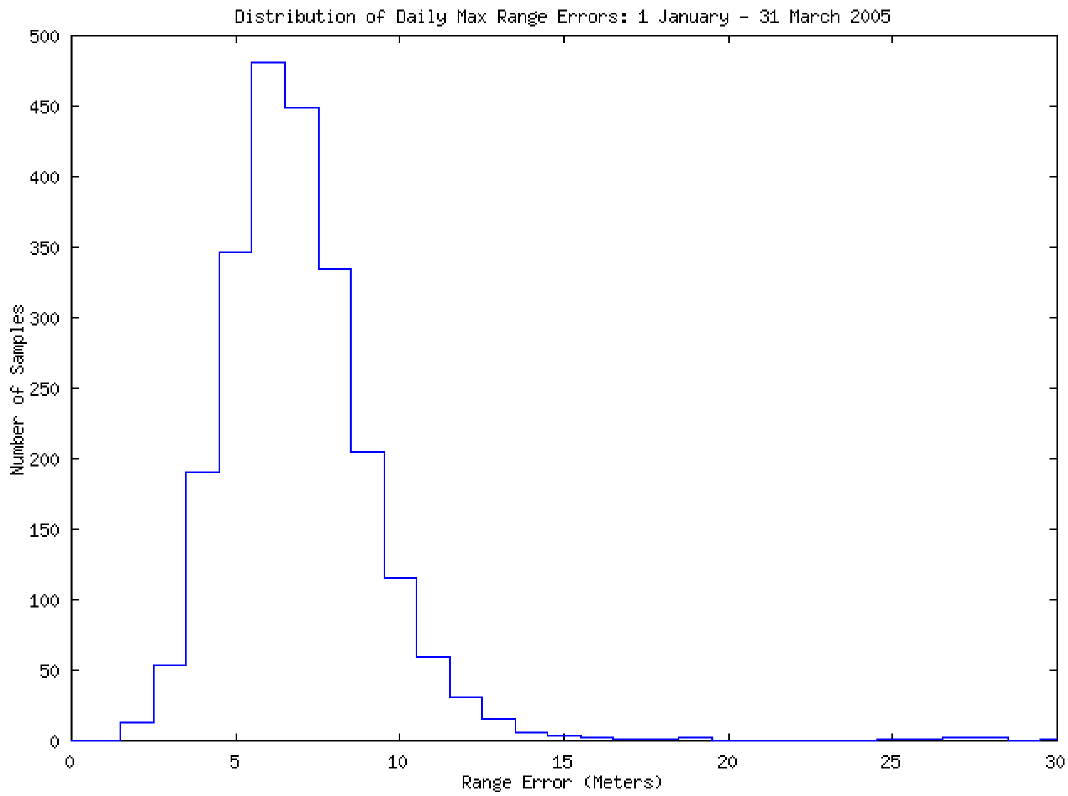


Figure 5-5: Distribution of Daily Max Range Rate Errors

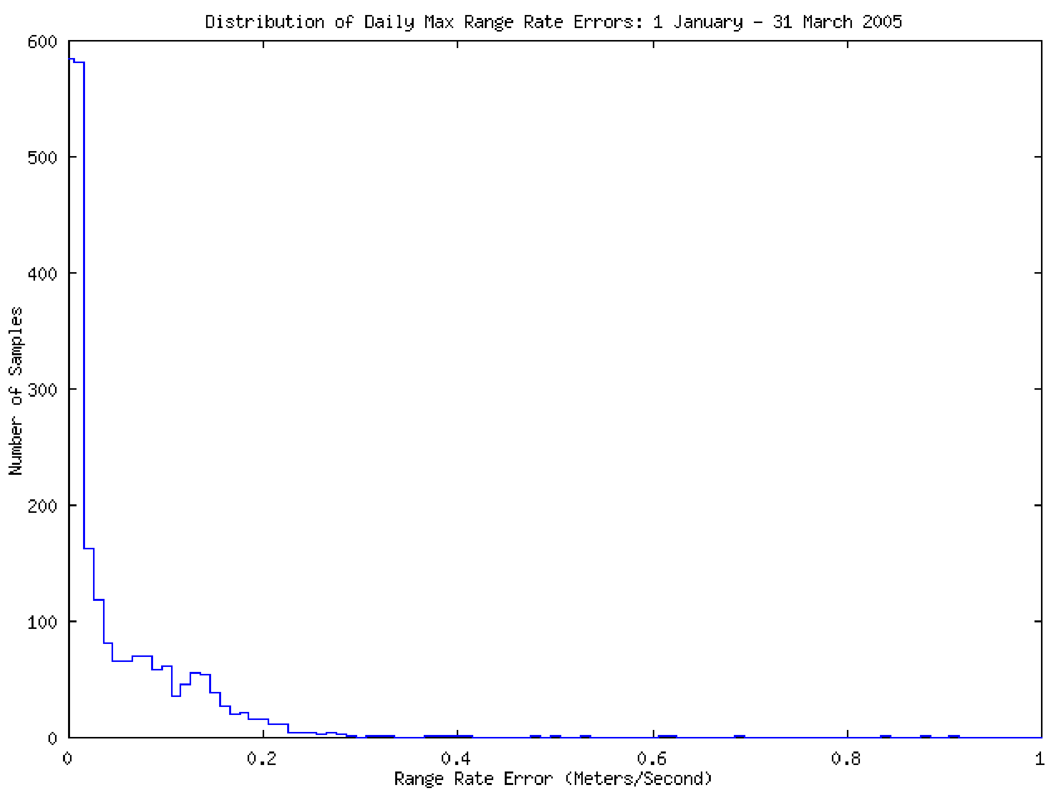


Figure 5-6: Distribution of Daily Max Acceleration Rate Errors

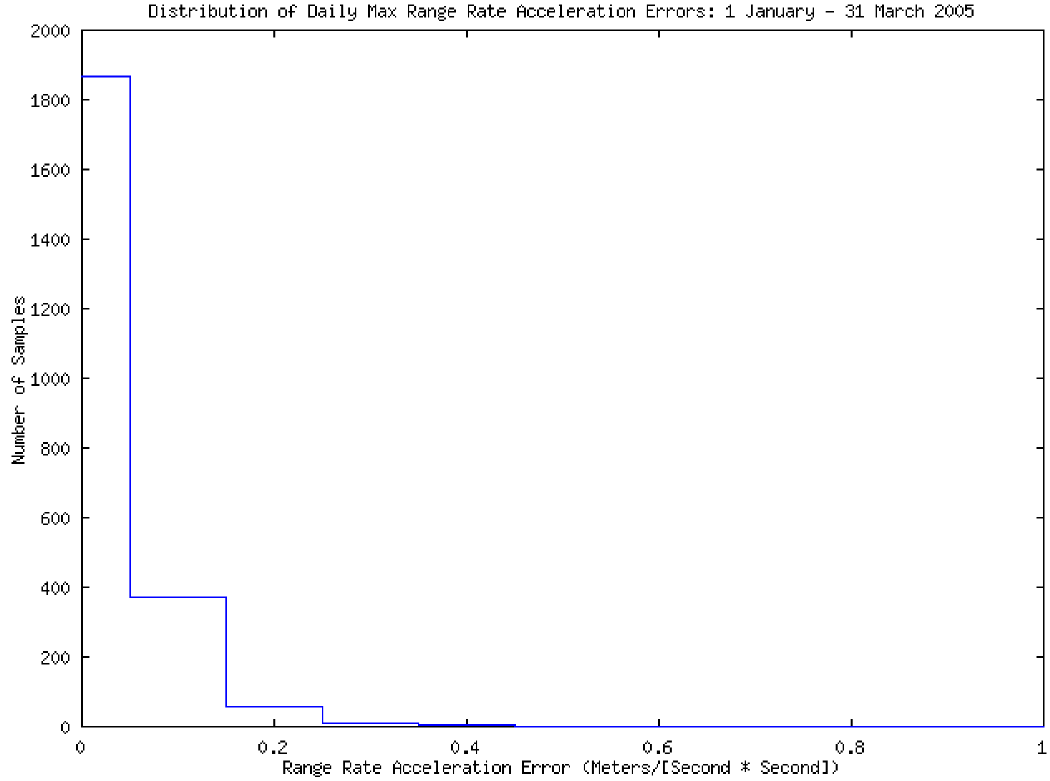
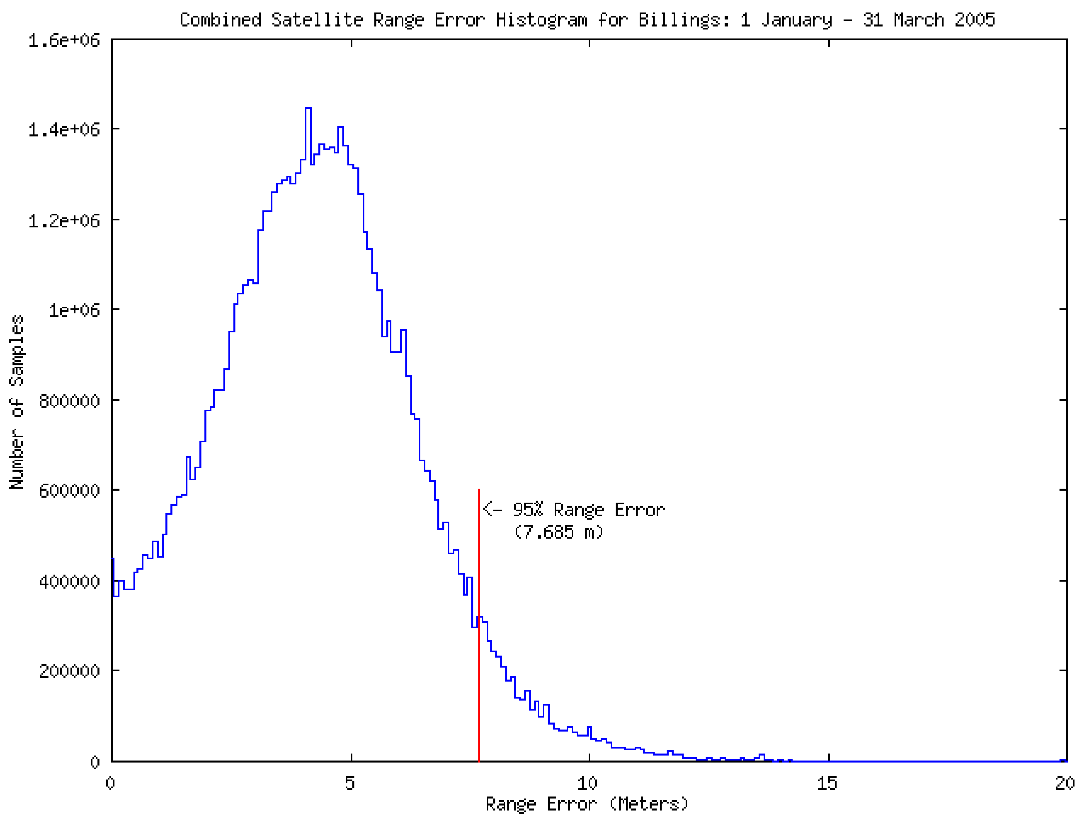


