**Discrepancy Report (DR)**
**WAAS Test Team, W. J. H. Technical Center**
**Atlantic City International Airport, AC NJ 08405**
**8/7/12**

***DR#: PRN 19 Ephemeris Update Anomaly on 17 June 2012, GPS Week 1690 Day 3***

**Discussion:**

On June 17, 2012, an anomalous ephemeris update caused a large satellite estimated position error for PRN-19 which resulted in a GPS integrity failure. PRN-19 remained "Healthy" for the duration of the event with a User Range Accuracy (URA) of 2.4 meters (URA index = 0). The user exposure to the event lasted 26.5 minutes.

An after the fact Notice Advisory to NAVSTAR Users (NANU) was issued the following day at 22:15 GMT. NANU number 2012039 of type UNUNOREF documented that PRN 19 was unusable on June 17 between 00:09 and 00:37 GMT.

The Issue of Data Clock (IODC) of the anomalous ephemeris data set was 0. The IODC of the prior good data set was 89, the IODC of the data set that corrected the problem was 93. The Time of Transmits (ToT) of the data sets rounded to the start of the next subframe 4 are listed in Table 1 below. (TOW is time of GPS week in seconds)

**Table 1 - Time of Transmit**

| IODC | ToT |
|---|---|
| 89 | TOW = 000018 (00:00:18 GPS) |
| 00 | TOW = 000648 (00:10:48 GPS) |
| 93 | TOW = 002238 (00:37:18 GPS) |

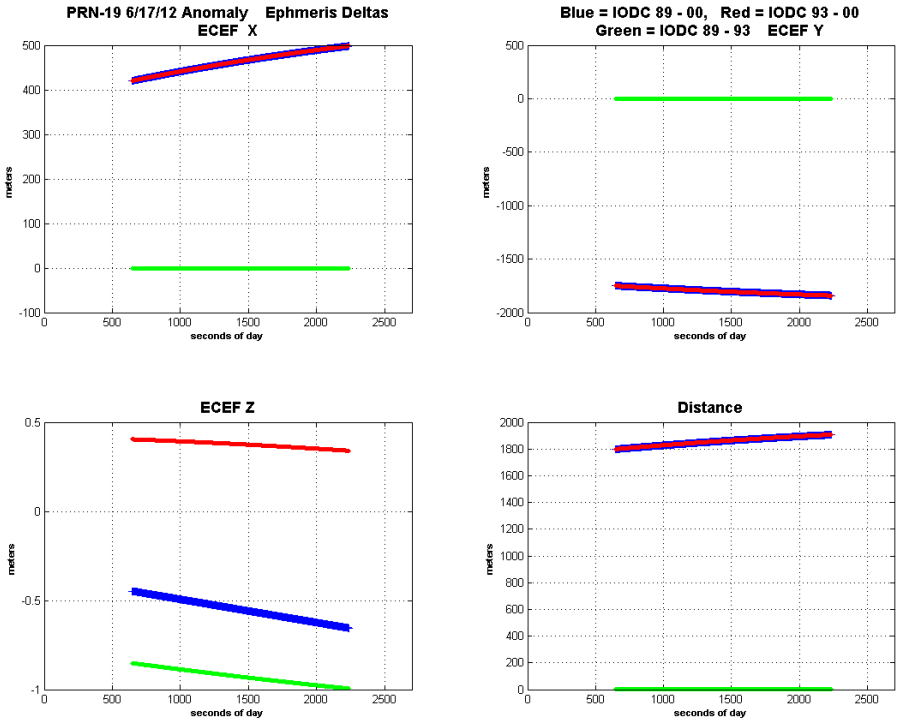
The estimated satellite position errors caused by the IODC 00 data set were in the ECEF X and Y directions. The ECEF Z direction and the clock correction terms remained good. Figure 1 provides plots of the ECEF X, Y, and Z differences and the total satellite position estimate displacement using the IODC 89 ephemeris as the reference. Figure 1 shows that IODC 89 and IODC 93 data sets are in close agreement and that the errors were as stated above.

