(Preprint) AAS 13-509

THE GPS SVN59 SATELLITE ANOMALY OF 17 JUNE 2012*

Thomas Johnson†, Stephen Malys‡, and Barbara Wiley§

The National Geospatial-Intelligence Agency (NGA) has a supportive role in the daily operations of the U.S. Global Positioning System (GPS). The Earth-Centered, Earth-Fixed World Geodetic System 1984 (WGS 84) reference frame is realized by the adoption of a self-consistent set of highly-accurate coordinates for the Department of Defense (DoD) GPS Monitor Stations. Over the past decades, numerous procedures and operational controls have been instituted to ensure the continuous uninterrupted GPS operations. It was a failure of these procedures that caused an erroneous broadcast message from GPS Space Vehicle Number 59 (SVN59) on June 17, 2012. This occurred due to an improper application of the leap second in the NGA Earth Orientation Parameter Predictions (EOPP) which NGA delivers to the USAF for their use in generating GPS satellite broadcast messages. The duration of the error was limited to 27 minutes due to quick discovery and resolution of the problem. An internal NGA 'after action review' of the events leading up to this failure resulted in the development and implementation of additional safe guards to prevent future incidents.

INTRODUCTION

The Defense Mapping Agency (DMA), a predecessor of the National Geospatial-Intelligence Agency (NGA), was a signatory on 1975 GPS Joint Program Office Charter and therefore, has had a supportive role in GPS since its beginning. NGA's GPS mission includes:

1. Provide and maintain global geodetic reference frame and coherent set of geophysical models (WGS 84),
2. Provide satellite tracking data to support daily GPS Operations,
3. In collaboration with the US Naval Observatory (USNO), provide Earth orientation predictions in support of GPS operations, and
4. Generation and distribution of GPS precise (post-fit) ephemerides and GPS clock solutions.

---

* Approved for Public Release Case 13-350.
† Program Manager, National Geospatial-Intelligence Agency, InnoVision Basic and Applied Research Office, 7500 GEOINT DR., Springfield, VA 22150.
‡ Senior Scientist for Geodesy and Geophysics, National Geospatial-Intelligence Agency, InnoVision Basic and Applied Research Office, 7500 GEOINT Dr., Springfield, VA 22150.
§ National Geospatial-Intelligence Agency, Source Geomatics Office, 3838 Vogel Rd., Arnold, MO 63010.

To achieve this mission, NGA has a 24/7 GPS operations team and 11 GPS monitor stations located around the world.

NGA is responsible for maintaining the WGS 84 global geodetic reference frame and other related geophysical models. The WGS 84 Earth-Centered, Earth-Fixed reference frame is realized by the adoption of a self-consistent set of highly-accurate coordinates for the DoD GPS Monitor Station (MS) antennas located around the world (Figure 1). These monitor station antennas are attached to the crust of the rotating Earth. The GPS time scale used for all GPS orbit processing is directly tied to UTC(USNO) through well-established, operational processes. The orbit determination process requires transformation between the Earth-Centered, Earth-Fixed reference frame and the Earth-Centered Inertial reference frame, and therefore knowledge and accurate prediction of small changes to the Earth's rotation angle (UT1). The quantity UT1−UTC is used in these transformations and will remain an essential element of information for GPS and other satellite missions requiring high-accuracy orbit determination. This paper briefly reviews NGA's GPS support role and the procedural failure that led to the erroneous upload to SVN59 that temporarily degraded system performance on 17 June 2012.

