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

**Submitted To**

**Federal Aviation Administration**
**GPS Product Team**

**1284 Maryland Avenue SW**
**Washington, DC 20024**

**Report #56**
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**Reporting Period: 1 October – 31 December 2006**

**Submitted by**

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# EXECUTIVE SUMMARY


The GPS Product Team has tasked the Navigation Branch at the William J. Hughes Technical Center to document the 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-four 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 (October 2001).

This report, Report #56, includes data collected from 1 October through 31 December 2006. The next quarterly report will be issued 30 April 2007.

Analysis of this data includes the following standards and categories: PDOP Availability, NANU Summary and Evaluation, Service Availability, Service Reliability, Position and Range Accuracy and Solar Storm Effects on GPS SPS performance.

PDOP availability is 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 global availability based on PDOP less than six for the CONUS was 99.996% or better.

NANU summary and evaluation was achieved by reviewing the “Notice: Advisory to Navstar Users” (NANU) reports issued between 1 October and 31 December 2006. Using this data, we compute a set of statistics that give a relative idea of constellation health for the both the current and a combined history of past quarters. A total of twenty-two outages were reported in the NANU’s this quarter. Eighteen outages were scheduled while four were unscheduled.

The quarterly service availability standard was verified using 24-hour position accuracy values computed from data collected at one-second intervals. All of the sites achieved a 100% availability which exceeds the SPS “average location” value of 99% and the “worst-case location” value of 90%.

Accuracy standards were verified by calculating the 24-hour 95% horizontal and vertical position error values. The User Range Error and Service Reliability standards were verified for each satellite from 24-hour accuracy values computed using data collected at the following six sites: Boston, Honolulu, Los Angeles, Miami, San Juan and Juneau. This data was also collected in one-second samples. All of the satellites met the URE and service reliability specifications. The maximum range error recorded was 26.651 meters on Satellite PRN 7. The SPS specification states that the range error should never exceed 30 meters. The maximum 24-hour RMS range error value of 2.515 was recorded on satellite 10. The SPS specification states that RMS URE cannot exceed 6 meters in any 24-hour interval.

Geomagnetic storms had little to no effect on GPS performance this quarter. All sites met all GPS Standard Positioning Service (SPS) specifications on those days with the most significant solar activity.

From the analysis performed on data collected between 1 October and 31 December 2006, 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-four WAAS reference station locations:

- Bethel, AK
- Billings, MT
- Fairbanks, AK
- Cold Bay, AK
- Kotzebue, 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

The analysis of the data is divided into the four performance categories stated in the Standard Positioning Service Performance Specification (October 2001). These categories are:

- PDOP Availability Standard
- Service Availability Standard
- 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.

### 1.3 Report Overview

Section 2 of this report summarizes the results obtained from the coverage calculation program called SPS_CoverageArea developed by the GPS test team. 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 constellation 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 evaluates the Service Availability Standard using 24-hour 95% horizontal and vertical position accuracy values.

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 on a measurement interval of one year. Data for the quarter is provided for completeness.

Section 5 provides the position 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 (October 2001).

**Table 1-1 SPS Performance Requirements**

| **PDOP Availability Standard** | **Conditions and Constraints** | **Evaluated in This Report** |
|---|---|---|
| ≥ 98% global Position Dilution of Precision (PDOP) of 6 or less<br><br>≥ 88% worst site PDOP of 6 or less | • Defined for position solution meeting the representative user conditions and operating within the service volume over any 24-hour interval.<br>• Based on using only satellites transmitting standard code and indicating “health” in the broadcast navigation message (sub-frame 1). | ✓ |
| **Service Availability Standard** | **Conditions and Constraints** | |
| ≥ 99% Horizontal Service Availability average location<br><br>≥ 99% Vertical Service Availability average location | • 36 meter horizontal (SIS only) 95% threshold.<br>• 77 meter vertical (SIS only) 95% threshold.<br>• Defined for position solution meeting the representative user conditions and operating within the service volume over any 24-hour interval. | ✓ |
| ≥ 95.87% global average on worst-case day | • Based on using only satellites transmitting standard code and indicating “healthy” in the broadcast navigation message (sub-frame 1). | ✓ |
| **Service Reliability Standard** | **Conditions and Constraints** | |
| ≥ 99.94% global average | • 30-meter Not-to-Exceed (NTE) SPS SIS URE.<br>• Standard based on a measurement interval of one year; average of daily values within the service volume.<br>• Standard based on 3 service failures per year, lasting no more than 6 hours each. | ✓ |
| ≥ 99.79% single point average | • 30-meter Not-to-Exceed (NTE) SPS SIS URE.<br>• Standard based on a measurement interval of one year; average of daily values from the worst-case point within the service volume.<br>• Standard based on 3 service failures per year, lasting no more than 6 hours each. | ✓ |

| **Accuracy Standard** | **Conditions and Constraints** | |
|---|---|---|
| Global Average Positioning Domain Accuracy<br>• ≤ 13 meters 95% All-in-View horizontal error (SIS only)<br>• ≤ 22 meters 95% All-in-View vertical error (SIS only) | • Defined for position solution meeting the representative user conditions.<br>• Standard based on a measurement interval of 24 hours averaged over all points within the service volume. | ✓ |
| Worst Site Positioning Domain Accuracy<br>• ≤ 36 meters 95% All-in-View Horizontal Error (SIS only)<br>• ≤ 77 meters 95% All-in-View Vertical Error (SIS only) | • Defined for position solution meeting the representative user conditions.<br>• Standard based on a measurement interval of 24 hours for any point within the service volume. | ✓ |
| Time Transfer Accuracy<br>• ≤ 40 nanoseconds time transfer error 95% of time (SIS only) | • Defined for time transfer solution meeting the representative user conditions.<br>• Standard based on a measurement interval of 24 hours averaged over all points within the service volume. | ✓ |
| **SPS SIS URE STANDARD** | **Conditions and Constraints** | |
| ≤ 6 meters RMS SIS SPS URE across the entire constellation | • Average of the constellation's individual satellite SPS SIS RMS URE values over any 24-hours interval, for any point thing the service volume. | ✓ |

# 2.0 PDOP Availability Standard

***PDOP Availability:*** *The percentage of time over any 24-hour interval that the PDOP value is less than or equal to its threshold for any point within the service volume.*

***Dilution of Precision (DOP):*** *The magnifying effect on GPS position error induced by mapping GPS ranging errors into position within the specified coordinate system through the geometry of the position solution. The DOP varies as a function of satellite positions relative to user position. 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. .*

| PDOP Availability Standard | Conditions and Constraints |
|---|---|
| ≥ 98% global Position Dilution of Precision (PDOP) of 6 or less<br><br>≥ 88% worst site PDOP of 6 or less | • Defined for position solution meeting the representative user conditions and operating within the service volume over any 24-hour interval.<br>• Based on using only satellites transmitting standard code and indicating "health" in the broadcast navigation message (sub-frame 1). |

Almanacs for GPS weeks 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 the GPS test team was used to calculate the PDOP at every 5$^{o}$ point between longitudes of 180W to 180E and 80S and 80N at one-minute intervals. This gives a total of 1440 samples for each of the 2376 grid points in the coverage area. Table 2-1 provides the global averages and worst-case availability over a 24-hour period for each week. Table 2-1 also gives the global 99.9% PDOP value for each of the thirteen GPS Weeks. The PDOP was 3.1445 or better 99.9% of the time for each of the 24-hour intervals.

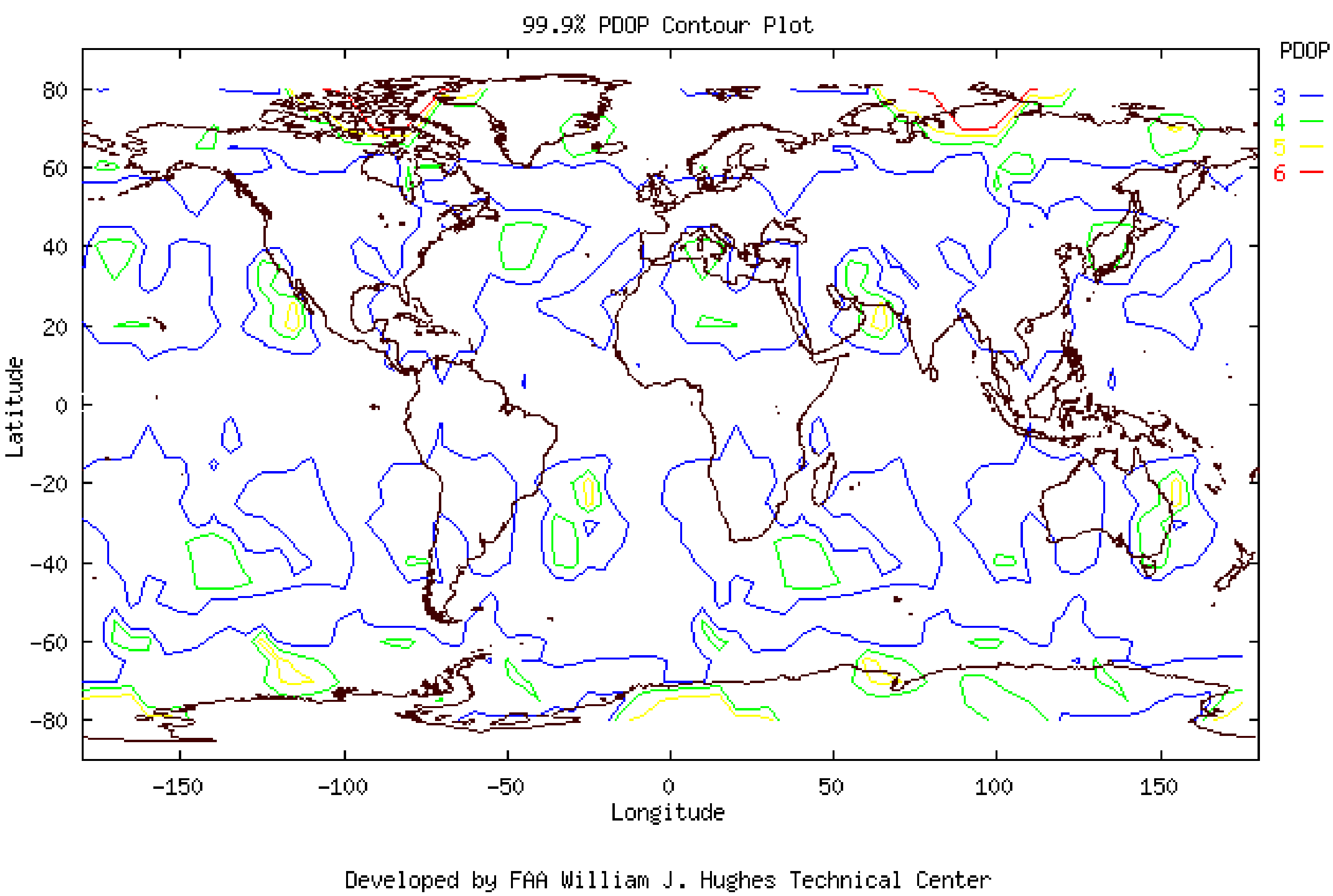
Figure 2-1 is a contour plot of PDOP values over the entire globe. Inside each contour area, the PDOP value is greater than or equal to the contour value shown in the legend for that color line. That areas' value is also less than the next higher contour value, unless another contour line lies within the current area. A single "DOP hole" where the PDOP value is greater than 6 was evaluated for satellite visibility for one 24-hour interval from the week shaded in Table 2-1. The histogram in figure 2-2 shows the satellite visibility at the DOP hole position for the 24 hour interval in question.

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

**Table 2-1 PDOP Availability Statistics**

| Date Range of Week | Global 99.9% PDOP Value* | Global Average* (Spec: ≥ 98%) | Worst-Case Point (Spec: ≥ 88%) |
|---|---|---|---|
| | | | |
| 1-7 Oct | 3.1371 | 99.996 | 99.583 |
| 8-14 Oct | 3.1445 | 99.997 | 99.722 |
| 15-21 Oct | 3.0742 | 100 | 99.792 |
| 22-28 Oct | 3.0727 | 100 | 99.792 |
| 29 Oct – 4 Nov | 3.0601 | 100 | 99.861 |
| 5-11 Nov | 3.0638 | 100 | 100 |
| 12-18 Nov | 3.0743 | 100 | 100 |
| 19-25 Nov | 3.0763 | 100 | 100 |
| 26 Nov – 2 Dec | 3.0843 | 100 | 100 |
| 3-9 Dec | 3.0668 | 100 | 100 |
| 10-16 Dec | 3.0458 | 100 | 100 |
| 17-23 Dec | 2.9994 | 100 | 100 |
| 24-31 Dec | 3.0078 | 100 | 100 |

Figure 2-1 PDOP Availability Plot (24-Hour Period: 2 October 2006)