Figure 2 provides the equivalent information for the broadcast clock correction information. The fine print on the y-axis is that the exponent for the y-axis is 10e-9.

Because of the high altitude of the GPS satellites, only a portion of the along track and cross track position errors project on to users on the surface of the earth. The magnitude of those errors also varies greatly by user location within the satellite's footprint.

Figure 3 provides a plot of the maximum PRN-19 range error by location for users estimating the elevation angle to PRN-19 to be >= 5 degrees. The anomalous IODC 00 ephemeris was used for the elevation angle calculation since that is what would have been used by the impacted users. The maximum is calculated over the duration of the anomaly event. During the event, PRN-19 was moving north to south over north central Africa, almost directly above the border between Chad and Niger. The white line in Figure 3 shows the path of PRN-19 during the event. Note, range error does not directly equate with position error. The position error can be much smaller, depending on how the erroneous measurement is weighted in the user's position solution.

## Figure 1 - PRN-19 Anomaly Satellite Position Differences




## Figure 2 - PRN-19 Anomaly Satellite Clock Differences

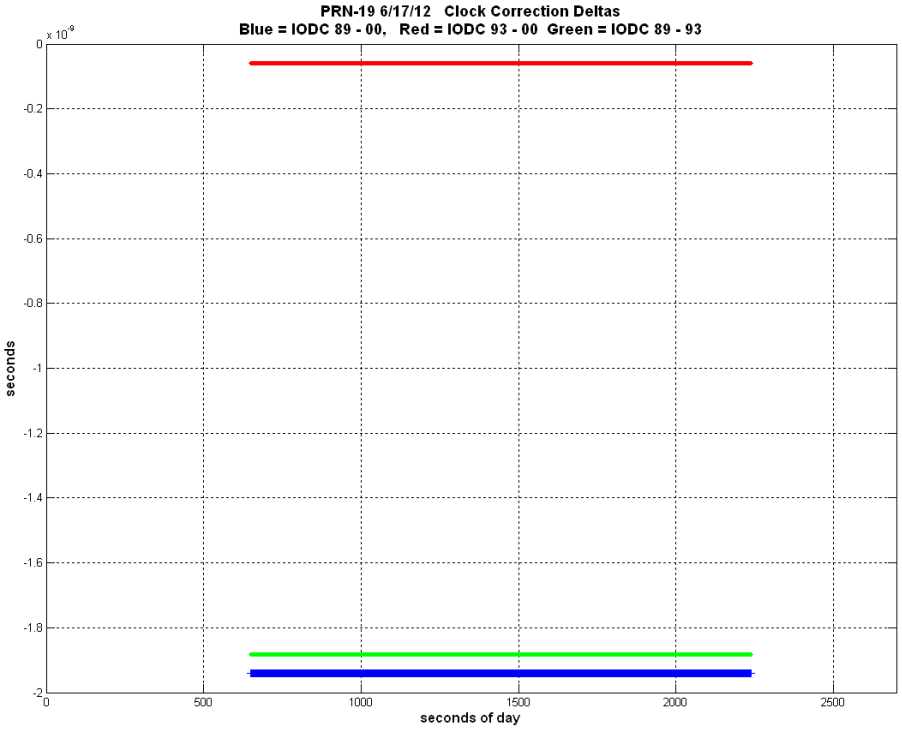
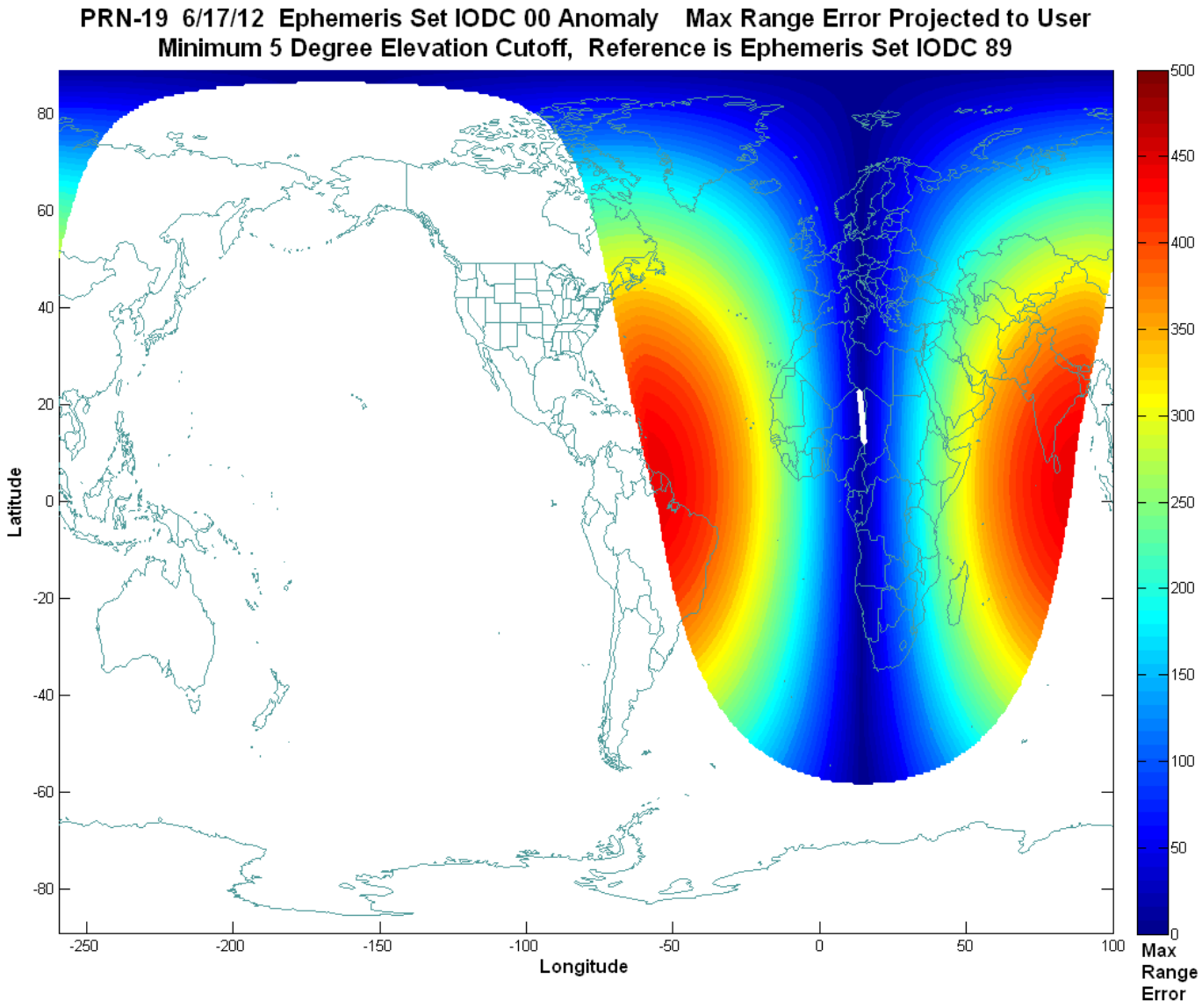


**Figure 3 - PRN-19 User Range Errors**



The parameters for the three ephemeris sets are provided in Table 2.