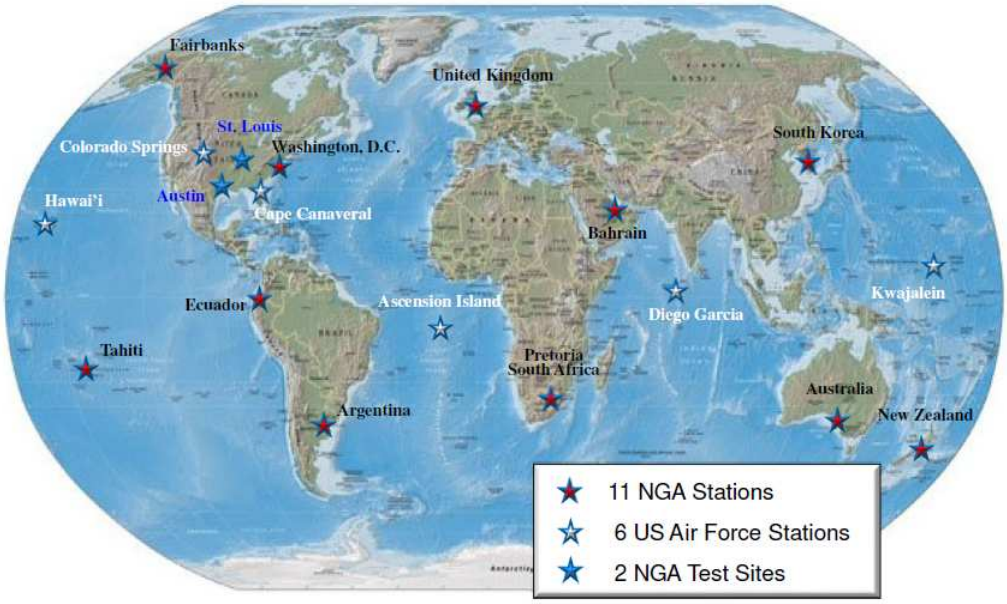

Figure 1. DoD GPS Monitor Station Network.

NGA OPERATIONAL SUPPORT

The NGA GPS Network Control Center supplies continuous real-time support to the U.S. Air Force 2nd Space Operations Squadron's (USAF 2SOP's) GPS operations. This support is a collaborative effort between NGA and the USAF that includes the sharing of data, anomaly resolution, and collaboration on GPS performance monitoring. NGA's GPS tracking data directly improves GPS broadcast ephemerides and satellite clock states and also serves to quickly detect on-orbit performance anomalies. NGA also generates its own precise (post-fit) GPS ephemerides daily in support of world-wide geodetic surveying and quality control for GPS operations.