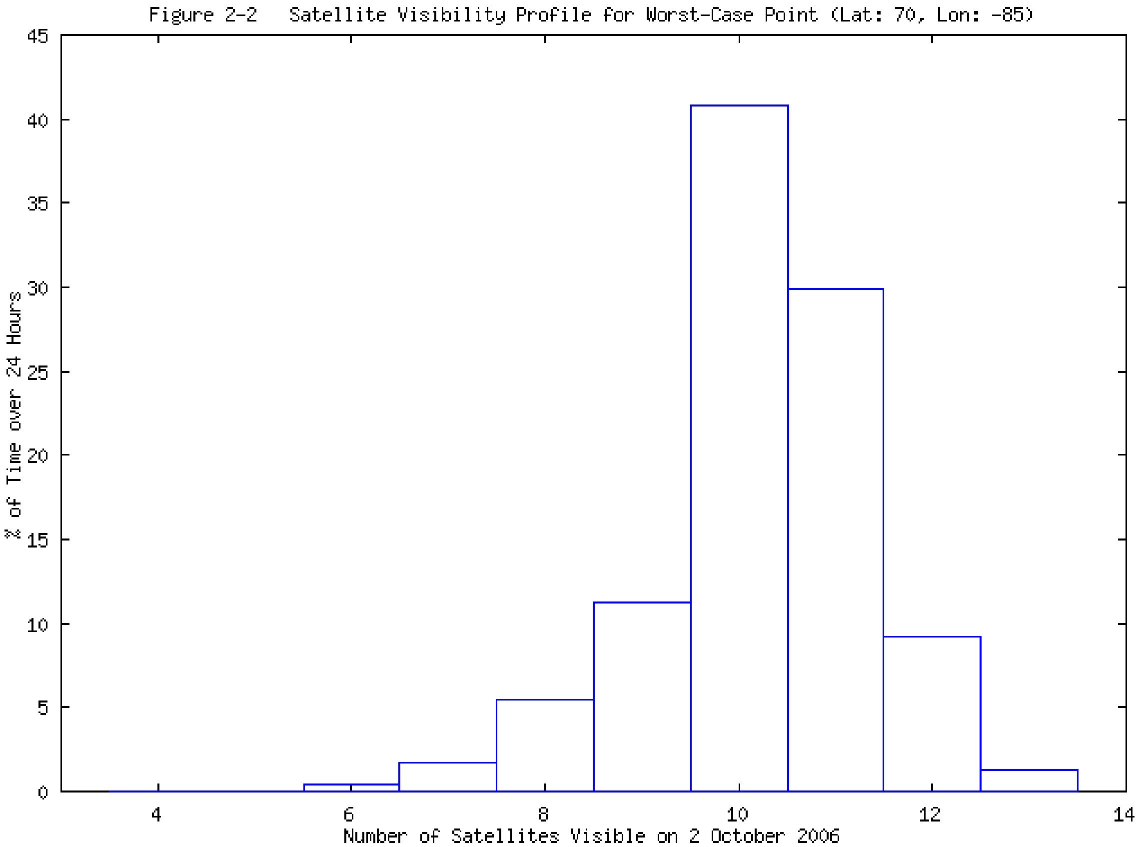


Figure 2-2 Satellite Visibility Profile for Worst-Case Point (Lat: 70, Lon: -85)
% of Time over 24 Hours
Number of Satellites Visible on 2 October 2006
0
5
10
15
20
25
30
35
40
45
4
6
8
10
12
14

# 3.0 NANU Summary and Evaluation

***NANU:*** Notice Advisory to NAVSTAR Users - a periodic bulletin alerting users to changes in the satellite system performance.

## 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 October through 31 December 2006, there were a total of twelve reported outages. Eight of these outages were maintenance activities and were reported in advance. Four were unscheduled outages. 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 |
|---|---|---|---|---|---|---|---|---|---|
| 99 | 9 | FCSTSUMM | 02-Oct | 15:53 | 03-Oct | 05:21 | | 13.47 | 13.47 |
| 105 | 29 | FCSTSUMM | 10-Oct | 03:33 | 10-Oct | 04:47 | | 1.23 | 1.23 |
| 106 | 24 | FCSTSUMM | 10-Oct | 22:15 | 10-Oct | 23:22 | | 1.12 | 1.12 |
| 108 | 24 | FCSTSUMM | 12-Oct | 08:30 | 12-Oct | 11:09 | | 4.38 | 4.38 |
| 110 | 27 | FCSTSUMM | 12-Oct | 16:23 | 12-Oct | 17:06 | | 0.72 | 0.72 |
| 117 | 16 | FCSTSUMM | 19-Oct | 12:08 | 19-Oct | 14:15 | | 2.12 | 2.12 |
| 119 | 3 | FCSTSUMM | 20-Oct | 07:12 | 20-Oct | 09:10 | | 1.97 | 1.97 |
| 122 | 7 | FCSTSUMM | 23-Oct | 22:32 | 24-Oct | 18:03 | | 19.52 | 19.52 |
| 123 | 16 | FCSTSUMM | 25-Oct | 13:23 | 25-Oct | 18:42 | | 5.32 | 5.32 |
| 132 | 20 | FCSTSUMM | 04-Nov | 06:02 | 04-Nov | 10:59 | | 4.95 | 4.95 |
| 135 | 7 | UNUSABLE | 04-Nov | 15:32 | 04-Nov | 21:07 | 5.58 | | 5.58 |
| 140 | 29 | FCSTSUMM | 08-Nov | 19:18 | 08-Nov | 21:06 | | 1.80 | 1.80 |
| 141 | 26 | FCSTSUMM | 09-Nov | 04:23 | 09-Nov | 11:37 | | 7.23 | 7.23 |
| 143 | 26 | FCSTSUMM | 11-Nov | 02:38 | 11-Nov | 16:03 | | 13.42 | 13.42 |
| 144 | 11 | FCSTSUMM | 12-Nov | 15:45 | 13-Nov | 01:08 | | 9.38 | 9.38 |
| 145 | 5 | UNUSABLE | 07-Nov | 01:35 | 13-Nov | 23:25 | 165.83 | | 165.83 |
| 149 | 15 | UNUSABLE | 01-Oct | 00:00 | 17-Nov | 22:15 | 1150.25 | | 1150.25 |
| 158 | 27 | FCSTSUMM | 08-Dec | 06:43 | 08-Dec | 13:05 | | 6.37 | 6.37 |
| 163 | 5 | FCSTSUMM | 15-Dec | 21:27 | 16-Dec | 05:53 | | 8.43 | 8.43 |
| 164 | 8 | FCSTSUMM | 19-Dec | 08:05 | 19-Dec | 12:13 | | 4.13 | 4.13 |
| 165 | 17 | FCSTSUMM | 20-Dec | 14:31 | 20-Dec | 16:07 | | 1.60 | 1.60 |
| 0706 | 3 | UNUSABLE | 27-Dec | 01:20 | 01-Jan | 00:00 | 118.67 | | 118.67 |
| **Total Actual Unscheduled and Scheduled Downtime and Total Actual Downtime** | | | | | | | **1440.33** | **107.16** | **1547.49** |

| | | Table 3-2 NANUs Forecasted to Affect Satellite Availability | | | | | | |
|---|---|---|---|---|---|---|---|---|
| NANU # | PRN | Type | Start Date | Start Time | End Date | End Time | Total | Comments |
| 98 | 9 | FCSTDV | 02-Oct | 15:30 | 03-Oct | 06:00 | 14.5 | See NANU 99 |
| 101 | 24 | FCSTMX | 10-Oct | 22:00 | 11-Oct | 00:00 | 2 | See NANU 106 |
| 102 | 24 | FCSTMX | 12-Oct | 06:45 | 12-Oct | 08:30 | 1.75 | See NANU 107 |
| 103 | 29 | FCSTMX | 10-Oct | 03:30 | 10-Oct | 05:30 | 2 | See NANU 105 |
| 104 | 27 | FCSTMX | 12-Oct | 16:15 | 12-Oct | 21:00 | 4.75 | See NANU 110 |
| 107 | 24 | FCSTEXTD | 12-Oct | 11:00 | N/A | N/A | N/A | See NANU 108 |
| 111 | 24 | FCSTMX | 17-Oct | 04:30 | 17-Oct | 08:30 | CANC | See NANU 115 |
| 113 | 16 | FCSTDV | 19-Oct | 11:30 | 19-Oct | 23:30 | 12 | See NANU 117 |
| 114 | 3 | FCSTMX | 20-Oct | 07:00 | 20-Oct | 11:00 | 4 | See NANU 119 |
| 116 | 4 | FCSTMX | 26-Oct | 14:15 | 26-Oct | 23:30 | CANC | See NANU 124 |
| 118 | 7 | FCSTDV | 23-Oct | 21:30 | 25-Oct | 04:30 | 31 | See NANU 122 |
| 120 | 16 | FCSTDV | 25-Oct | 11:00 | 25-Oct | 23:00 | 12 | See NANU 123 |
| 121 | 20 | FCSTMX | 27-Oct | 06:00 | 27-Oct | 14:30 | CANC | See NANU 125 |
| 126 | 20 | FCSTMX | 04-Nov | 05:30 | 04-Nov | 16:00 | 10.5 | See NANU 132 |
| 127 | 26 | FCSTMX | 06-Nov | 03:00 | 06-Nov | 20:00 | CANC | See NANU 136 |
| 128 | 26 | FCSTDV | 09-Nov | 13:00 | 10-Nov | 04:30 | RESCD | See NANU 131 |
| 129 | 29 | FCSTMX | 08-Nov | 19:00 | 08-Nov | 23:00 | 4 | See NANU 140 |
| 130 | 4 | FCSTMX | 13-Nov | 13:30 | 14-Nov | 01:30 | CANC | See NANU 142 |
| 131 | 26 | FCSTRESCD | 09-Nov | 04:00 | 09-Nov | 17:00 | 13 | See NANU 141 |
| 133 | 7 | UNUSUFN | 04-Nov | 15:32 | N/A | N/A | N/A | See NANU 135 |
| 137 | 26 | FCSTMX | 11-Nov | 02:00 | 11-Nov | 20:00 | 18 | See NANU 143 |
| 138 | 11 | FCSTMX | 12-Nov | 12:00 | 13-Nov | 12:00 | 24 | See NANU 144 |
| 139 | 5 | UNUSUFN | 07-Nov | 01:35 | N/A | N/A | N/A | See NANU 145 |
| 151 | 15 | UNUSUFN | 17-Nov | 22:15 | N/A | N/A | N/A | See NANU 150 |
| 152 | 27 | FCSTDV | 08-Dec | 06:30 | 08-Dec | 18:30 | 12 | See NANU 158 |
| 153 | 26 | FCSTMX | 08-Dec | 22:00 | 09-Dec | 10:00 | CANC | See NANU 156 |
| 154 | 19 | FCSTMX | 10-Dec | 10:00 | 10-Dec | 22:00 | CANC | See NANU 157 |
| 159 | 5 | FCSTDV | 15-Dec | 21:00 | 16-Dec | 09:00 | 12 | See NANU 163 |
| 160 | 8 | FCSTDV | 19-Dec | 07:00 | 19-Dec | 19:00 | 12 | See NANU 164 |
| 162 | 17 | FCSTDV | 20-Dec | 14:00 | 21-Dec | 06:00 | 16 | See NANU 165 |
| 166 | 3 | UNUSUFN | 27-Dec | 01:20 | N/A | N/A | N/A | See NANU 0706 |
| | | | | | | **Total Forecast Downtime** | **205.5** | |

| | Table 3-3 NANUs Canceled | | | | |
|---|---|---|---|---|---|
| NANU# | PRN | Type | Start Date | Start Time | Comments |
| 115 | 24 | FCSTCANC | 17-Oct | 04:30 | See Nanu 111 |
| 124 | 4 | FCSTCANC | 26-Oct | 14:15 | See Nanu 116 |
| 125 | 20 | FCSTCANC | 27-Oct | 06:00 | See Nanu 121 |
| 136 | 26 | FCSTCANC | 06-Nov | 03:00 | See Nanu 127 |
| 142 | 4 | FCSTCANC | 13-Nov | 13:30 | See Nanu 130 |
| 156 | 26 | FCSTCANC | 07-Dec | 22:32 | See Nanu 153 |
| 157 | 19 | FCSTCANC | 07-Dec | 22:36 | See Nanu 154 |

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 Oct - 31 Dec, 2006** | **1 October, 1999- 31 Dec. 2006** |
| Total Forecast Downtime (hrs): | 205.50 | 6105.48 |
| Total Actual Downtime (hrs): | 1547.49 | 22625.65 |
| Total Actual Scheduled Downtime (hrs): | 107.16 | 3305.57 |
| Total Actual Unscheduled Downtime (hrs): | 1440.33 | 19320.08 |
| Total Satellite Observed MTTR (hrs): | 70.34 | 48.14 |
| Scheduled Satellite Observed MTTR (hrs): | 5.95 | 9.90 |
| Unscheduled Satellite Observed MTTR (hrs): | 360.08 | 142.06 |
| # Total Satellite Outages: | 22 | 470 |
| # Scheduled Satellite Outages: | 18 | 334 |
| # Unscheduled Satellite Outages: | 4 | 136 |
| Percent Operational -- Scheduled Downtime: | 99.84 | 99.81 |
| Percent Operational -- All Downtime: | 99.91 | 98.70 |

Nanu 100 advised users that more than 30 PRNs will need to be processed
Nanu 109 corrects start time on Nanu 108 to 06:46
Nanu 112 is USABINIT for PRN 31
Nanu 134 corrects start time on Nanu 133 to 15:32
Nanu 146 informs users that only 30 PRNs will be used since PRN15 will be a test vehicle
Nanu 147 informs users of Launch of PRN 12
Nanu 148 informs users PRN15 was decomissioned
Nanu 150 informs users PRN 15 was set as a test vehicle
Nanu 155 informs users that SNV 23 using PRN 32 will be turned on about Jan 10
Nanu 161 is USABINIT for PRN 12

**Service Availability:** The percentage of time over any 24-hour interval that the predicted 95% positioning error is less than its threshold for any given point within the service volume.

• **Horizontal Service Availability:** The percentage of time over any 24-hour interval that the predicted 95% horizontal error is less than its threshold for any point within the service volume.
• **Vertical Service Availability:** The percentage of time over any 24-hour interval that the predicted 95% vertical error is less than its threshold for any point within the service volume.

| Service Availability Standard | Conditions and Constraints |
|---|---|
| ≥ 99% Horizontal Service Availability average location<br><br>≥ 99% Vertical Service Availability average location | • 36 meter horizontal (SIS only) 95% threshold.<br>• 77 meter vertical (SIS only) 95% threshold.<br>• Defined for position solution meeting the representative user conditions and operating within the service volume over any 24-hour interval. |
| ≥ 95.87% global average on worst-case day | • Based on using only satellites transmitting standard code and indicating "healthy" in the broadcast navigation message (sub-frame 1). |

To verify availability, the data collected from receivers at the twenty-four WAAS sites was reduced to calculate 24-hour accuracy information and reported in Table 3-5. The data was collected at one-second intervals between 1 October and 31 December 2006.