**Table 2 - Ephemeris Parameters**

| Parameter | IODC 89 | IODC 00 | IODC 93 |
|---|---|---|---|
| ToT | 6 | 636 | 2226 |
| URA | 2.4 | 2.4 | 2.4 |
| Health | 0 | 0 | 0 |
| IODC | 89 | 0 | 93 |
| $T_{OC}$ | 7200 | 7184 | 7168 |
| $a_{f0}$ | -0.000275939 | -0.000275937 | -0.000275937 |
| $a_{f1}$ | -3.64E-12 | -3.64E-12 | -3.64E-12 |
| $a_{f2}$ | 0 | 0 | 0 |
| IODE | 89 | 0 | 93 |
| $C_{rs}$ | 12.96875 | 12.96875 | 12.96875 |
| del_N ($\Delta$n) | 4.74E-09 | 4.74E-09 | 4.74E-09 |
| $M_0$ | -2.863937464 | -2.866268834 | -2.868605092 |
| $C_{UC}$ | 6.63E-07 | 6.63E-07 | 6.63E-07 |
| ecc (e) | 0.008430906 | 0.008430919 | 0.008430911 |
| $C_{US}$ | 7.93E-06 | 7.92E-06 | 7.93E-06 |
| sqrt_A | 5153.58362 | 5153.583572 | 5153.583628 |
| $T_{OE}$ | 7200 | 7184 | 7168 |
| $C_{ic}$ | -1.47E-07 | -1.47E-07 | -1.47E-07 |
| OMEGA_0 ($\Omega_0$) | -2.562771535 | -2.562698513 | -2.562771291 |
| $C_{is}$ | -8.57E-08 | -8.57E-08 | -8.57E-08 |
| $i_0$ | 0.960489037 | 0.960489013 | 0.960489012 |
| $C_{rc}$ | 228.6875 | 228.8125 | 228.6875 |
| omega ($\omega$) | 0.179028451 | 0.179025969 | 0.179028304 |
| OMEGADOT | -7.82E-09 | -7.82E-09 | -7.82E-09 |
| IDOT | 5.16E-10 | 5.16E-10 | 5.16E-10 |
| GPS Week | 1693 | 1693 | 1693 |
| Fit | 4 | 4 | 4 |

**SBAS Response**

The SBAS response to the 6/17/19 PRN-19 ephemeris anomaly was:

**Table 3 - SBAS Response to the Anomaly**

| | |
|---|---|
| WAAS | Prevented the use of the IODC 00 data and set PRN-19 to "Do Not Use" until PRN-19 set out of view of WAAS 25.5 minutes later when it was set to "Not Monitored". |
| EGNOS | EGNOS set PRN-19 to "not monitored" during the event and held it "Not Monitored" for approximately two additional hours beyond the end of the event. |
| GAGAN | Although still under test, GAGAN prevented the use of the IODC 00 data and set PRN-19 to "Do Not Use" until it started using the IODC 93 data set. |
| MSAS | PRN-19 was not visible by MSAS during the event. |

**FD/FDE RAIM Performance Within the WAAS Service Area**

RAIM is Receiver Autonomous Integrity Monitoring. RAIM is required for aviation certified receivers when not using an augmentation system like WAAS. RAIM performance was evaluated using receiver measurement data from the WAAS Gander Newfoundland Canada reference station.

Older aviation receivers still assume GPS Selective Availability (SA) is turned on (SA ON), while newer receivers assume SA is off (SA OFF). The SA ON uncertainty penalty makes the RAIM on SA ON receivers less sensitive to smaller errors and results in larger uncertainty bounds being calculated.

The Gander data was processed using both SA ON and SA OFF algorithms. The SA OFF algorithm successfully detected the problem and excluded the faulty PRN-19 data. The SA ON algorithm also successfully detected and excluded PRN-19 at the beginning of the event, but allowed PRN-19 back into the solution for last 7 minutes that PRN-19 was in view of Gander. PRN-19 was allowed back into the solution because the error was small enough relative to the SA ON uncertainties. Table 4 contains the overview of the RAIM results for Gander. Note, the maximums do not occur at the same time for the different rows.

**Table 4 - WAAS Gander RAIM Results for 6/17/12 PRN-19 Anomaly**

| Mode | Time | Exclude PRN 19? | Maximum Horizontal Error | Horizontal Protection Level |
|---|---|---|---|---|
| SA OFF | entire event | Yes | 3.1 m | 50.0 m |
| SA ON | 00:10:48 to 00:30:00 | Yes | 2.7 m | 257.8 m |
| SA ON | 00:30:00 to 00:37:18 | No | 35.5 | 156.6 m |