Figure 5-7: Range Error Histogram



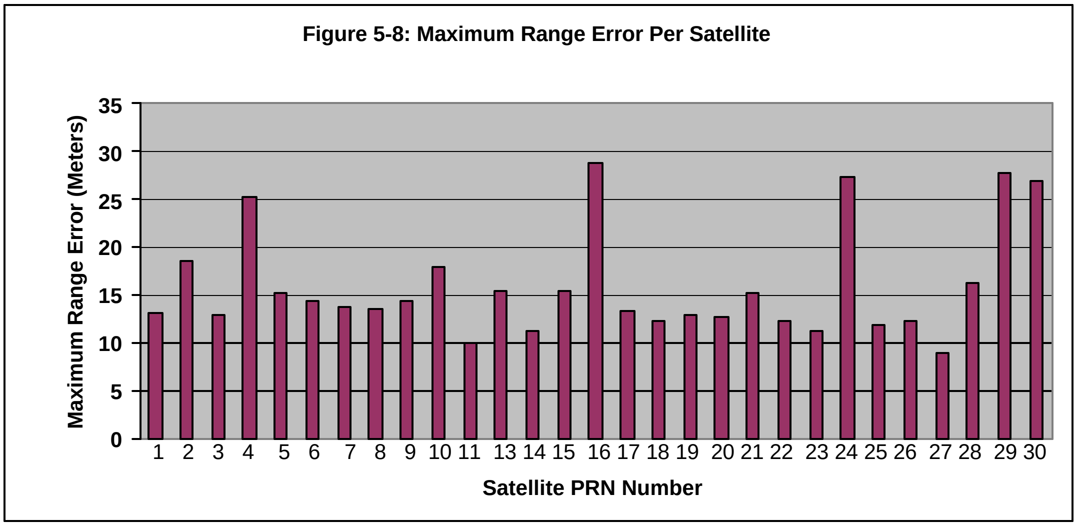


Figure 5-8: Maximum Range Error Per Satellite
Maximum Range Error (Meters)
35
30
25
20
15
10
5
0
1 2 3 4 5 6 7 8 9 10 11 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Satellite PRN Number