**Table 3-5 Accuracies Exceeding Threshold Statistics**

| Site | Total Number of Seconds of SPS Monitoring | Instances of 24-hour Threshold Failures | Quarters Service Availability % |
|---|---|---|---|
| **Billings** | 6321829 | 0 | 100% |
| **Albuquerque** | 7933886 | 0 | 100% |
| **Anchorage** | 7924553 | 0 | 100% |
| **Boston** | 7624856 | 0 | 100% |
| **Washington, DC** | 7941090 | 0 | 100% |
| **Honolulu** | 7568947 | 0 | 100% |
| **Houston** | 7938034 | 0 | 100% |
| **Kansas City** | 5713697 | 0 | 100% |
| **Los Angeles** | 6596012 | 0 | 100% |
| **Salt Lake City** | 7877428 | 0 | 100% |
| **Miami** | 7367797 | 0 | 100% |
| **Minneapolis** | 7303321 | 0 | 100% |
| **Oakland** | 7939889 | 0 | 100% |
| **Cleveland** | 6881610 | 0 | 100% |
| **Seattle** | 7938370 | 0 | 100% |
| **San Juan** | 7853767 | 0 | 100% |
| **Atlanta** | 7894541 | 0 | 100% |
| **Juneau** | 7170769 | 0 | 100% |
| **Cold Bay** | 7905432 | 0 | 100% |
| **Fairbanks** | 7785422 | 0 | 100% |
| **Bethel** | 7500626 | 0 | 100% |
| **Kotzebue** | 7777706 | 0 | 100% |
| **Global Average over Reporting Period = 100% (SPS Spec. > 95.87%)** | | | |

# 4.0 Service Reliability Standard

***Service Reliability:*** *The percentage of time over a specified time interval that the instantaneous SIS SPS URE is maintained within a specified reliability threshold at any given point within the service volume, for all healthy GPS satellites.*

| Service Reliability Standard | Conditions and Constraints |
|---|---|
| ≥ 99.94% global average | • 30-meter Not-to-Exceed (NTE) SPS SIS URE.<br>• Standard based on a measurement interval of one year; average of daily values within the service volume.<br>• Standard based on 3 service failures per year, lasting no more than 6 hours each. |
| ≥ 99.79% single point average | • 30-meter Not-to-Exceed (NTE) SPS SIS URE.<br>• Standard based on a measurement interval of one year; average of daily values from the worst-case point within the service volume.<br>• Standard based on 3 service failures per year, lasting no more than 6 hours each. |

Table 4-1 shows a comparison to the service reliability standard for range data collected at a receiver in Billings, Montana. Although the specification calls for yearly evaluations, we will be evaluating this SPS requirement at quarterly intervals. Additional range analysis results can be found in table 5-2 on page 21. The maximum User Range Error recorded this quarter was 26.651 meters at Boston on satellite PRN 7.

**Table 4-1 Service Reliability Based on User Range Error**

| Date Range of Data Collection | Site | Number of Samples This Quarter | Number of Samples where SPS URE > 30m NTE | Service Reliability Percentage |
|---|---|---|---|---|
| 1 October – 31 Dec 2006 | **Boston** | 55,860,062 | 0 | 100% |
| 1 October – 31 Dec 2006 | **Honolulu** | 56,157,071 | 0 | 100% |
| 1 October – 31 Dec 2006 | **Los Angeles** | 49,185,180 | 0 | 100% |
| 1 October – 31 Dec 2006 | **Miami** | 56,089,367 | 0 | 100% |
| 1 October – 31 Dec 2006 | **San Juan** | 59,971,879 | 0 | 100% |
| 1 October – 31 Dec 2006 | **Juneau** | 52,829,017 | 0 | 100% |
| 1 October – 31 Dec 2006 | **Global** | 330,092,576 | 0 | 100% |

# 5.0 Accuracy Standard

**Positioning Accuracy:** The statistical difference, at a 95% probability, between position measurements and a surveyed benchmark for any point within the service volume over any 24-hour interval.

• **Horizontal Positioning Accuracy:** The statistical difference, at a 95% probability, between horiz position measurements and a surveyed benchmark for any point within the service volume over any 24-hour interval.
• **Vertical Positioning Accuracy:** The statistical difference, at a 95% probability, between vertical position measurements and a surveyed benchmark for any point within the service volume over any 24-hour interval.

| Accuracy Standard | Conditions and Constraints |
|---|---|
| Global Average Positioning Domain Accuracy<br>• ≤ 13 meters 95% All-in-View horizontal error (SIS only)<br>• ≤ 22 meters 95% All-in-View vertical error (SIS only) | • Defined for position solution meeting the representative user conditions.<br>• Standard based on a measurement interval of 24 hours averaged over all points within the service volume. |
| Worst Site Positioning Domain Accuracy<br>• ≤ 36 meters 95% All-in-View Horizontal Error (SIS only)<br>• ≤ 77 meters 95% All-in-View Vertical Error (SIS only) | • Defined for position solution meeting the representative user conditions.<br>• Standard based on a measurement interval of 24 hours for any point within the service volume. |
| Time Transfer Accuracy<br>• ≤ 40 nanoseconds time transfer error 95% of time (SIS only) | • Defined for time transfer solution meeting the representative user conditions.<br>• Standard based on a measurement interval of 24 hours averaged over all points within the service volume. |
| **SPS SIS URE STANDARD** | **Conditions and Constraints** |
| ≤ 6 meters RMS SIS SPS URE across the entire constellation | • Average of the constellation’s individual satellite SPS SIS RMS URE values over any 24-hours interval, for any point thing the service volume. |

### 5.1 Position Accuracy

The data used for this section was collected for every second between 1 October through 31 December 2006 at the NSTB and WAAS selected locations.

Table 5-1 provides the 95% and 99.99% horizontal and vertical error accuracies for the quarter. Every twenty-four hour analysis period this quarter passed both the worst-case and global position accuracy requirements set forth by the SPS specification.

**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) |
|---|---|---|---|---|
| **Billings** | 2.363 | 4.219 | 7.467 | 10.119 |
| **Albuquerque** | 2.328 | 4.383 | 7.415 | 9.455 |
| **Anchorage** | 2.112 | 5.221 | 4.672 | 10.665 |
| **Boston** | 2.576 | 4.607 | 9.282 | 12.891 |
| **Washington, DC** | 2.612 | 4.776 | 8.591 | 16.907 |
| **Honolulu** | 4.679 | 5.456 | 8.200 | 12.881 |
| **Houston** | 2.345 | 5.215 | 6.855 | 10.178 |
| **Kansas City** | 2.477 | 5.000 | 5.875 | 12.561 |
| **Los Angeles** | 2.228 | 4.904 | 7.887 | 9.879 |
| **Salt Lake City** | 2.332 | 4.412 | 7.853 | 11.541 |
| **Miami** | 2.377 | 5.513 | 6.168 | 16.098 |
| **Minneapolis** | 2.503 | 4.589 | 7.546 | 10.170 |
| **Oakland** | 2.305 | 4.875 | 8.158 | 10.226 |
| **Cleveland** | 2.590 | 4.616 | 5.709 | 16.264 |
| **Seattle** | 2.357 | 4.501 | 6.239 | 10.426 |
| **San Juan** | 2.469 | 5.117 | 7.242 | 24.321 |
| **Atlanta** | 2.506 | 5.074 | 6.473 | 10.950 |
| **Juneau** | 2.103 | 4.579 | 5.716 | 9.036 |
| **Cold Bay** | 2.340 | 5.110 | 5.237 | 9.851 |
| **Fairbanks** | 2.017 | 5.114 | 4.754 | 10.655 |
| **Bethel** | 2.072 | 5.033 | 4.692 | 11.151 |
| **Kotzebue** | 2.015 | 5.329 | 4.825 | 11.812 |

Figures 5-1 and 5-2 are the combined histograms of the vertical and horizontal errors for all twenty-two WAAS sites from 1 October to 31 December 2006.

**Figure 5-1 Global Vertical Error Histogram**

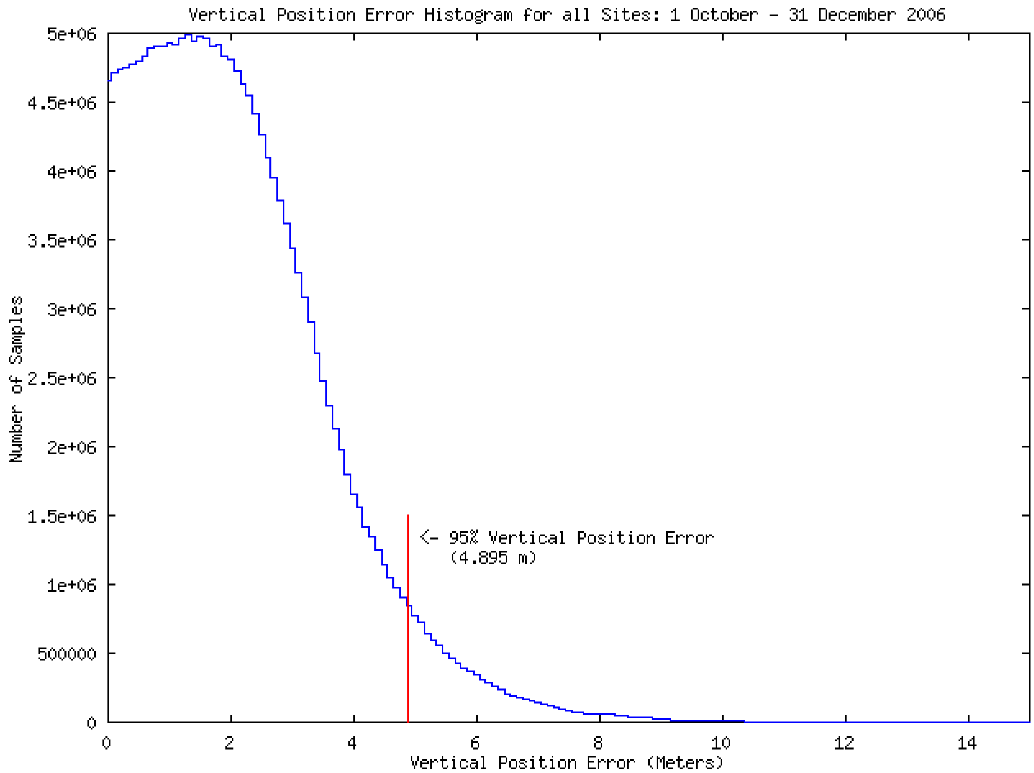
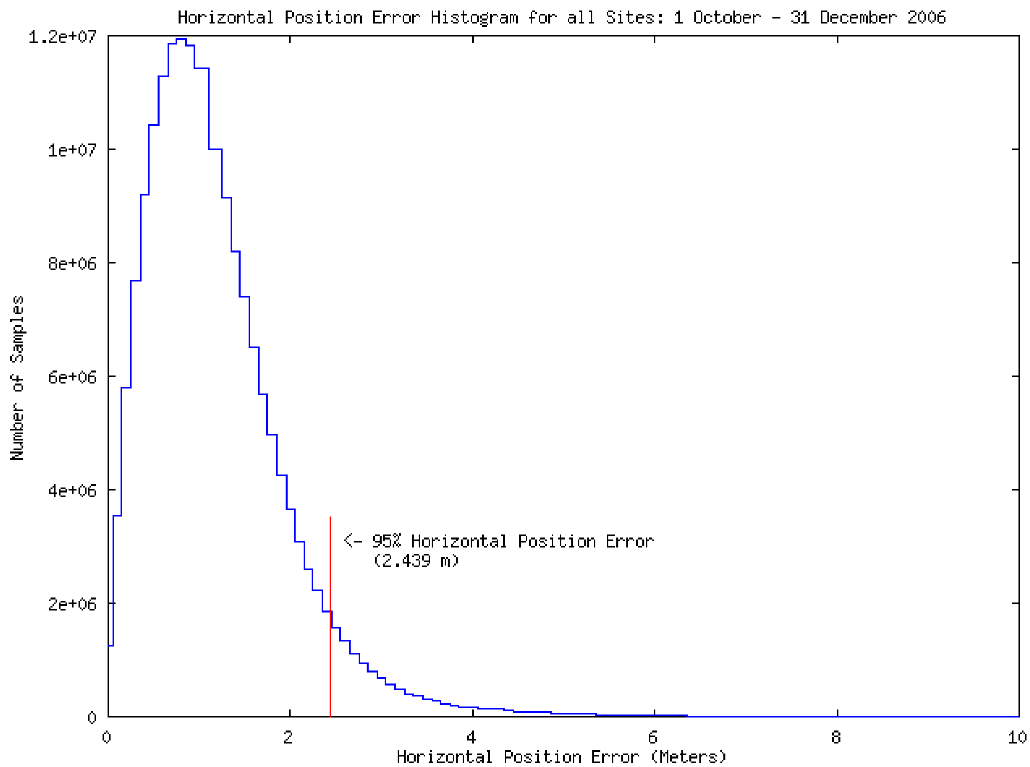