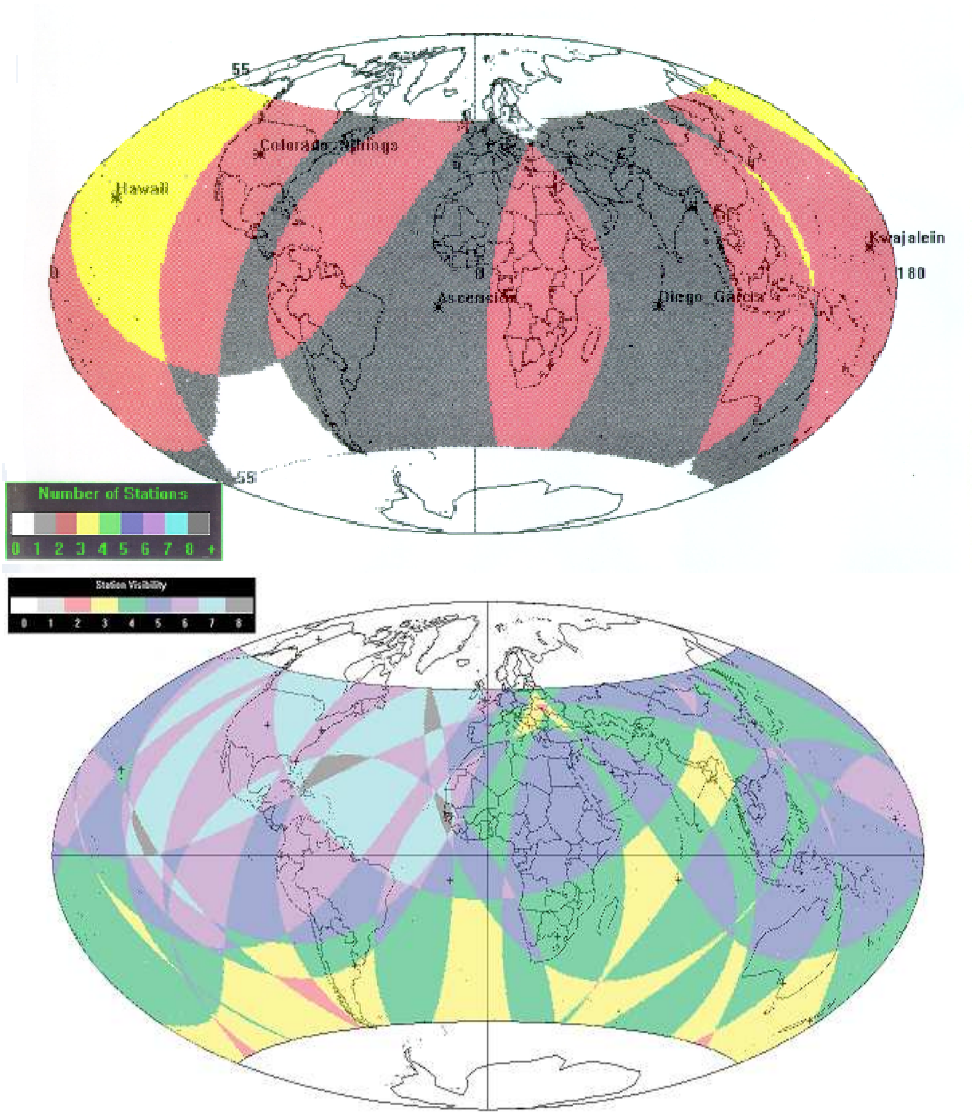

Figure 2. NGA Monitor Stations (MS) impact on GPA satellite visibility: (top) Satellite visibility by ground based AF MS and (bottom) Satellite visibility by combined AF and NGA MS network. (Visibility Legend Information: White: 0 MS, Dark Gray: 1 MS, Salmon: 2 MS, Yellow: 3 MS, Green: 4 MS, Blue: 5 MS, Violet 6 MS, Cyan 7 MS, and Light Gray 8 MS)

Daily Earth Orientation Parameter Predictions (EOPP) and post-fit estimates, generated using USNO's daily Earth Orientation Parameter (EOP) solutions, are used in Earth-fixed to inertial reference frame transformations that are critical to daily GPS operations. Over the past several decades, procedures, Interface Control Documents (ICD), and operational, configuration-controlled software have been designed to deal with EOP predictions and especially leap seconds. The required accuracy of these EOP predictions and their message formats are documented in the ICD-GPS-211. Currently, ICD-GPS-211 between NGA and the USAF 2SOPS indicates that the UT1−UTC parameter is to be maintained to less than 1.0 second which requires the occasional insertion of leap seconds as determined by the IERS. More details on these procedures are found in Malys (2011).[1] Note that in the coming years, this ICD will be replaced by ICD-GPS-811. This new ICD defines the requirements for data transfer between NGA and the USAF's Next Genera-

tion Operational Control Segment known as 'OCX'. This new interface treats the UT1−UTC parameter in a similar fashion. The main point here is the fact that the handling of the leap second has been 'institutionalized' within procedures, software, and documentation.

EFFECT ON GPS OPERATIONS

NGA's additional MSs have greatly improved the satellite visibility compared to the USAF's six original MS, see Figure 2. Prior to the addition of the NGA MSs, large regions existed where satellites were not visible or only visible by one USAF MS. Now, with the addition of NGA stations, each satellite is rarely visible by less than three MSs.

As indicated earlier, the ICDs state requirements for the transfer of data between NGA, GPS Operational Control Segment, and other satellite operations. This has led to the development of procedures to ensure the proper production, verification, and dissemination of EOP predictions including processes for the insertion of leap seconds at the internationally-agreed-upon moment.

On 16 June 2012, there was an apparent breakdown in these procedures that accidentally and prematurely applied a leap second into the standard EOPP product. This product that contained the incorrect UT1−UTC was delivered to USAF/2SOPS for use in generating integrated reference trajectories. These reference trajectories were then used with tracking data in the Kalman Filter Process that resulted in an incorrect representation of the satellite positions.

The EOPP containing the premature leap second created a single erroneous upload to SVN59 on 17 June 2013. This resulted in an erroneous broadcast message from SVN59. The condition was discovered quickly and lasted for only 27 minutes (0009Z to 0036Z) before it was corrected.

NGA's 'After Action Review' has led to revised and redundant quality control procedures which were implemented to prevent a re-occurrence of this procedural failure.

CONCLUSION

The DoD GPS Monitor Stations, the 'starting point' for all GPS Positioning, Navigation and Timing (PNT) are located on the rotating Earth that is wobbling through space as it orbits the Sun. Therefore, a regular source of EOPP including UT1−UTC predictions will continue to be needed for GPS, and other DoD operations, including NGA.

Daily EOPP are critical to GPS operations. Operational software and automated routines for the transfer of EOPP between NGA, the GPS Operational Control Segment, and other DoD organizations have been developed in accordance to agreed-upon ICDs. The delivery of a daily EOPP product with a premature leap second applied to the USAF 2SOPS on 17 June 2012 is an unfortunate example of what can happen when there is a breakdown in these procedures. Therefore, NGA has added additional safe guards to prevent this from happening in the future.

REFERENCES

[1] Malys, S. (2011), "Proposal for the Redefinition of UTC: Influence on NGA Earth Orientation Predictions and GPS Operations" Paper AAS 11-675 (with discussion) from *Decoupling Civil Timekeeping from Earth Rotation—A Colloquium Exploring Implications of Redefining UTC*, American Astronautical Society Science and Technology Series, Vol. 113, pp. 265-270.