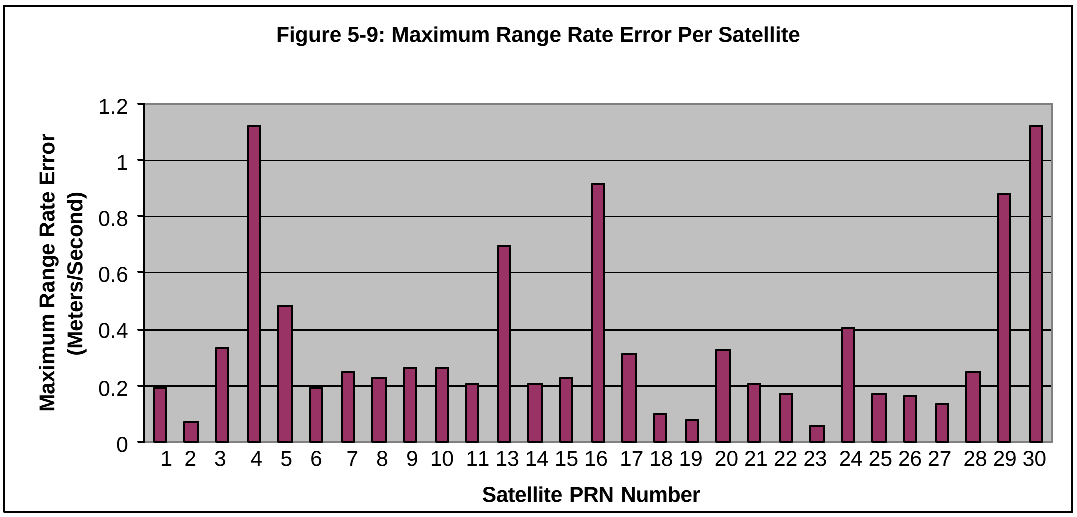


Figure 5-9: Maximum Range Rate Error Per Satellite
Maximum Range Rate Error (Meters/Second)
1.2
1
0.8
0.6
0.4
0.2
0
1 2 3 4 5 6 7 8 9 10 11 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Satellite PRN Number

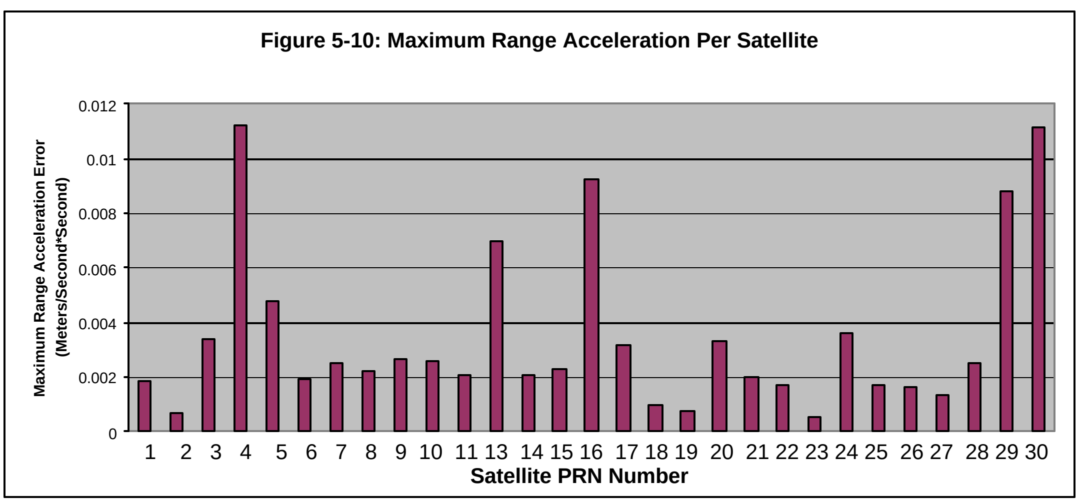


Figure 5-10: Maximum Range Acceleration Per Satellite
Maximum Range Acceleration Error (Meters/Second*Second)
0.012
0.01
0.008
0.006
0.004
0.002
0
1 2 3 4 5 6 7 8 9 10 11 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Satellite PRN Number