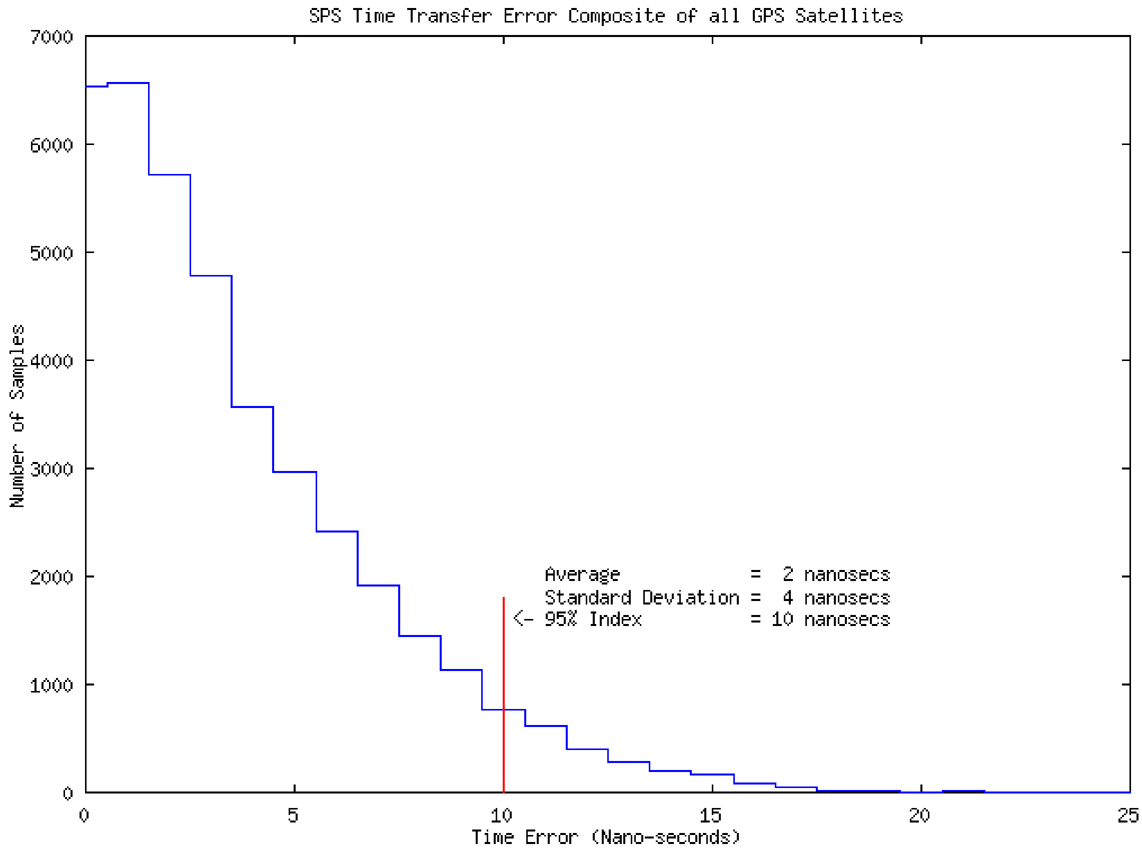

**Figure 5-2 Global Horizontal Error Histogram**



### 5.2 Time Transfer Accuracy

The GPS time error data between 1 October and 31 December 2006 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**



### 5.3 Range Domain Accuracy

Tables 5-3 through 5-5 provide the statistical data for the range error, range rate error and the range acceleration error for each satellite. This data was collected between 1 October and 31 December 2006. The WAAS receiver at Houston was used to collect range measurement.

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 5-2 Range Error Statistics (meters)**

| PRN | Range Error Mean | RMS Range Error (≤ 6 m) | 1s | 95% Range Error | Max Range Error (SPS Spec. ≤ 30 m) | Samples |
|---|---|---|---|---|---|---|
| 1 | 0.777 | 2.136 | 1.671 | 3.870 | 12.897 | 10898660 |
| 2 | 1.134 | 2.043 | 1.435 | 3.764 | 18.327 | 12336200 |
| 3 | 0.641 | 1.770 | 1.331 | 3.195 | 16.046 | 9763083 |
| 4 | 0.770 | 1.965 | 1.475 | 3.736 | 19.742 | 12218323 |
| 5 | 1.212 | 2.080 | 1.388 | 3.743 | 17.534 | 11575385 |
| 6 | 0.629 | 1.756 | 1.333 | 3.262 | 11.985 | 12022925 |
| 7 | 1.004 | 1.808 | 1.293 | 3.285 | 26.651 | 11776159 |
| 8 | 0.781 | 2.162 | 1.553 | 3.931 | 13.247 | 10777793 |
| 9 | 0.328 | 1.854 | 1.523 | 3.453 | 13.304 | 11001058 |
| 10 | 1.437 | 2.515 | 1.737 | 4.483 | 16.667 | 11841593 |
| 11 | 0.918 | 1.741 | 1.290 | 3.179 | 16.639 | 10377231 |
| 12 | 0.076 | 1.608 | 1.352 | 2.941 | 9.029 | 2897097 |
| 13 | 0.381 | 1.450 | 1.215 | 2.701 | 19.486 | 11840004 |
| 14 | 1.259 | 1.861 | 1.259 | 3.433 | 10.622 | 12005244 |
| 16 | 0.797 | 1.606 | 1.223 | 2.983 | 16.072 | 11143681 |
| 17 | 0.319 | 1.831 | 1.455 | 3.540 | 18.504 | 12207248 |
| 18 | 1.281 | 1.897 | 1.208 | 3.287 | 13.637 | 11008641 |
| 19 | 1.291 | 1.909 | 1.257 | 3.300 | 16.794 | 10735680 |
| 20 | 1.195 | 1.817 | 1.255 | 3.430 | 11.250 | 12147430 |
| 21 | 1.146 | 1.937 | 1.313 | 3.407 | 12.887 | 10203958 |
| 22 | 1.307 | 1.979 | 1.252 | 3.417 | 13.149 | 10641121 |
| 23 | 0.925 | 1.664 | 1.242 | 2.977 | 15.136 | 11141496 |
| 24 | 1.382 | 2.441 | 1.677 | 4.381 | 15.835 | 12309478 |
| 25 | 0.301 | 1.694 | 1.372 | 3.262 | 15.340 | 12397377 |
| 26 | 0.761 | 1.732 | 1.355 | 3.243 | 12.719 | 10290916 |
| 27 | 0.560 | 1.913 | 1.397 | 3.431 | 14.829 | 10580492 |
| 28 | 1.142 | 2.116 | 1.434 | 3.807 | 17.298 | 10667623 |
| 29 | 0.985 | 2.028 | 1.412 | 3.668 | 11.437 | 10572115 |
| 30 | 0.492 | 1.895 | 1.544 | 3.529 | 13.512 | 11483658 |
| 31 | 0.346 | 1.562 | 1.313 | 2.930 | 16.048 | 11212199 |

**Table 5-3 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 | Samples |
|---|---|---|---|---|---|---|
| 1 | 0.0000 | 0.0026 | 0.0026 | 0.0036 | 0.1883 | 10898660 |
| 2 | 0.0000 | 0.0019 | 0.0018 | 0.0036 | 0.0693 | 12336200 |
| 3 | 0.0000 | 0.0022 | 0.0022 | 0.0035 | 0.2424 | 9763083 |
| 4 | 0.0000 | 0.0019 | 0.0019 | 0.0035 | 0.1657 | 12218323 |
| 5 | 0.0000 | 0.0020 | 0.0020 | 0.0035 | 0.1865 | 11575385 |
| 6 | 0.0000 | 0.0019 | 0.0019 | 0.0036 | 0.1411 | 12022925 |
| 7 | 0.0000 | 0.0019 | 0.0019 | 0.0034 | 0.1615 | 11776159 |
| 8 | 0.0000 | 0.0021 | 0.0021 | 0.0038 | 0.1535 | 10777793 |
| 9 | 0.0000 | 0.0023 | 0.0023 | 0.0040 | 0.1698 | 11001058 |
| 10 | 0.0000 | 0.0020 | 0.0020 | 0.0037 | 0.1584 | 11841593 |
| 11 | 0.0000 | 0.0020 | 0.0020 | 0.0037 | 0.1171 | 10377231 |
| 12 | 0.0000 | 0.0018 | 0.0018 | 0.0034 | 0.0431 | 2897097 |
| 13 | 0.0000 | 0.0019 | 0.0019 | 0.0036 | 0.0804 | 11840004 |
| 14 | 0.0000 | 0.0018 | 0.0018 | 0.0035 | 0.0987 | 12005244 |
| 16 | 0.0000 | 0.0019 | 0.0019 | 0.0036 | 0.0947 | 11143681 |
| 17 | 0.0000 | 0.0019 | 0.0019 | 0.0036 | 0.1272 | 12207248 |
| 18 | 0.0000 | 0.0019 | 0.0018 | 0.0036 | 0.1259 | 11008641 |
| 19 | 0.0000 | 0.0019 | 0.0019 | 0.0037 | 0.2591 | 10735680 |
| 20 | 0.0000 | 0.0018 | 0.0018 | 0.0034 | 0.1021 | 12147430 |
| 21 | 0.0000 | 0.0019 | 0.0019 | 0.0038 | 0.0946 | 10203958 |
| 22 | 0.0000 | 0.0019 | 0.0019 | 0.0036 | 0.1259 | 10641121 |
| 23 | 0.0000 | 0.0018 | 0.0018 | 0.0034 | 0.0827 | 11141496 |
| 24 | -0.0001 | 0.0022 | 0.0022 | 0.0037 | 0.1625 | 12309478 |
| 25 | 0.0000 | 0.0020 | 0.0020 | 0.0034 | 0.1821 | 12397377 |
| 26 | 0.0000 | 0.0019 | 0.0019 | 0.0035 | 0.1269 | 10290916 |
| 27 | 0.0000 | 0.0020 | 0.0020 | 0.0037 | 0.1669 | 10580492 |
| 28 | 0.0000 | 0.0020 | 0.0020 | 0.0036 | 0.1528 | 10667623 |
| 29 | 0.0000 | 0.0020 | 0.0020 | 0.0035 | 0.2341 | 10572115 |
| 30 | 0.0000 | 0.0023 | 0.0023 | 0.0040 | 0.1717 | 11483658 |
| 31 | 0.0000 | 0.0018 | 0.0018 | 0.0034 | 0.1241 | 11212199 |

**Table 5-4 Range Acceleration Error Statistics (meters/second$^2$)**

| PRN | Range Acceleration Error Mean | Range Acceleration Error RMS | Range Acceleration 1σ | Max Range Acceleration Error | Samples |
|---|---|---|---|---|---|
| 1 | 0 | 0.000021 | 0.000021 | 0.001850 | 10898660 |
| 2 | 0 | 0.000014 | 0.000014 | 0.000690 | 12336200 |
| 3 | 0 | 0.000017 | 0.000017 | 0.002420 | 9763083 |
| 4 | 0 | 0.000015 | 0.000015 | 0.001660 | 12218323 |
| 5 | 0 | 0.000015 | 0.000015 | 0.001880 | 11575385 |
| 6 | 0 | 0.000015 | 0.000015 | 0.001410 | 12022925 |
| 7 | 0 | 0.000015 | 0.000015 | 0.001600 | 11776159 |
| 8 | 0 | 0.000017 | 0.000017 | 0.001530 | 10777793 |
| 9 | 0 | 0.000018 | 0.000018 | 0.001700 | 11001058 |
| 10 | 0 | 0.000015 | 0.000015 | 0.001590 | 11841593 |
| 11 | 0 | 0.000016 | 0.000016 | 0.001160 | 10377231 |
| 12 | 0 | 0.000014 | 0.000014 | 0.000380 | 2897097 |
| 13 | 0 | 0.000015 | 0.000015 | 0.000810 | 11840004 |
| 14 | 0 | 0.000014 | 0.000014 | 0.000980 | 12005244 |
| 16 | 0 | 0.000014 | 0.000014 | 0.000890 | 11143681 |
| 17 | 0 | 0.000015 | 0.000015 | 0.001270 | 12207248 |
| 18 | 0 | 0.000014 | 0.000014 | 0.001250 | 11008641 |
| 19 | 0 | 0.000015 | 0.000015 | 0.002600 | 10735680 |
| 20 | 0 | 0.000014 | 0.000014 | 0.001020 | 12147430 |
| 21 | 0 | 0.000015 | 0.000015 | 0.000920 | 10203958 |
| 22 | 0 | 0.000014 | 0.000014 | 0.001250 | 10641121 |
| 23 | 0 | 0.000014 | 0.000014 | 0.000840 | 11141496 |
| 24 | 0 | 0.000016 | 0.000016 | 0.001630 | 12309478 |
| 25 | 0 | 0.000016 | 0.000016 | 0.001810 | 12397377 |
| 26 | 0 | 0.000015 | 0.000015 | 0.001270 | 10290916 |
| 27 | 0 | 0.000016 | 0.000016 | 0.001660 | 10580492 |
| 28 | 0 | 0.000015 | 0.000015 | 0.001520 | 10667623 |
| 29 | 0 | 0.000016 | 0.000016 | 0.002360 | 10572115 |
| 30 | 0 | 0.000019 | 0.000019 | 0.001720 | 11483658 |
| 31 | 0 | 0.000013 | 0.000013 | 0.001240 | 11212199 |

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. The highest maximum range error occurred on satellite 7 with an error of 26.651 meters. Satellite 12 had the lowest maximum range error of 9.029 meters.

**Figure 5-4 Distribution of Daily Max Range Errors**

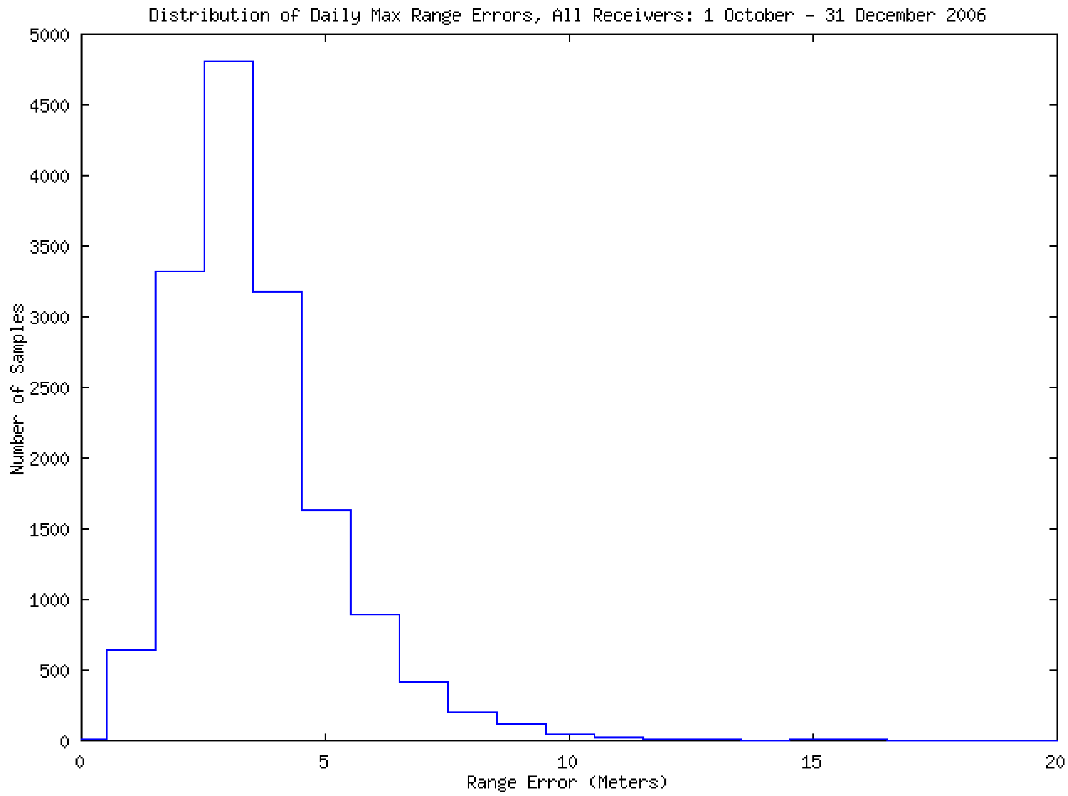



**Figure 5-5: Distribution of Daily Max Range Rate Errors**

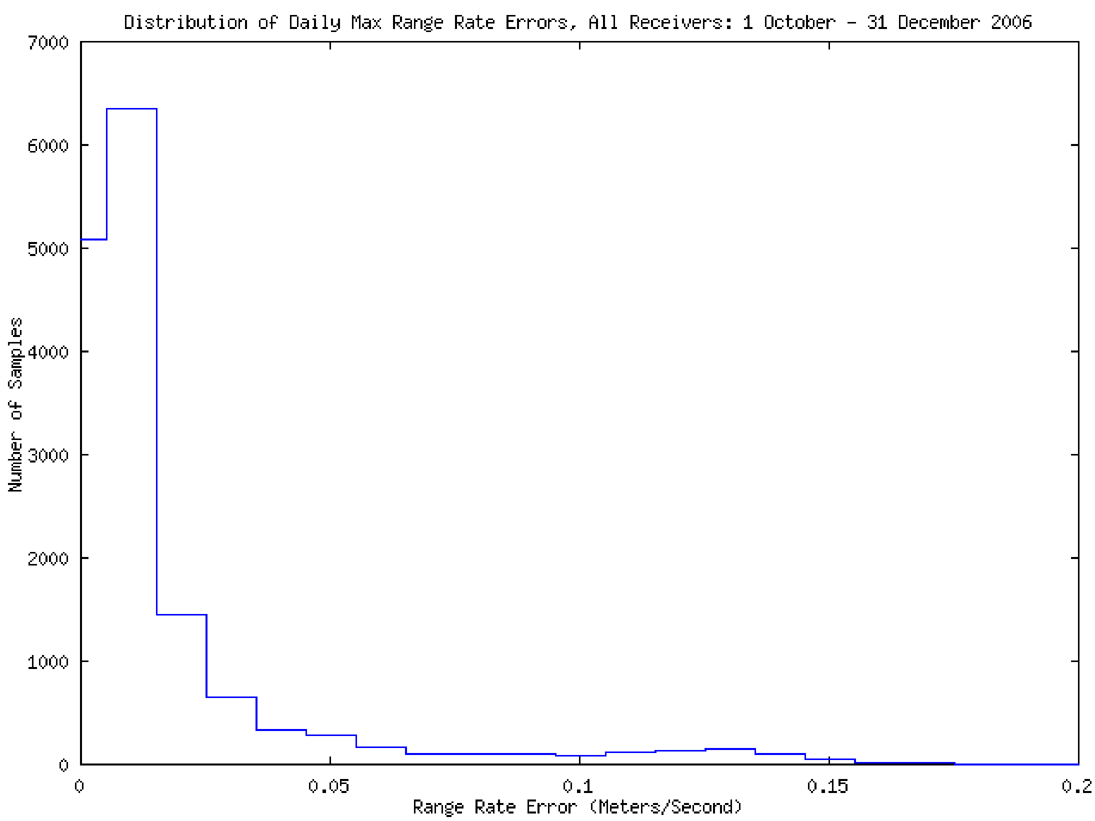


**Figure 5-6: Distribution of Daily Max Acceleration Rate Errors**

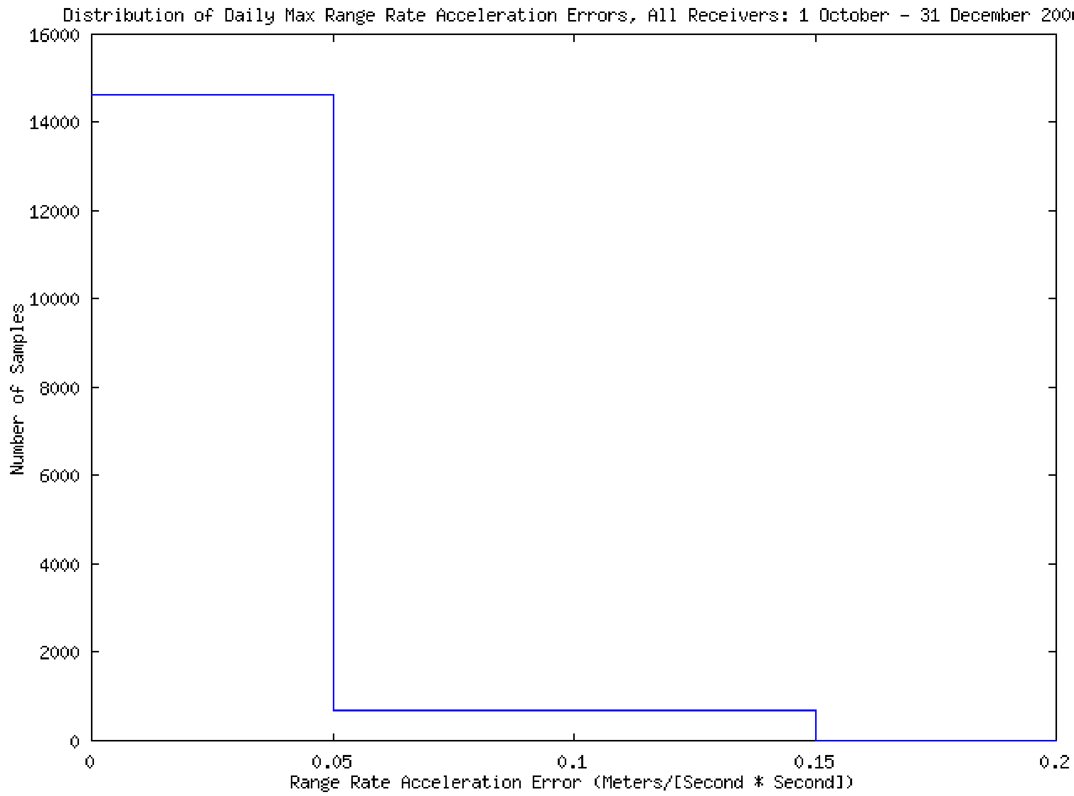
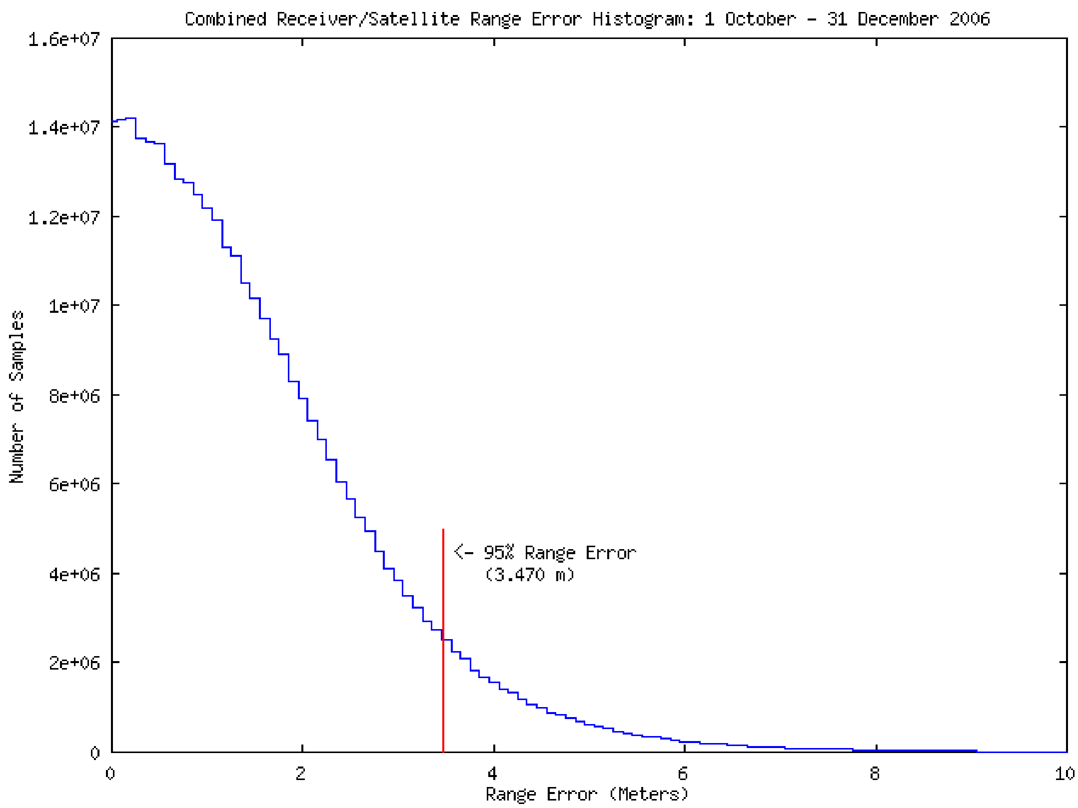



**Figure 5-7: Range Error Histogram**



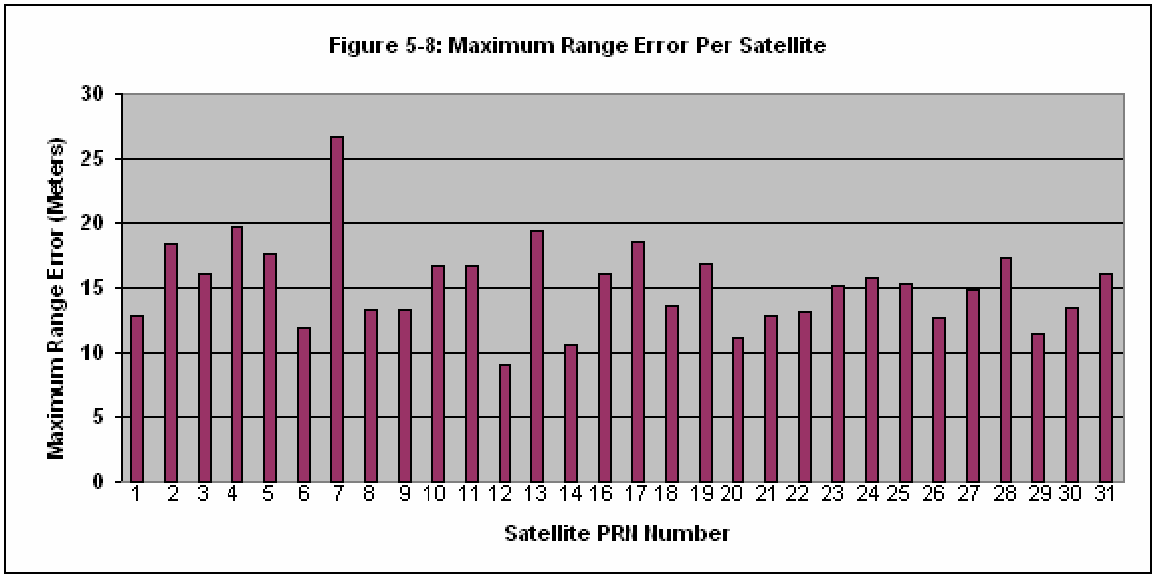


Figure 5-8: Maximum Range Error Per Satellite
Maximum Range Error (Meters)
0
5
10
15
20
25
30
1 2 3 4 5 6 7 8 9 10 11 12 13 14 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Satellite PRN Number

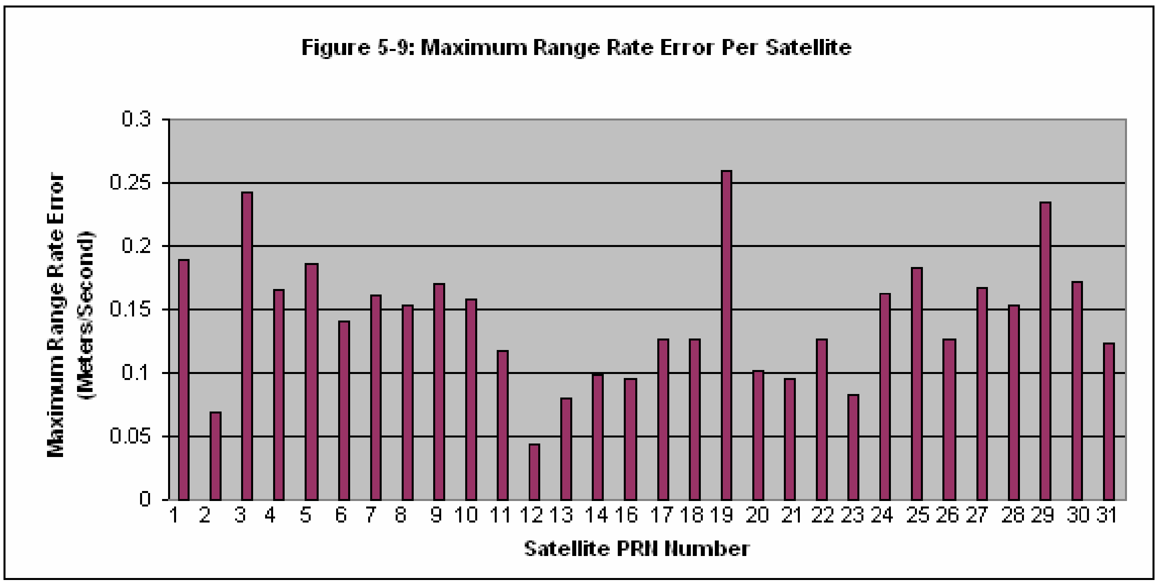


Figure 5-9: Maximum Range Rate Error Per Satellite
Maximum Range Rate Error (Meters/Second)
0
0.05
0.1
0.15
0.2
0.25
0.3
1 2 3 4 5 6 7 8 9 10 11 12 13 14 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Satellite PRN Number