6.0 Solar Storms

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

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

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

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

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

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

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

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

Figure 6-1 K-Index for 17-19 2005

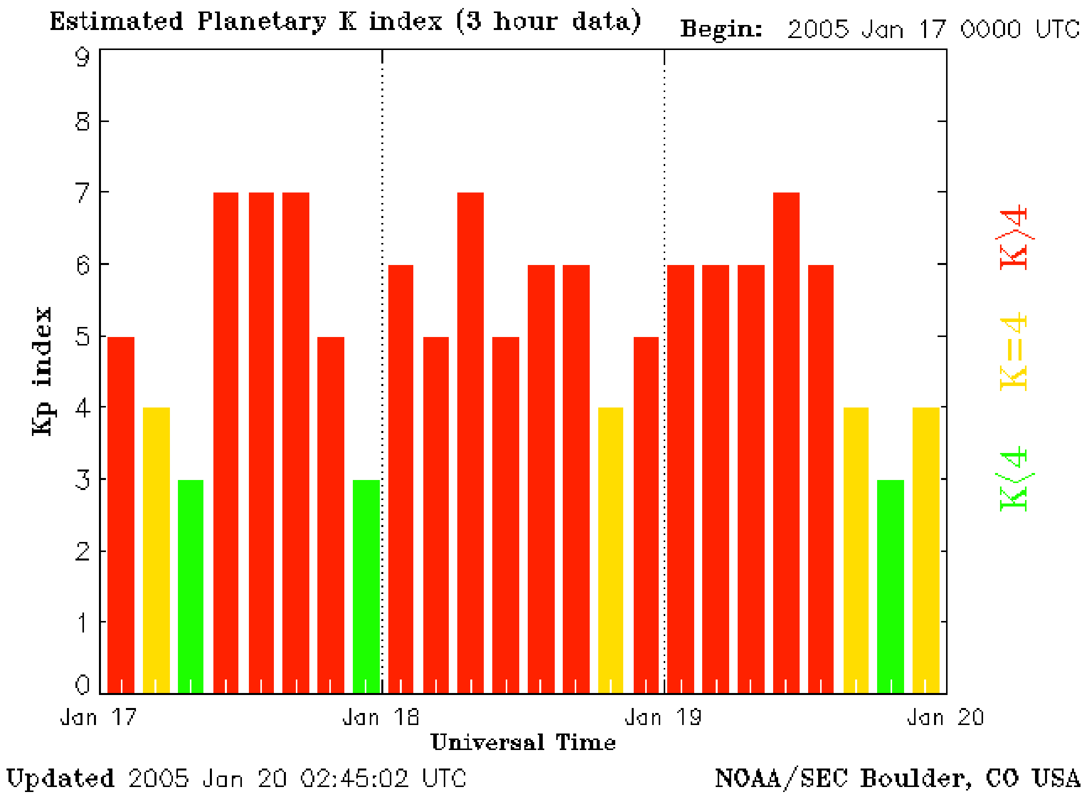


Figure 6-2 K-Index for 20-22 January 2005

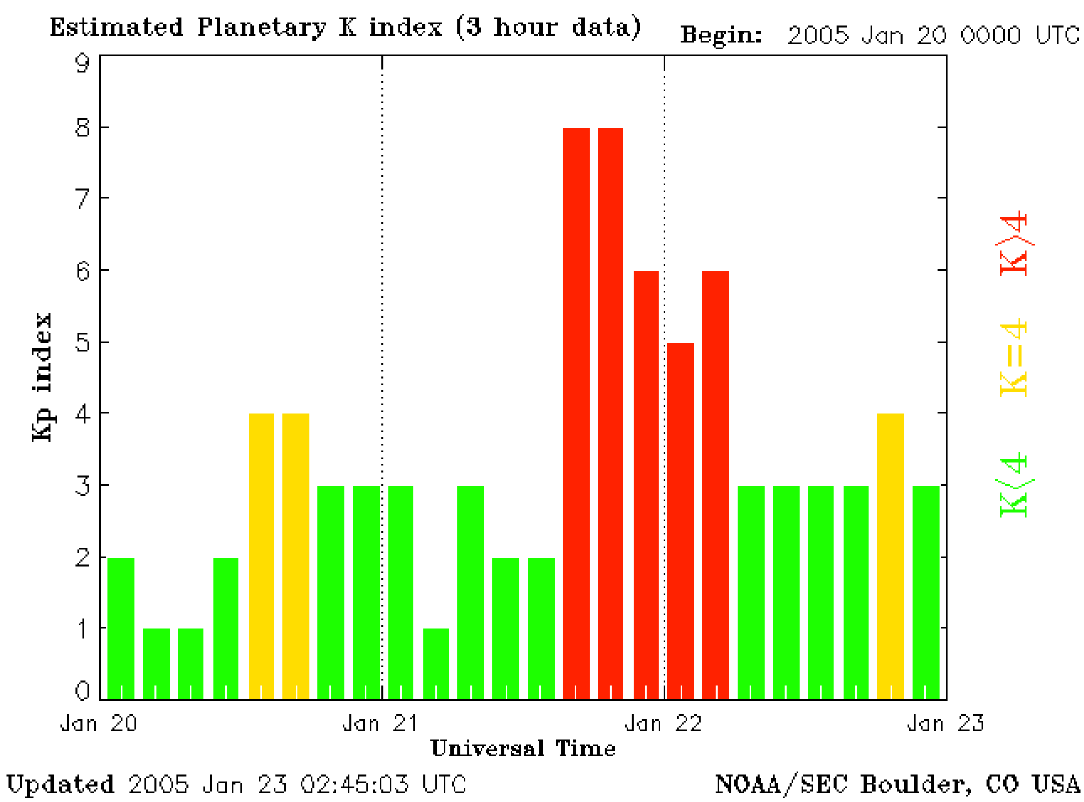
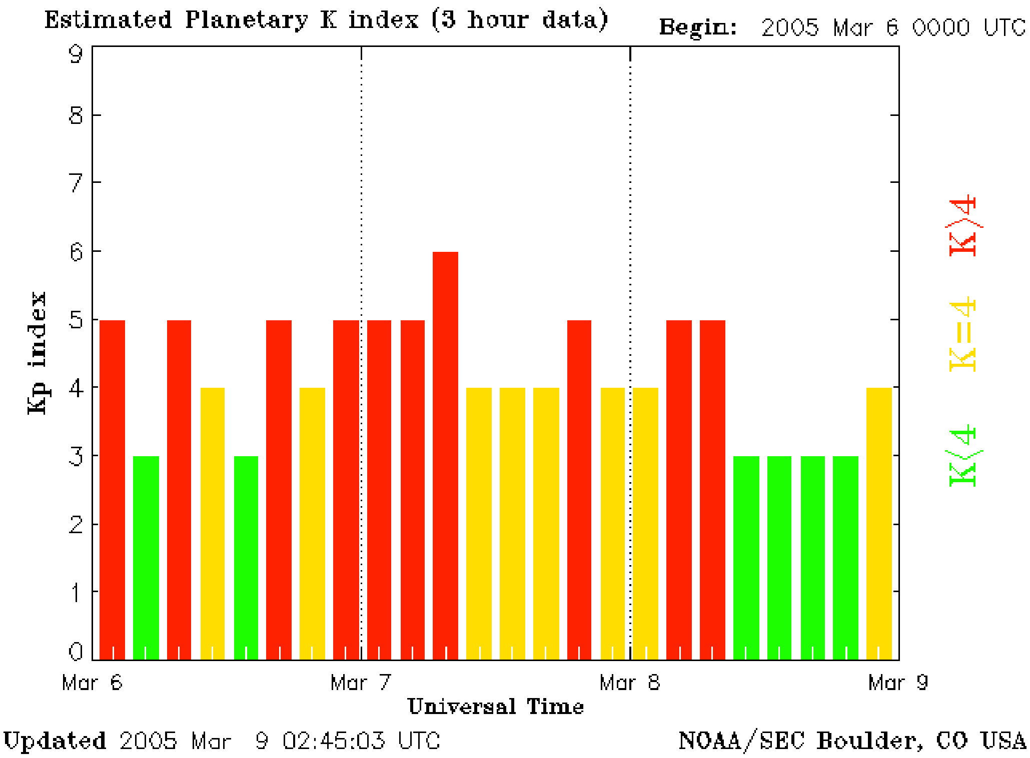


Figure 6-3 K-Index for 6-8 March 2005



Tables 6-1 and 6-2 below show the PDOP and position accuracy information, respectively, for the days corresponding to Figure 6-1. The GPS SPS performance met the availability requirements during all storms that occurred during this quarter.