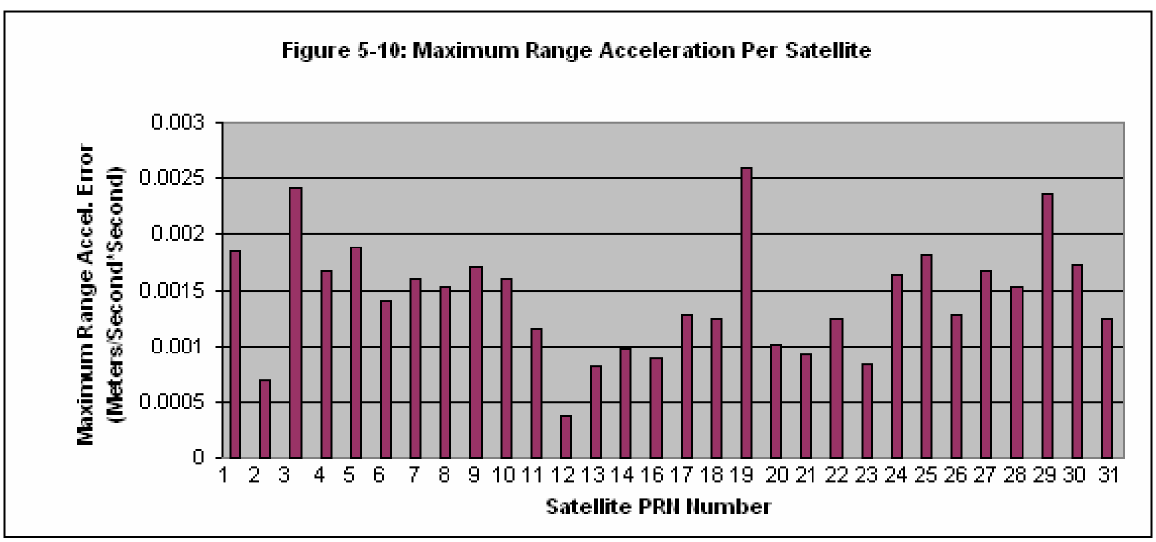


Figure 5-10: Maximum Range Acceleration Per Satellite
Maximum Range Accel. Error (Meters/Second*Second)
0
0.0005
0.001
0.0015
0.002
0.0025
0.003
1 2 3 4 5 6 7 8 9 10 11 12 13 14 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Satellite PRN Number

# 6.0 Solar Storms

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

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

> *The aurora is caused by the interaction of high-energy particles (usually electrons) with neutral atoms in the earth's upper atmosphere. These high-energy particles can 'excite' (by collisions) valence electrons that are bound to the neutral atom. The 'excited' electron can then 'de-excite' and return back to its initial, lower energy state, but in the process it releases a photon (a light particle). The combined effect of many photons being released from many atoms results in the aurora display that you see.*
>
> *The details of how high energy particles are generated during geomagnetic storms constitute an entire discipline of space science in its own right. The basic idea, however, is that the Earth's magnetic field (let us say the 'geomagnetic field') is responding to an outwardly propagating disturbance from the Sun. As the geomagnetic field adjusts to this disturbance, various components of the Earth's field change form, releasing magnetic energy and thereby accelerating charged particles to high energies. These particles, being charged, are forced to stream along the geomagnetic field lines. Some end up in the upper part of the earth's neutral atmosphere and the auroral mechanism begins.*
>
> *An instrument called a magnetometer may also measure the disturbance of the geomagnetic field. At NOAA's operations center magnetometer data is received from dozens of observatories in one-minute intervals. The data is received at or near to 'real-time' and allows NOAA to keep track of the current state of the geomagnetic conditions. In order to reduce the amount of data NOAA converts the magnetometer data into three-hourly indices, which give a quantitative, but less detailed measure of the level of geomagnetic activity. The K-index scale has a range from 0 to 9 and is directly related to the maximum amount of fluctuation (relative to a quiet day) in the geomagnetic field over a three-hour interval.*
>
> *The K-index is therefore updated every three hours. The K-index is also necessarily tied to a specific geomagnetic observatory. For locations where there are no observatories, one can only estimate what the local K-index would be by looking at data from the nearest observatory, but this would be subject to some errors from time to time because geomagnetic activity is not always spatially homogenous.*
>
> *Another item of interest is that the location of the aurora usually changes geomagnetic latitude as the intensity of the geomagnetic storm changes. The location of the aurora often takes on an 'oval-like' shape and is appropriately called the auroral oval.*

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

**Figure 6-1 K-Index for 14-16 December 2006**

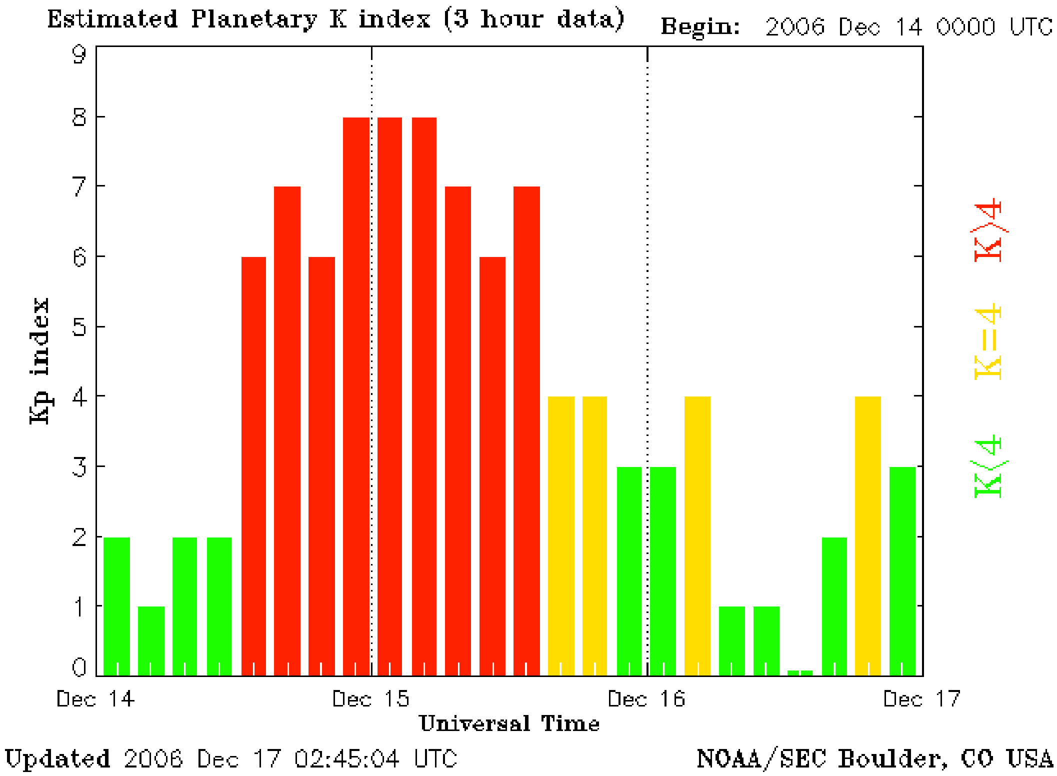



**Figure 6-2 K-Index for 6-8 December 2006**

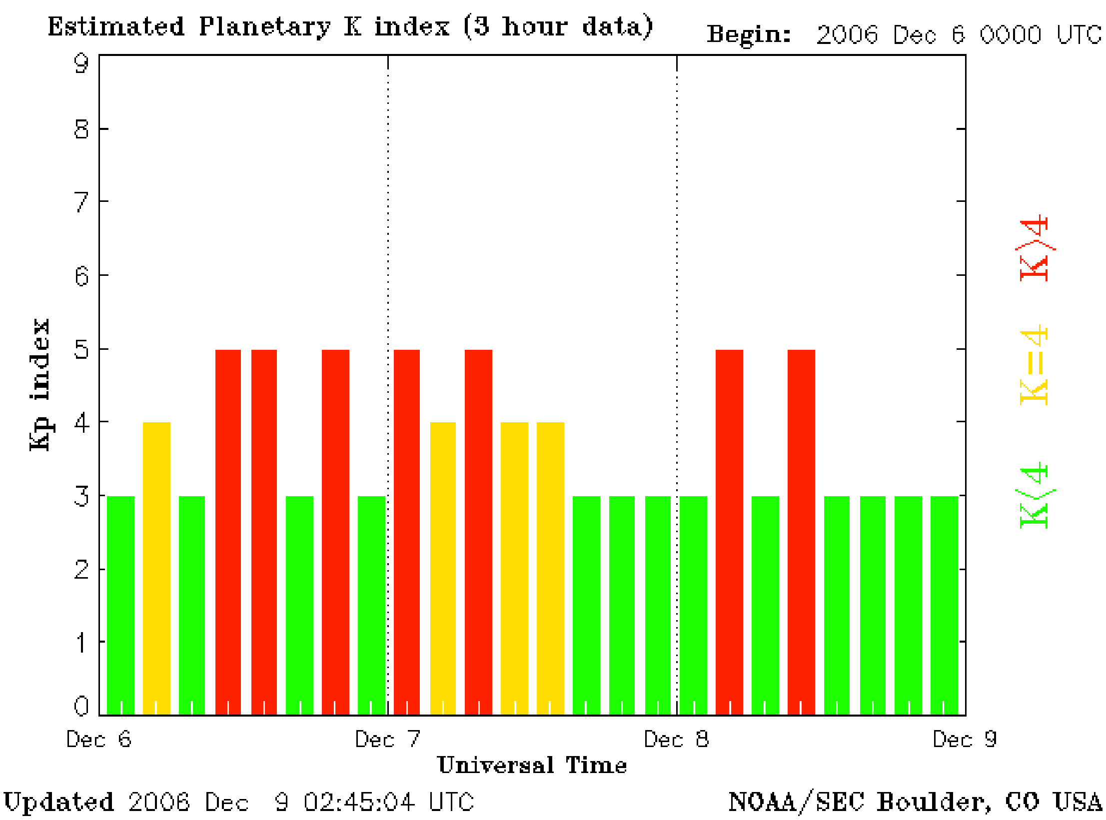
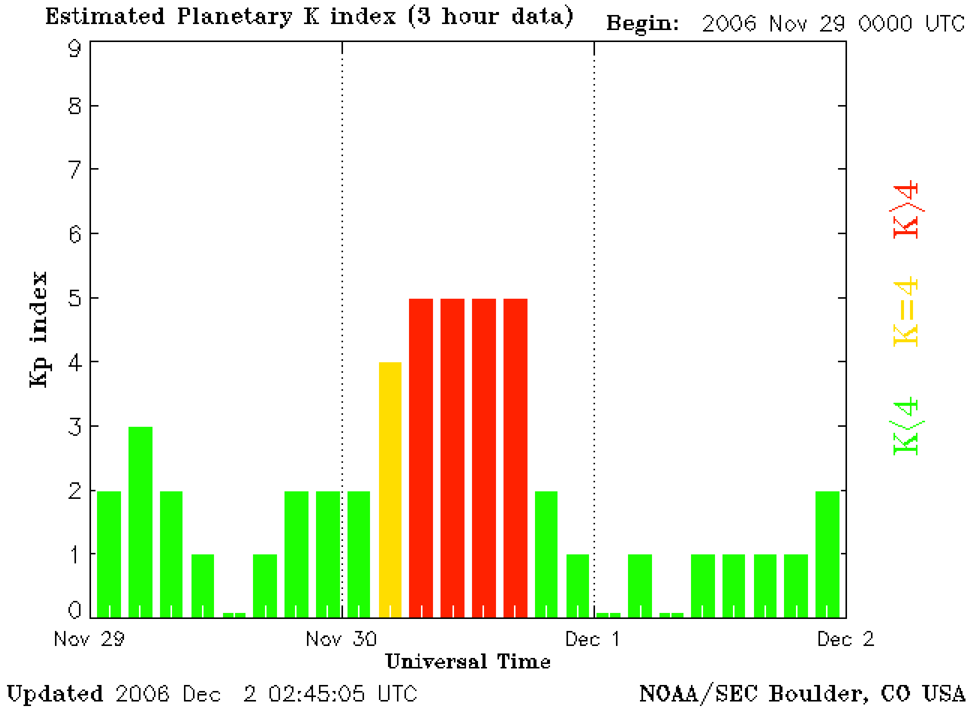


**Figure 6-3 K-Index for 29 November - 1 December 2006**




Tables 6-1 shows the position accuracy information for the day corresponding to Figure 6-1. The GPS SPS performance met all requirements during all storms that occurred during this quarter.