Table 6-1 PDOP Statistics for 17 January 2005

Site	Min PDOP	Max PDOP	Mean PDOP	99.99% PDOP	99.99% VDOP
Bangor	1.600	5.965	2.495	5.965	5.713
Mauna Loa	1.239	4.193	1.723	4.193	4.031
Billings	1.196	2.942	1.736	2.942	2.399
Cold Bay	1.153	4.560	1.686	4.550	4.209
Juneau	1.253	3.584	1.733	3.580	3.098
Albuquerque	1.240	3.149	1.716	3.147	2.432
Anchorage	1.188	3.420	1.735	3.419	3.187
Boston	1.197	3.318	1.704	3.318	2.761
Washington, D.C.	1.208	3.318	1.703	3.311	2.855
Honolulu	1.235	2.934	1.675	2.934	2.643
Houston	1.185	2.928	1.710	2.928	2.352
Kansas City	1.199	3.074	1.745	3.074	2.487
Los Angeles	1.184	2.847	1.734	2.846	2.420
Salt Lake City	1.202	2.977	1.726	2.976	2.463
Miami	1.212	3.231	1.736	3.230	2.968
Minneapolis	1.199	2.976	1.717	2.974	2.577
Oakland	1.176	2.844	1.718	2.844	2.492
Cleveland	1.241	3.354	1.670	2.552	2.208
Seattle	1.220	2.926	1.715	2.926	2.456
San Juan	1.259	3.260	1.714	3.260	3.098
Atlanta	1.236	3.646	1.736	3.638	3.170

Table 6-2 Horizontal & Vertical Accuracy Statistics for 17 January 2005

Site	95% Horizontal (Meters)	95% Vertical (Meters)	99.99% Horizontal (Meters)	99.99% Vertical (Meters)
Bangor	3.514	8.207	9.035	14.822
Mauna Loa	6.946	6.465	7.950	9.020
Billings	2.383	7.964	3.195	11.741
Cold Bay	2.034	7.170	4.127	11.695
Juneau	2.213	9.099	3.182	10.952
Albuquerque	3.024	6.273	4.485	9.285
Anchorage	2.375	8.634	3.952	11.848
Boston	2.836	6.720	3.584	8.478
Washington, D.C.	2.698	6.946	3.199	8.292
Honolulu	5.866	5.798	7.436	7.497
Houston	3.079	6.616	4.318	9.171
Kansas City	2.681	7.765	4.264	11.299
Los Angeles	4.044	4.967	5.078	7.364
Salt Lake City	3.153	6.960	4.114	9.484
Miami	2.608	6.043	4.267	9.630
Minneapolis	2.420	8.589	4.063	10.164
Oakland	4.279	6.151	5.136	9.084
Cleveland	2.841	3.790	3.407	5.097
Seattle	2.571	6.905	3.695	9.099
San Juan	2.600	4.474	4.369	12.734
Atlanta	3.304	7.782	4.600	10.177

APPENDICES A – D

Conditions and Constraints	*Coverage Standard*	*Measured Performance*
• Probability of 4 or more satellites in view over any 24 hour interval, averaged over the globe • 4 satellites must provide PDOP of 6 or less • 5° mask angle with no obscura • Standard is predicated on 24 operational satellites, as the constellation is defined in the almanac	≥ 99.9% global average	99.997%
• 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	99.306% Availability 99.9% PDOP was 3.29427
Conditions and Constraints	***Satellite Availability Standard***	***Measured Performance***
• Conditioned on coverage standard • Standard based on a typical 24 hour interval, averaged over the globe • Typical 24 hour interval defined using averaging period of 30 days	≥ 99.85% global average	100%
• 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	100%
• Conditioned on coverage standard • Standard represents a worst-case 24 hour interval, averaged over the globe	≥ 95.87% global average on worst-case day	100%
• 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	100%
Conditions and Constraints	***Service Reliability Standard***	***Measured Performance***
• Conditioned on coverage and service avail. standards • 500 meter NTE predictable horizontal error reliability threshold • Standard based on a measurement interval of one year; average of daily values over the globe • Standard predicated on a maximum of 18 hours of major service failure behavior over the sample interval	≥ 99.97% global average	100%
• Conditioned on coverage and service availability standards • 500 meter Not-to-Exceed (NTE) predictable horizontal error reliability threshold • Standard based on a measurement interval of one year; average of daily values from the worst-case point on the globe • Standard based on a maximum of 18 hours of major service failure behavior over the sample interval	≥ 99.79% single point average	100%

Conditions and Constraints	***Accuracy Standard***	***Measured Performance***
• Conditioned on coverage, service availability and service reliability standards • Standard based on a measurement interval of 24 hours, for any point on the globe	Predictable Accuracy ≤ 100 m horz. error 95% of time ≤ 156 m vert. error 95% of time ≤ 300 m horz. error 99.99% of time ≤ 500 m vert. error 99.99% of time	≤6.948m HE 95% ≤12.551m HE 99.99% ≤6.328m VE 95% ≤18.342m VE 99.99%
• Conditioned on coverage, service availability and service reliability standards • Standard based on a measurement interval of 24 hours, for any point on the globe	Repeatable Accuracy ≤ 141 m horz. error 95% of time ≤ 221 m vert. error 95% of time	≤1.590m HE 95% ≤3.823m VE 95%
• Conditioned on coverage, service availability and service reliability standards • Standard based on a measurement interval of 24 hours, for any point on the globe • Standard presumes that the receivers base their position solutions on the same satellites, with position solutions computed at approximately the same time	Relative Accuracy ≤ 1.0 m horz. error 95% of time ≤ 1.5 m vert. error 95% of time	Future Reports
• Conditioned on coverage, service availability and service reliability standards • Standard based upon SPS receiver time as computed using the output of the position solution • Standard based on a measurement interval of 24 hours, for any point on the globe • Standard is defined with respect to Universal Coordinated Time, as it is maintained by the United States Naval Observatory	Time Transfer Accuracy ≤ 340 nanoseconds time transfer error 95% of time	≤17 ns 95% of the time
• Conditioned on satellite indicating healthy status • Standard based on a measurement interval of 24 hours, for any point on the globe • Standard restricted to range domain errors allocated to space/control segments • Standards are not constellation values -- each satellite is required to meet the standards • Assessment requires minimum of four hours of data over the 24 hour period for a satellite in order to evaluate that satellite against the standard	Range Domain Accuracy ≤ 150 m NTE range error ≤ 2 m/s NTE range rate error ≤ 19 mm/s^2 NTE range acceleration error ≤ 8 mm/s^2 range acceleration error 95% of time	28.801m NTE Range Error 1.12424m/s NTE Rate Error 11.23mm/s^2 NTE Accl. Error ≤8mm/s^2 99.999% of the time

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#  Prepared by the U.S. Dept. of Commerce, NOAA, Space Environment Center.
#  Please send comment and suggestions to SEC.Webmaster@noaa.gov
#
#              Current Quarter Daily Geomagnetic Data
#
```

	Middle Latitude		High Latitude		Estimated	
	- Fredericksburg -		---- College ----		--- Planetary ---	
Date	A	K-indices	A	K-indices	A	K-indices
2005 01 01	10	1 3 2 2 2 2 3 3	34	4 5 3 4 5 3 6 3	15	1 4 3 2 3 3 4 3
2005 01 02	20	3 3 3 3 2 4 3 5	64	2 3 7 6 5 7 4 5	33	4 4 5 4 3 5 3 5
2005 01 03	14	3 3 2 3 4 3 2 2	44	3 3 6 6 6 5 4 2	22	4 4 3 3 5 4 3 2
2005 01 04	16	4 4 2 3 3 3 2 3	41	3 3 4 5 6 6 5 3	23	4 4 3 4 4 4 3 3
2005 01 05	11	4 3 2 3 2 2 1 1	26	3 2 5 6 4 3 3 1	21	5 4 5 4 3 3 1 2
2005 01 06	4	1 0 0 0 2 1 3 1	18	1 4 0 3 4 4 3 4	4	2 0 0 0 0 1 3 1
2005 01 07	21	0 0 0 1 4 4 4 6	70	4 5 0 4 8 7 4 5	37	1 0 0 1 6 6 4 7
2005 01 08	20	5 5 3 3 3 2 2 2	34	6 5 3 6 4 1 2 3	30	6 6 3 4 3 3 2 2
2005 01 09	3	1 1 0 3 0 1 1 0	3	1 2 0 1 0 0 2 0	4	1 1 0 3 1 1 1 1
2005 01 10	4	0 1 1 1 2 1 1 2	5	0 1 1 1 2 2 2 2	6	1 1 1 1 2 2 2 2
2005 01 11	9	1 3 3 2 1 3 2 2	22	1 4 5 3 3 5 2 3	14	1 4 4 2 2 3 2 3
2005 01 12	18	3 4 3 3 4 3 3 3	47	3 4 3 7 6 5 4 4	30	4 5 3 5 5 3 3 3
2005 01 13	10	2 3 2 1 2 3 3 2	20	3 3 2 4 4 4 3 4	13	2 4 2 2 3 3 3 3
2005 01 14	11	2 2 2 1 1 1 4 4	9	4 2 2 1 1 1 2 3	12	2 2 2 1 1 1 4 4
2005 01 15	11	2 3 3 2 3 3 2 2	29	4 4 6 5 3 3 3 1	22	3 6 4 3 3 3 3 2
2005 01 16	10	2 1 2 2 3 3 2 3	16	1 2 3 5 4 3 2 2	12	2 2 2 2 3 3 2 3
2005 01 17	27	3 2 2 5 5 5 4 3	114	4 4 4 8 8 8 6 4	63	5 4 3 7 7 7 5 3
2005 01 18	35	6 4 5 4 4 4 3 4	136	6 5 8 7 8 8 5 5	72	6 5 7 5 6 6 4 5
2005 01 19	31	5 5 5 4 5 2 2 3	106	4 4 7 9 7 6 2 4	62	6 6 6 7 6 4 3 4
2005 01 20	10	0 1 1 2 4 4 2 2	24	2 2 1 2 5 6 3 4	12	2 1 1 2 4 4 3 3
2005 01 21	30	3 1 2 1 2 6 6 5	92	2 2 4 5 4 8 8 7	61	3 1 3 2 2 8 8 6
2005 01 22	23	5 6 2 2 2 2 3 3	41	5 5 5 5 5 5 4 3	28	5 6 3 3 3 3 4 3
2005 01 23	12	4 3 2 2 2 3 2 2	24	3 2 4 4 5 5 3 2	17	4 4 3 3 3 4 3 2
2005 01 24	5	2 1 1 2 2 2 1 1	12	3 1 2 3 4 3 2 1	6	2 1 1 2 2 2 2 1
2005 01 25	2	1 0 1 0 1 1 1 1	9	1 0 0 4 2 2 3 3	4	1 0 1 1 1 1 2 1
2005 01 26	0	0 0 0 0 0 0 0 0	1	0 0 0 1 1 0 0 0	4	1 1 0 1 1 1 1 1
2005 01 27	2	0 0 0 0 0 2 1 2	0	0 0 0 1 0 0 0 0	3	0 0 0 0 1 2 1 1
2005 01 28	5	2 1 0 0 1 1 2 3	3	0 0 0 1 0 1 2 2	6	2 2 1 0 1 1 3 2
2005 01 29	16	2 2 3 4 3 3 3 4	26	2 1 3 5 5 5 4 3	20	3 2 3 4 3 3 4 4
2005 01 30	10	2 3 2 4 2 2 1 2	23	3 2 2 6 5 3 2 2	16	3 4 3 4 3 2 2 2
2005 01 31	15	3 2 3 4 4 3 2 1	43	2 2 3 6 7 6 3 1	19	3 2 3 4 5 4 3 1
2005 02 01	4	3 0 1 1 1 1 1 1	6	2 0 0 3 3 2 0 1	6	3 0 1 2 1 2 2 2
2005 02 02	7	1 2 2 2 1 2 3 1	8	0 0 3 3 2 3 2 1	8	1 1 3 2 2 2 3 1
2005 02 03	5	1 3 2 1 1 1 1 0	9	0 4 4 3 1 0 1 0	8	1 4 3 1 1 2 1 1
2005 02 04	2	0 0 0 1 1 1 1 0	2	0 0 0 2 2 1 0 0	3	0 0 0 1 2 1 1 1
2005 02 05	1	0 0 1 0 1 0 0 0	0	0 0 0 0 1 0 0 0	4	1 1 1 0 1 0 1 1
2005 02 06	6	0 2 3 1 1 1 2 2	8	0 2 4 2 0 2 2 2	9	2 2 4 1 1 1 2 3
2005 02 07	19	2 2 2 2 3 3 5 5	50	2 2 2 5 7 6 6 4	23	3 3 2 3 5 4 5 5
2005 02 08	27	5 6 3 2 2 3 3 4	71	4 5 3 5 6 6 8 4	34	4 6 4 3 4 4 4 4
2005 02 09	14	2 3 4 3 3 2 2 3	45	3 3 6 6 6 5 4 3	25	3 4 5 4 4 3 3 3
2005 02 10	11	3 3 2 2 3 2 3 1	29	3 4 5 5 5 4 3 2	17	4 4 3 3 4 2 3 2
2005 02 11	7	2 3 2 2 1 1 2 2	19	1 2 3 6 4 2 2 2	11	2 3 3 3 2 1 3 2
2005 02 12	3	2 2 1 0 1 0 2 0	3	2 1 1 0 1 0 1 1	5	2 2 1 1 1 1 2 0
2005 02 13	2	2 1 1 1 0 0 1 0	3	1 2 0 2 1 0 1 1	4	1 1 1 1 0 1 2 1
2005 02 14	4	0 2 1 0 2 1 2 2	4	0 1 1 2 2 0 2 1	5	0 2 1 1 1 1 2 2
2005 02 15	1	0 1 1 0 0 0 0 0	2	1 0 1 0 0 0 1 2	5	1 1 2 0 1 1 2 2
2005 02 16	8	3 1 1 2 3 2 2 2	29	2 1 2 5 6 5 4 3	13	2 1 2 4 4 3 3 3
2005 02 17	7	2 2 0 1 1 1 1 4	7	2 1 0 3 3 2 0 2	6	1 2 0 1 2 2 2 3

2005 02 18	14	4 3 3 2 3 3 2 2	37	4 4 5 6 5 5 2 2	25	5 4 4 3 4 4 3 2
2005 02 19	8	1 1 3 3 2 2 2 2	40	3 5 5 6 6 4 3 1	14	1 2 3 4 4 3 3 2
2005 02 20	6	3 2 2 0 1 1 2 2	16	4 3 3 1 3 4 3 2	12	4 3 3 0 2 3 2 2
2005 02 21	4	3 2 2 0 1 0 0 1	18	2 3 3 4 4 2 4 3	8	3 3 1 2 1 2 1 2
2005 02 22	3	1 1 0 0 1 1 2 2	2	0 0 0 0 0 2 2 1	4	1 1 0 0 1 2 2 1
2005 02 23	2	1 0 1 1 1 0 1 1	1	0 0 1 0 0 0 0 1	4	1 1 2 1 1 2 1 1
2005 02 24	4	0 1 1 1 3 1 1 1	8	0 0 0 1 5 1 2 1	5	0 0 1 1 3 1 2 2
2005 02 25	9	1 1 2 2 3 3 3 2	12	0 0 2 3 3 4 4 1	9	1 1 2 2 2 3 3 2
2005 02 26	9	2 2 2 2 3 3 2 1	18	1 1 2 4 5 5 2 1	9	2 2 2 3 3 3 2 2
2005 02 27	6	0 2 2 1 3 2 1 1	9	0 1 2 2 5 1 1 1	8	0 2 3 1 3 2 2 1
2005 02 28	8	1 2 3 2 2 2 1 3	15	1 1 4 5 3 2 2 2	12	1 3 3 3 3 3 1 4
2005 03 01	10	2 2 3 3 2 2 2 3	16	2 1 3 6 2 1 2 2	11	2 1 3 3 2 2 2 4
2005 03 02	8	2 3 2 2 2 3 1 0	21	2 3 5 5 4 4 0 1	12	3 3 3 3 3 3 1 1
2005 03 03	2	1 1 1 0 1 1 1 0	3	1 1 1 0 2 1 1 1	4	1 1 0 1 1 2 2 1
2005 03 04	1	0 0 0 0 0 0 1 1	0	1 0 0 0 0 0 0 0	3	1 0 0 0 1 1 1 0
2005 03 05	8	2 3 2 1 1 1 2 3	19	1 4 4 3 4 4 2 3	10	1 3 2 2 2 2 3 3
2005 03 06	17	4 2 3 3 3 3 3 4	60	3 3 5 7 5 7 5 4	36	5 3 5 4 3 5 4 5
2005 03 07	28	5 4 5 3 4 2 4 4	63	5 3 5 7 6 6 6 3	42	5 5 6 4 4 4 5 4