**Table 6-1 Horizontal & Vertical Accuracy Statistics for 15 December 2006**

| Site | 95% Horizontal (Meters) | 95% Vertical (Meters) | 99.99% Horizontal (Meters) | 99.99% Vertical (Meters) |
|---|---|---|---|---|
| **Billings** | 2.201 | 8.482 | 2.542 | 10.302 |
| **Albuquerque** | 3.015 | 7.370 | 4.142 | 9.160 |
| **Anchorage** | 2.847 | 7.417 | 3.560 | 11.137 |
| **Boston** | 3.129 | 8.785 | 5.211 | 18.167 |
| **Washington, DC** | 3.394 | 8.461 | 4.744 | 17.356 |
| **Honolulu** | 5.752 | 7.851 | 8.259 | 14.382 |
| **Houston** | 3.321 | 7.890 | 4.937 | 9.050 |
| **Kansas City** | 2.503 | 8.965 | 3.746 | 10.323 |
| **Los Angeles** | 2.465 | 8.723 | 3.838 | 9.980 |
| **Salt Lake City** | 3.384 | 7.221 | 4.193 | 9.455 |
| **Miami** | 2.457 | 8.896 | 3.061 | 13.027 |
| **Minneapolis** | 3.460 | 8.992 | 4.723 | 16.477 |
| **Oakland** | 2.522 | 8.361 | 3.474 | 9.664 |
| **Cleveland** | 3.223 | 8.126 | 4.265 | 9.708 |
| **Seattle** | 2.986 | 8.771 | 5.480 | 17.785 |
| **San Juan** | 2.889 | 8.731 | 5.383 | 17.336 |
| **Atlanta** | 2.382 | 8.213 | 3.062 | 10.830 |
| **Juneau** | 2.830 | 8.368 | 4.599 | 16.550 |
| **Cold Bay** | 2.884 | 8.639 | 4.867 | 16.930 |
| **Fairbanks** | 2.671 | 7.323 | 11.405 | 22.308 |
| **Bethel** | 4.837 | 5.890 | 6.098 | 11.419 |
| **Kotzebue** | 2.379 | 6.729 | 5.515 | 12.092 |

# APPENDICES A – D

| *Conditions and Constraints* | *PDOP Availability Standard* | *Measured Performance* |
|---|---|---|
| • Defined for position solution meeting the representative user conditions and operating within the service volume over any 24-hour interval.<br>• Based on using only satellites transmitting standard code and indicating "health" in the broadcast navigation message (sub-frame 1). | ≥ 98% global Position Dilution of Precision (PDOP) of 6 or less<br><br>≥ 88% worst site PDOP of 6 or less | ≥ 99.996%<br><br>≥ 99.583% |
| ***Conditions and Constraints*** | ***Service Availability Standard*** | ***Measured Performance*** |
| • 36 meter horizontal (SIS only) 95% threshold.<br>• 77 meter vertical (SIS only) 95% threshold.<br>• Defined for position solution meeting the representative user conditions and operating within the service volume over any 24-hour interval. | ≥ 99% Horizontal Service Availability average location<br><br>≥ 99% Vertical Service Availability average location | 100% |
| • Based on using only satellites transmitting standard code and indicating "healthy" in the broadcast navigation message (sub-frame 1). | ≥ 95.87% global average on worst-case day | 100% |
| ***Conditions and Constraints*** | ***Service Reliability Standard*** | ***Measured Performance*** |
| • 30-meter Not-to-Exceed (NTE) SPS SIS URE.<br>• Standard based on a measurement interval of one year; average of daily values within the service volume.<br>• Standard based on 3 service failures per year, lasting no more than 6 hours each. | ≥ 99.94% global average | 100% |
| • 30-meter Not-to-Exceed (NTE) SPS SIS URE.<br>• Standard based on a measurement interval of one year; average of daily values from the worst-case point within the service volume.<br>• Standard based on 3 service failures per year, lasting no more than 6 hours each. | ≥ 99.79% single point average | 100% |

| ***Conditions and Constraints*** | ***Accuracy Standard*** | ***Measured Performance*** |
|---|---|---|
| • Defined for position solution meeting the representative user conditions.<br>• Standard based on a measurement interval of 24 hours averaged over all points within the service volume. | Global Average Positioning Domain Accuracy<br>• ≤ 13 meters 95% All-in-View horizontal error (SIS only)<br>• ≤ 22 meters 95% All-in-View vertical error (SIS only) | 2.441 m<br>4.893 m |
| • Defined for position solution meeting the representative user conditions.<br>• Standard based on a measurement interval of 24 hours for any point within the service volume. | Worst Site Positioning Domain Accuracy<br>• ≤ 36 meters 95% All-in-View Horiz Error (SIS only)<br>• ≤ 77 meters 95% All-in-View Vertical Error (SIS only) | 4.679 m<br>5.513 m |
| • Defined for time transfer solution meeting the representative user conditions.<br>• Standard based on a measurement interval of 24 hours averaged over all points within the service volume. | Time Transfer Accuracy<br>• ≤ 40 nanoseconds time transfer error 95% of time (SIS only) | 10 nanoseconds 95% |
| • Average of the constellation's individual satellite SPS SIS RMS URE values over any 24-hours interval, for any point in the service volume. | ≤ 6 meters RMS SIS SPS URE across the entire constellation | 1.901 meters |

```
#  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
2006 10 01       14   4 4 3 3 3 2 1 1   37   4 4 5 6 6 4 1 1   25   5 5 4 4 3 3 1 3
2006 10 02        6   2 2 3 1 2 1 1 1   13   2 2 4 4 3 2 2 1    7   2 2 2 2 2 2 1 2
2006 10 03        6   1 3 1 1 2 2 1 1    9   2 1 1 4 3 3 1 0    5   1 2 1 1 2 2 1 2
2006 10 04        2   0 2 1 0 1 1 1 0    2   0 1 1 0 1 2 0 1    3   1 2 1 0 0 1 1 1
2006 10 05        2   0 0 1 1 1 1 2 0    2   0 0 1 1 1 0 1 0    3   1 0 1 0 1 1 1 1
2006 10 06        2   0 0 2 1 0 0 1 0    3   0 0 1 3 1 0 0 0    3   0 0 2 1 1 1 0 1
2006 10 07        7   0 2 1 0 2 2 3 3    4   0 0 1 1 2 2 2 2    9   0 1 1 0 1 3 3 4
2006 10 08        6   3 1 1 2 2 2 1 1   11   3 0 1 5 3 2 1 0    7   3 0 0 2 2 2 1 1
2006 10 09        3   0 3 1 0 1 0 1 0    2   0 1 2 1 0 0 0 0    5   1 3 2 0 1 1 1 2
2006 10 10        0   1 0 0 0 0 0 0 0    0   0 0 0 1 0 0 1 0    2   1 0 0 0 0 1 0 1
2006 10 11        2   1 1 2 0 1 0 0 0    2   1 0 1 1 1 0 0 0    3   1 0 2 0 1 1 0 1
2006 10 12        3   2 1 1 0 1 1 0 2    5   0 0 0 2 3 3 0 1    5   2 1 1 1 1 2 0 3
2006 10 13       15   1 2 3 3 3 2 4 4   32   1 2 6 4 5 5 3 4   24   2 3 4 4 3 3 5 4
2006 10 14       12   3 3 2 2 2 3 3 3   32   2 3 5 6 4 5 3 3   18   4 4 3 3 2 3 3 4
2006 10 15        9   3 3 3 2 1 1 2 2   14   3 2 4 4 3 2 2 1   10   3 3 2 3 1 1 1 2
2006 10 16        7   3 1 2 1 2 1 1 3   13   1 1 2 3 4 3 1 4    8   3 2 2 1 1 1 2 3
2006 10 17        2   2 0 0 1 1 0 1 0    2   1 0 1 2 1 1 0 0    2   1 0 0 1 0 0 1 0
2006 10 18        2   2 2 1 0 0 0 1 0    3   0 1 1 2 2 0 0 0    4   1 2 1 0 0 0 1 1
2006 10 19        1   0 1 0 1 1 0 0 0    1   0 0 0 2 0 0 0 0    2   0 1 0 1 1 0 0 1
2006 10 20        9   2 0 2 2 3 2 3 3   10   2 0 1 3 4 3 2 2   10   2 0 1 2 3 3 3 3
2006 10 21       10   3 2 3 2 2 3 2 2   25   3 3 3 5 5 5 2 2   15   3 2 3 3 3 4 3 2
2006 10 22       12   2 4 2 2 3 2 2 3   19   3 3 5 1 4 4 2 2   13   2 5 3 1 2 2 3 3
2006 10 23        2   0 0 0 1 0 1 1 1    3   2 0 0 2 2 1 1 0    3   1 0 0 1 1 1 1 1
2006 10 24        3   0 0 2 1 1 1 1 1    4   0 0 2 1 3 0 1 1    4   0 1 2 1 1 1 1 1
2006 10 25        4   2 2 2 1 1 1 0 0    2   0 1 2 1 0 0 0 0    4   1 2 2 1 0 0 0 0
2006 10 26        1   0 0 1 1 1 0 0 0    3   0 0 1 2 2 1 0 0    1   0 0 1 0 1 0 0 0
2006 10 27        3   1 0 0 1 1 1 2 2    2   0 0 0 2 1 0 1 1    2   1 0 0 1 0 0 1 2
2006 10 28       12   1 2 3 3 2 3 2 4   28   1 1 4 6 4 5 2 4   14   1 2 3 4 2 3 3 4
2006 10 29       13   3 3 3 2 3 2 3 3   36   4 4 6 5 5 4 3 3   21   3 4 4 3 3 3 4 4
2006 10 30        6   2 1 2 3 1 1 1 1   14   3 2 3 5 3 2 1 0    9   3 2 2 3 2 2 1 2
2006 10 31        2   2 0 0 0 1 1 1 1    4   0 0 0 1 3 2 1 0    4   2 0 1 0 1 1 1 2
2006 11 01        5   2 2 1 1 1 2 1 1   10   2 1 4 2 4 1 1 0    6   2 1 1 1 2 1 2 2
2006 11 02        6   2 3 1 1 1 1 2 1    9   1 2 2 3 3 3 2 1    8   2 3 1 1 2 3 3 2
2006 11 03        5   1 3 1 2 2 1 1 0   21   2 2 3 5 6 2 1 0    8   1 3 1 3 3 1 1 1
2006 11 04        4   1 2 1 1 1 1 2 1    9   1 3 4 2 1 2 1 1    6   1 2 2 1 1 2 2 2
2006 11 05        3   0 0 2 2 1 1 0 0   15   0 0 3 5 5 2 1 0    5   0 1 2 3 1 1 0 1
2006 11 06        1   0 0 2 0 0 0 1 0    2   0 0 2 2 0 0 0 0    1   0 0 1 0 0 0 0 1
2006 11 07        0   0 0 0 0 1 0 0 0    0   0 0 0 0 0 0 0 0    0   0 0 0 0 0 0 0 0
2006 11 08        0   0 0 0 0 0 0 0 0    0   0 0 0 0 0 0 0 0    1   0 0 0 0 1 0 0 0
2006 11 09        7   0 0 0 0 1 2 3 4    5   0 0 0 0 0 2 3 3   10   0 0 0 0 1 3 4 4
2006 11 10       29   3 5 4 6 4 3 3 2   45   3 5 4 7 6 4 3 2   36   4 6 4 6 5 3 3 2
2006 11 11       20   3 4 4 4 4 3 3 2   41   3 4 6 6 6 4 3 2   20   3 4 4 4 4 3 3 2
2006 11 12        9   2 3 3 3 2 2 1 1    9   2 2 3 4 3 1 0 0    7   2 3 2 2 2 2 1 1
2006 11 13        1   0 0 2 0 0 1 0 0    0   0 0 1 0 0 0 0 0    2   0 0 1 0 0 0 0 1
2006 11 14        3   0 1 1 1 1 1 1 2    4   0 0 1 3 2 1 1 1    4   0 1 1 1 1 1 1 2
2006 11 15        6   2 3 1 1 1 2 1 2    7   2 1 1 3 2 0 3 1    5   2 2 0 1 1 0 0 2
2006 11 16        5   4 1 1 0 1 1 0 0    4   3 1 2 1 1 0 0 0    8   5 2 1 0 1 1 0 1
2006 11 17        3   1 2 1 1 2 1 0 0   15   1 2 3 2 5 2 2 4    5   2 2 1 1 2 1 0 1
2006 11 18        0   0 0 0 0 0 0 0 0    1   0 0 0 2 0 0 0 1    2   0 0 0 0 1 0 0 1
2006 11 19        2   0 2 1 1 0 0 0 0    3   2 1 2 1 0 0 0 0    3   1 1 1 1 1 0 0 0
2006 11 20        1   0 0 0 0 1 1 1 0    1   0 1 0 0 0 0 0 1    2   0 0 0 0 1 1 0 1
2006 11 21        1   1 0 0 0 1 0 0 0    0   0 0 0 0 0 0 0 0    1   0 0 0 0 0 0 0 1
2006 11 22        3   0 0 0 1 2 1 1 2    4   2 1 0 0 0 0 2 3    4   0 0 0 0 1 1 3 3
2006 11 23        8   0 1 3 3 2 1 2 3   34   4 1 5 6 5 4 3 4   18   1 1 4 5 4 3 3 3
2006 11 24       10   3 3 3 2 2 2 2 2   32   2 5 5 5 6 2 2 2   21   3 5 5 3 3 2 2 2
2006 11 25       10   1 3 1 1 2 3 3 3   21   3 2 1 4 5 5 3 2   15   2 4 2 2 3 4 4 3
2006 11 26        9   2 3 3 2 3 1 2 2   17   3 2 3 4 5 2 2 2   15   3 4 4 3 2 1 3 3
2006 11 27        7   3 1 2 3 1 1 2 0   13   2 1 4 4 3 1 1 1    6   2 1 2 2 1 1 2 1
```

| | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2006 11 28 | 4 | 1 | 1 | 0 | 1 | 2 | 2 | 1 | 1 | 10 | 0 | 1 | 1 | 4 | 4 | 2 | 2 | 1 | 5 | 1 | 1 | 0 | 2 | 2 | 1 | 1 | 2 |
| 2006 11 29 | 6 | 1 | 3 | 3 | 1 | 0 | 1 | 1 | 1 | -1 | 0 | 2 | 0 | -1 | 0 | 1 | 1 | 1 | 6 | 2 | 3 | 2 | 1 | 0 | 1 | 2 | 2 |
| 2006 11 30 | 15 | 2 | 3 | 4 | 4 | 4 | 3 | 1 | 0 | 73 | 2 | 5 | 8 | 7 | 6 | 5 | 3 | 1 | 28 | 2 | 4 | 5 | 5 | 5 | 5 | 2 | 1 |
| 2006 12 01 | 3 | 1 | 1 | 0 | 1 | 1 | 1 | 2 | 1 | 3 | -1 | 0 | 0 | 2 | 2 | 1 | 1 | 1 | 4 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 2 |
| 2006 12 02 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 2 | 0 | 0 | 1 | 1 | 2 | 0 | 0 | 0 | 2 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 |
| 2006 12 03 | 2 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 3 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 1 |
| 2006 12 04 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| 2006 12 05 | 2 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 2 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 2 |
| 2006 12 06 | 15 | 3 | 3 | 2 | 3 | 3 | 2 | 4 | 3 | 52 | 2 | 4 | 3 | 7 | 6 | 6 | 5 | 3 | 28 | 3 | 4 | 3 | 5 | 5 | 3 | 5 | 3 |
| 2006 12 07 | 14 | 4 | 3 | 4 | 3 | 3 | 2 | 1 | 2 | 46 | 5 | 4 | 6 | 6 | 6 | 4 | 3 | 3 | 25 | 5 | 4 | 5 | 4 | 4 | 3 | 3 | 3 |
| 2006 12 08 | 17 | 4 | 4 | 3 | 3 | 3 | 2 | 3 | 3 | 48 | 4 | 5 | 6 | 6 | 6 | 5 | 3 | 2 | 25 | 3 | 5 | 3 | 5 | 3 | 3 | 3 | 3 |
| 2006 12 09 | 6 | 1 | 1 | 1 | 0 | 0 | 1 | 2 | 4 | 13 | 4 | 3 | 2 | 2 | 0 | 3 | 3 | 3 | 7 | 1 | 1 | 1 | 0 | 0 | 1 | 2 | 4 |
| 2006 12 10 | 8 | 1 | 2 | 1 | 2 | 3 | 3 | 2 | 2 | 29 | 3 | 2 | 3 | 5 | 6 | 5 | 3 | 2 | 14 | 2 | 3 | 1 | 3 | 4 | 4 | 3 | 3 |
| 2006 12 11 | 11 | 3 | 3 | 3 | 1 | 1 | 1 | 2 | 4 | 19 | 3 | 4 | 4 | 4 | 3 | 2 | 2 | 4 | 15 | 3 | 4 | 3 | 1 | 1 | 1 | 2 | 5 |
| 2006 12 12 | 15 | 2 | 3 | 3 | 2 | 3 | 3 | 2 | 4 | 50 | 4 | 6 | 6 | 5 | 6 | 4 | 4 | 4 | 26 | 3 | 5 | 3 | 3 | 4 | 3 | 5 | 4 |
| 2006 12 13 | 5 | 2 | 3 | 0 | 0 | 1 | 1 | 1 | 2 | 5 | 3 | 2 | 0 | 1 | 1 | 1 | 1 | 1 | 5 | 3 | 3 | 0 | 0 | 0 | 0 | 0 | 2 |
| 2006 12 14 | 30 | 2 | 1 | 2 | 3 | 5 | 5 | 3 | 6 | 68 | 1 | 4 | 3 | 4 | 7 | 7 | 7 | 5 | 63 | 2 | 1 | 2 | 2 | 6 | 7 | 6 | 8 |
| 2006 12 15 | 48 | 7 | 6 | 5 | 5 | 4 | 2 | 3 | 3 | 120 | 6 | 7 | 8 | 8 | 7 | 6 | 4 | 3 | 104 | 8 | 8 | 7 | 6 | 7 | 4 | 4 | 3 |
| 2006 12 16 | 10 | 2 | 3 | 1 | 1 | 1 | 3 | 3 | 3 | 7 | 3 | 3 | 1 | 1 | 0 | 2 | 2 | 2 | 11 | 3 | 4 | 1 | 1 | 0 | 2 | 4 | 3 |
| 2006 12 17 | 3 | 2 | 1 | 0 | 0 | 0 | 1 | 2 | 1 | 4 | 2 | 2 | 0 | 0 | 1 | 1 | 2 | 1 | 4 | 2 | 1 | 0 | 0 | 0 | 1 | 1 | 1 |
| 2006 12 18 | 7 | 1 | 2 | 1 | 1 | 2 | 2 | 2 | 3 | 8 | 1 | 0 | 1 | 4 | 3 | 2 | 1 | 2 | 8 | 1 | 2 | 1 | 2 | 1 | 2 | 2 | 4 |
| 2006 12 19 | 9 | 2 | 3 | 2 | 3 | 3 | 2 | 1 | 1 | 33 | 2 | 3 | 3 | 7 | 5 | 4 | 2 | 2 | 14 | 3 | 4 | 2 | 4 | 3 | 1 | 2 | 2 |
| 2006 12 20 | 16 | 4 | 3 | 2 | 2 | 3 | 3 | 4 | 3 | 45 | 4 | 3 | 3 | 6 | 6 | 5 | 5 | 5 | 24 | 4 | 4 | 3 | 2 | 4 | 3 | 5 | 4 |
| 2006 12 21 | 9 | 4 | 2 | 3 | 2 | 2 | 2 | 1 | 1 | 29 | 3 | 2 | 6 | 5 | 5 | 3 | 3 | 2 | 14 | 4 | 3 | 4 | 3 | 3 | 2 | 2 | 1 |
| 2006 12 22 | 10 | 3 | 2 | 2 | 3 | 2 | 2 | 2 | 3 | 55 | 2 | 5 | 7 | 7 | 5 | 4 | 3 | 3 | 14 | 3 | 3 | 4 | 4 | 3 | 2 | 2 | 3 |
| 2006 12 23 | 10 | 2 | 2 | 3 | 2 | 3 | 3 | 2 | 2 | 29 | 3 | 1 | 4 | 5 | 6 | 4 | 4 | 2 | 15 | 2 | 2 | 3 | 2 | 3 | 4 | 4 | 2 |
| 2006 12 24 | 7 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 14 | 2 | 1 | 4 | 2 | 4 | 3 | 3 | 2 | 10 | 3 | 2 | 3 | 1 | 2 | 3 | 2 | 2 |
| 2006 12 25 | 4 | 3 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 10 | 3 | 2 | 2 | 2 | 3 | 3 | 1 | 2 | 6 | 3 | 2 | 2 | 1 | 2 | 1 | 0 | 1 |
| 2006 12 26 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 3 | 1 | 0 | 1 | 2 | 1 | 1 | 1 | 0 | 3 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 |
| 2006 12 27 | 2 | 1 | 1 | 0 | 0 | 1 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 2 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 2006 12 28 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 2 |
| 2006 12 29 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 2006 12 30 | 2 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2006 12 31 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

## Appendix C Performance Analysis (PAN) Problem Report

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

**Problem Description:**

There were no issued with SPS performance this quarter.

The terms and definitions discussed below are taken from the Standard Positioning Service Performance Specification (October 2001). An understanding of these terms and definitions is a necessary prerequisite to full understanding of the Signal Specification.

**General Terms and Definitions**

**Almanac Longitude of the Ascending Node (.o):** Equatorial angle from the Prime Meridian (Greenwich) at the weekly epoch to the ascending node at the ephemeris reference epoch.

**Coarse/Acquisition (C/A) Code:** A PRN code sequence used to modulate the GPS L1 carrier.

**Corrected Longitude of Ascending Node (Ok) and Geographic Longitude of the Ascending Node (GLAN):** Equatorial angle from the Prime Meridian (Greenwich) to the ascending node, both at arbitrary time $T_k$.

**Dilution of Precision (DOP):** The magnifying effect on GPS position error induced by mapping GPS ranging errors into position within the specified coordinate system through the geometry of the position solution. The DOP varies as a function of satellite positions relative to user position. 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.

**Equatorial Angle:** An angle along the equator in the direction of Earth rotation.

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

**Ground track Equatorial Crossing (GEC, ?, 2 SOPS GLAN):** Equatorial angle from the Prime Meridian (Greenwich) to the location a ground track intersects the equator when crossing from the Southern to the Northern hemisphere. GEC is equal to Ok when the argument of latitude (? ) is zero.

**Instantaneous User Range Error (URE):** The difference between the pseudo range measured at a given location and the expected pseudo range, as derived from the navigation message and the true user position, neglecting the bias in receiver clock relative to GPS time. A signal-in-space (SIS) URE includes residual orbit, satellite clock, and group delay errors. A system URE (sometimes known as a User Equivalent Range Error, or UERE) contains all line-of-sight error sources, to include SIS, single-frequency ionosphere model error, troposphere model error, multipath and receiver noise.

**Longitude of Ascending Node (LAN):** A general term for the location of the ascending node – the point that an orbit intersects the equator when crossing from the Southern to the Northern hemisphere.

**Longitude of the Ground track Equatorial Crossing (GEC, ?, 2 SOPS GLAN):** Equatorial angle from the Prime Meridian (Greenwich) to the location a ground track intersects the equator when crossing from the Southern to the Northern hemisphere. GEC is equal to Ok when the argument of latitude (? ) is zero.

**Mean Down Time (MDT):** A measure of time required to restore function after any downing event.

**Mean Time Between Downing Events (MTBDE):** A measure of time between any downing events.

**Mean Time Between Failures (MTBF):** A measure of time between unscheduled downing events.

**Mean Time to Restore (MTTR):** A measure of time required to restore function after an unscheduled downing event.

**Navigation Message:** Data contained in each satellite's ranging signal and consisting of 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. The message structure is described in Section 2.1.2 of the SPS Performance Standard.

**Operational Satellite:** A GPS satellite which is capable of, but is not necessarily transmitting a usable ranging signal.

**PDOP Availability:** Defined to be the percentage of time over any 24-hour interval that the PDOP value is less than or equal to its threshold for any point within the service volume.

**Positioning Accuracy:** Defined to be the statistical difference, at a 95% probability, between position measurements and a surveyed benchmark for any point within the service volume over any 24-hour interval.

- **Horizontal Positioning Accuracy:** Defined to be the statistical difference, at a 95% probability, between horizontal position measurements and a surveyed benchmark for any point within the service volume over any 24-hour interval.
- **Vertical Positioning Accuracy:** Defined to be the statistical difference, at a 95% probability, between vertical position measurements and a surveyed benchmark for any point within the service volume over any 24-hour interval.

**Position Solution:** An estimate of a user’s location derived from ranging signal measurements and navigation data from GPS.

**Position Solution Geometry:** The set of direction cosines that define the instantaneous relationship of each satellite's ranging signal vector to each of the position solution coordinate axes.

**Pseudo Random Noise (PRN):** A binary sequence that appears to be random over a specified time interval unless the shift register configuration and initial conditions for generating the sequence are known. Each satellite generates a unique PRN sequence that is effectively uncorrelated (orthogonal) to any other satellite’s code over the integration time constant of a receiver’s code tracking loop.

**Representative SPS Receiver:** The minimum signal reception and processing assumptions employed by the U.S. Government to characterize SPS performance in accordance with performance standards defined in Section 3 of the SPS Performance Standard. Representative SPS receiver capability assumptions are identified in Section 2.2 of the SPS Performance Standard.

**Right Ascension of Ascending Node (RAAN):** Equatorial angle from the celestial principal direction to the ascending node.

**Root Mean Square (RMS) SIS URE:** A statistic that represents instantaneous SIS URE performance in an RMS sense over some sample interval. The statistic can be for an individual satellite or for the entire constellation. The sample interval for URE assessment used in the SPS Performance Standard is 24 hours.

**Selective Availability:** Protection technique formerly employed to deny full system accuracy to unauthorized users. SA was discontinued effective midnight May 1, 2000.

**Service Availability:** Defined to be the percentage of time over any 24-hour interval that the predicted 95% positioning error is less than its threshold for any given point within the service volume.

- **Horizontal Service Availability:** Defined to be the percentage of time over any 24-hour interval that the predicted 95% horizontal error is less than its threshold for any point within the service volume.
- **Vertical Service Availability:** Defined to be the percentage of time over any 24-hour interval that the predicted 95% vertical error is less than its threshold for any point within the service volume.

**Service Degradation:** A condition over a time interval during which one or more SPS performance standards are not supported.

**Service Failure:** A condition over a time interval during which a healthy GPS satellite's ranging signal exceeds the Not-to-Exceed (NTE) SPS SIS URE tolerance.

**Service Reliability:** The percentage of time over a specified time interval that the instantaneous SIS SPS URE is maintained within a specified reliability threshold at any given point within the service volume, for all healthy GPS satellites.

**Service Volume:** The spatial volume supported by SPS performance standards. Specifically, the SPS Performance Standard supports the terrestrial service volume. The terrestrial service volume covers from the surface of the Earth up to an altitude of 3,000 kilometers.

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

**SPS Performance Standard:** A quantifiable minimum level for a specified aspect of GPS SPS performance. SPS performance standards are defined in Section 3.0.

**SPS Ranging Signal:** An electromagnetic signal originating from an operational satellite. The SPS ranging signal consists of a Pseudo Random Noise (PRN) C/A code, a timing reference and sufficient data to support the position solution generation process. A description of the GPS SPS signal is provided in Section 2. The formal definition of the SPS ranging signal is provided in ICDGPS-200C.

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

**SPS SIS User Range Error (URE) Statistic:**

- A satellite SPS SIS URE statistic is defined to be the Root Mean Square (RMS) difference between SPS ranging signal measurements (neglecting user clock bias and errors due to propagation environment and receiver), and "true" ranges between the satellite and an SPS user at any point within the service volume over a specified time interval.
- A constellation SPS SIS URE statistic is defined to be the average of all satellite SPS SIS URE statistics over a specified time interval.

**Time Transfer Accuracy Relative to UTC (USNO):** The difference at a 95% probability between user UTC time estimates and UTC (USNO) at any point within the service volume over any 24-hour interval.

**Transient Behavior:** Short-term behavior not consistent with steady-state expectations.

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

**User Navigation Error (UNE):** Given a sufficiently stationary and ergodic satellite constellation ranging error behavior over a minimum sample interval, multiplication of the DOP and a constellation ranging error standard deviation value will yield an approximation of the RMS position error. This RMS approximation is known as the UNE (UHNE for horizontal, UVNE for vertical, and so on). The user is cautioned that any divergence away from the stationary and ergodic assumptions will cause the UNE to diverge from a RMS value based on actual measurements.

**User Range Accuracy (URA):** A conservative representation of each satellite's expected (1ó) SIS URE performance (excluding residual group delay) based on historical data. A URA value is provided that is representative over the curve fit interval of the navigation data from which the URA is read. The URA is a coarse representation of the URE statistic in that it is quantized to levels represented in ICDGPS200C.