2005 03 08	17	4 4 3 2 2 2 3 4	45	4 5 6 6 4 4 4 5	26	4 5 5 3 3 3 3 4
2005 03 09	13	2 4 3 2 2 2 3 3	31	2 4 5 5 5 4 4 3	20	3 4 4 3 3 3 4 4
2005 03 10	10	3 2 3 2 2 3 2 1	28	3 4 5 4 5 5 1 1	13	3 3 3 3 3 3 2 1
2005 03 11	3	2 2 1 0 1 0 0 1	8	3 2 3 3 2 0 0 1	6	2 2 2 1 2 1 1 1
2005 03 12	2	1 1 1 0 1 0 1 1	2	1 1 1 1 1 0 0 0	4	1 1 1 0 1 1 2 1
2005 03 13	4	0 0 0 0 1 1 2 3	5	1 3 0 2 1 0 1 2	6	1 0 0 1 2 2 2 3
2005 03 14	12	4 3 2 3 3 2 2 1	30	3 5 4 5 6 3 2 1	21	4 4 3 4 5 3 2 2
2005 03 15	3	1 1 1 0 1 1 1 1	2	1 1 1 0 1 0 0 1	4	2 1 1 1 1 1 1 1
2005 03 16	4	1 0 0 1 3 2 1 1	6	0 0 0 1 4 3 1 1	6	0 0 1 1 3 2 2 2
2005 03 17	8	2 2 2 2 2 3 2 1	25	3 4 4 6 3 4 2 1	12	3 3 2 4 2 3 2 2
2005 03 18	6	0 1 2 2 0 1 3 3	9	1 1 1 4 1 2 3 2	9	1 1 2 3 1 3 3 3
2005 03 19	9	4 4 2 1 1 0 0 1	12	3 3 3 4 4 0 0 0	14	5 4 2 2 2 1 1 1
2005 03 20	4	0 3 1 1 1 0 1 1	5	0 0 1 3 3 1 1 0	5	1 2 1 2 2 1 1 1
2005 03 21	5	0 0 2 3 3 1 0 1	21	0 0 1 6 6 1 1 0	8	1 1 1 3 4 2 1 1
2005 03 22	2	1 0 0 0 1 1 1 2	0	0 0 0 0 0 0 0 0	3	0 0 1 0 1 1 1 2
2005 03 23	3	0 0 0 0 2 1 2 2	2	1 0 0 0 1 1 2 0	4	1 0 0 0 1 1 2 2
2005 03 24	4	0 1 0 0 3 2 1 1	5	0 0 0 3 3 2 1 1	6	0 1 1 1 3 2 2 2
2005 03 25	15	1 3 4 2 4 3 2 3	22	1 3 5 3 5 4 3 2	18	1 4 5 3 3 3 2 3
2005 03 26	12	1 4 3 3 3 2 2 1	43	2 2 6 7 6 3 2 2	16	2 4 4 4 3 2 2 2
2005 03 27	8	2 1 3 2 2 2 2 2	24	3 2 4 5 5 4 3 2	13	2 1 4 3 3 3 3 2
2005 03 28	2	1 2 1 0 0 0 1 1	1	1 1 1 0 0 0 0 0	4	1 2 1 0 1 1 2 2
2005 03 29	3	0 1 1 0 1 1 1 2	1	0 0 0 0 0 1 1 2	5	0 1 1 0 1 2 2 3
2005 03 30	6	2 2 3 1 2 1 0 1	15	2 2 4 5 3 3 0 0	9	2 3 4 2 1 2 1 1
2005 03 31	5	1 2 2 1 1 1 2 2	5	1 2 3 1 0 1 2 1	9	1 3 3 2 1 2 3 2

Background:

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

Problem Description:

There were no problems this quarter.

The terms and definitions discussed below are taken from the Standard Positioning Service Performance Specification (SPS) (June 2, 1995). An understanding of these terms and definitions is a necessary prerequisite to full understanding of the Signal Specification.

General Terms and Definitions

Block I and Block II Satellites. The Block I is a GPS concept validation satellite; it does not have all of the design features and capabilities of the production model GPS satellite, the Block II. The FOC 24 satellite constellation is defined to consist entirely of Block II/IIA satellites. For the purposes of this Signal Specification, the Block II satellite and a slightly modified version of the Block II known as the Block IIA provide an identical service.

Dilution of Precision (DOP). The magnifying effect on GPS position error induced by mapping GPS ranging errors into position through the position solution. The DOP may be represented in any user local coordinate desired. Examples are HDOP for local horizontal, VDOP for local vertical, PDOP for all three coordinates, and TDOP for time.

Geometric Range. The difference between the estimated locations of a GPS satellite and an SPS receiver.

Major Service Failure. A condition over a time interval during which one or more SPS performance standards are not met and the civil community was not warned in advance.

Minimum SPS Receiver Capabilities. Minimum standards for signal reception and processing capabilities that are incorporated into the design of an SPS receiver. This ensures consistent performance with the SPS performance standards.

Navigation Data. Data provided to the SPS receiver via each satellite's ranging signal, containing the ranging signal time of transmission, the transmitting satellite's orbital elements, an almanac containing abbreviated orbital element information to support satellite selection, ranging measurement correction information, and status flags.

Navigation Message. Message structure designed to carry navigation data.

Operational Satellite. A GPS satellite that is capable of, but may or may not be, transmitting a usable ranging signal. For the purposes of the SPS, any satellite contained within the transmitted navigation message almanac is considered to be an operational satellite.

Position Solution. The use of ranging signal measurements and navigation data from at least four satellites to solve for three position coordinates and a time offset.

Selective Availability. Protection technique employed by the DOD to deny full system accuracy to unauthorized users.

Service Disruption. A condition over a time interval during which one or more SPS performance standards are not supported, but the civil community was warned in advance.

SPS Performance Envelope. The range of variation in specified aspects of SPS performance.

SPS Performance Standard. A quantifiable minimum level for a specified aspect of GPS SPS performance.

Standard Positioning Service (SPS). Three-dimensional position and time determination capability provided to a user equipped with a minimum capability GPS SPS receiver in accordance with GPS national policy and the performance specifications.

SPS Ranging Signal Measurement. The difference between the ranging signal time of reception (as defined by the receiver's clock) and the time of transmission contained within the satellite's navigation data (as defined by the satellite's clock) multiplied by the speed of light. Also known as the *pseudo range*.

SPS Signal, or SPS Ranging Signal. An electromagnetic signal originating from an operational satellite. The SPS ranging signal consists of a Pseudo Random Noise (PRN) Coarse/Acquisition (C/A) code, a timing reference and sufficient data to support the position solution generation process.

Usable SPS Ranging Signal. An SPS ranging signal that can be received, processed and used in a position solution by a receiver with minimum SPS receiver capabilities.

Performance Parameter Definitions

The definitions provided below establish the basis for correct interpretation of the GPS SPS performance standards. The GPS performance parameters contained in the SPS are defined differently than other radio navigation systems in the Federal Radio Navigation Plan. For a more comprehensive treatment of these definitions and their implications on system use, refer to Annex B of the SPS.

Coverage. The percentage of time over a specified time interval that a sufficient number of satellites are above a specified mask angle and provide an acceptable position solution geometry at any point on or near the Earth. The term "near the Earth" means on or within approximately 200 kilometers of the Earth's surface.

Positioning Accuracy. Given reliable service, the percentage of time over a specified time interval that the difference between the measured and expected user position or time is within a specified tolerance at any point on or near the Earth. This general accuracy definition is further refined through the more specific definitions of four different aspects of positioning accuracy:

- **Predictable Accuracy.** Given reliable service, the percentage of time over a specified time interval that the difference between a position measurement and a surveyed benchmark is within a specified tolerance at any point on or near the Earth.

- **Repeatable Accuracy.** Given reliable service, the percentage of time over a specified time interval that the difference between a position measurement taken at one time and a position measurement taken at another time at the same location is within a specified tolerance at any point on or near the Earth.

- **Relative Accuracy.** Given reliable service, the percentage of time over a specified time interval that the difference between two receivers' position estimates taken at the same time is within a specified tolerance at any point on or near the Earth.

- **Time Transfer Accuracy.** Given reliable service, the percentage of time over a specified time interval that the difference between a Universal Coordinated Time (commonly referred to as UTC) time estimate from the position solution and UTC as it is managed by the United States Naval Observatory (USNO) is within a specified tolerance.

Range Domain Accuracy. Range domain accuracy deals with the performance of each satellite's SPS ranging signal. Range domain accuracy is defined in terms of three different aspects:

- **Range Error.** Given reliable service, the percentage of time over a specified time interval that the difference between an SPS ranging signal measurement and the "true" range between the satellite and an SPS user is within a specified tolerance at any point on or near the Earth.

- **Range Rate Error.** Given reliable service, the percentage of time over a specified time interval that the instantaneous rate-of-change of range error is within a specified tolerance at any point on or near the Earth.

- **Range Acceleration Error.** Given reliable service, the percentage of time over a specified time interval that the instantaneous rate-of-change of range rate error is within a specified tolerance at any point on or near the Earth.

Service Availability. Given coverage, the percentage of time over a specified time interval that a sufficient number of satellites are transmitting a usable ranging signal within view of any point on or near the Earth.

Service Reliability. Given service availability, the percentage of time over a specified time interval that the instantaneous predictable horizontal error is maintained within a specified reliability threshold at any point on or near the Earth. Note that service reliability does not take into consideration the reliability characteristics of the SPS receiver or possible signal interference. Service reliability may be used to measure the total number of major failure hours experienced by the satellite constellation over a specified time interval.