UNCLASSIFIED
TLP: WHITE

Best Practices for Leap Second Event Occurring on 31 December 2016

This paper is intended as a best practices guide to be used for the upcoming Leap Second event scheduled for Saturday, 31 December 2016.

Sponsored by the Department of Homeland Security's National Cybersecurity and Communications Integration Center in coordination with the United States Naval Observatory, National Institute of Standards and Technology, the USCG Navigation Center, and the National Coordination Office for Space-Based Positioning, Navigation and Timing. This product is intended to assist federal, state, local, and private sector organizations with preparations for Saturday, 31 December 2016 Leap Second event.

The decision to add a leap second is made by the International Earth Rotation and Reference Systems Service, an international standards body, to accommodate for variations in the Earth's rotational speed. The U.S. federal government's Global Positioning System (GPS) broadcasts leap second correction information in the navigation message. However, it is the responsibility of users to assure that their hardware and software recognizes and manages the leap second correctly; errors and equipment failures can occur when GPS receivers and clocks process the leap second signal incorrectly. Please ensure all software and firmware is up to date.

Please report operational challenges you experience to the following organizations:

GPS — United States Coast Guard Navigation Center (NAVCEN) 703-313-5900 or via the NAVCEN Website, http://www.navcen.uscg.gov/ under "Report a GPS Problem"

NIST Time Dissemination Services — Michael Lombardi at NIST, Boulder, Colorado at 303-497-3212, or michael.lombardi@nist.gov.

---

1. Leap Second Introduction

The Coordinated Universal Time (UTC) time standard, based on atomic clocks, is widely used for international timekeeping. UTC is the basis of legal time for most of the world, including the United States. For the DoD, UTC (USNO), UTC as realized by the U.S. Naval Observatory (USNO), is the standard for all DoD systems/operations. UTC (NIST), UTC as realized by the National Institute of Standards and Technology (NIST), is official time for civilian use. The two time scales are equivalent to within 50 nanoseconds, and for many applications either may be used.

UTC must be adjusted at irregular intervals to keep it close to mean solar time, due to irregularities in Earth's rotation. These adjustments, called leap seconds, are pre-determined. The next leap second will occur on 31 December 2016 at 23:59:59 UTC.

Specifically, a positive leap second will be inserted between second 23:59:59 UTC of 31 December and second 00:00:00 UTC of 1 January 2017. This extra second is displayed on UTC clocks as 23:59:60.

Historically, previous Leap Seconds have posed challenges to operations. With these challenges in mind, this best practices guide provides:

- Information to prepare for the upcoming Leap Second;
- Steps to resolve any operational issues;
- Guidance for reporting Leap Second related operational issues.

UTC is the official term for the time maintained cooperatively by many countries, using atomic clocks. The term is often used colloquially to refer to time scales based on the time zone of the prime meridian, zero longitude (e.g., military time, Zulu time, Greenwich Mean Time (GMT)). (Time scales based on astronomy [e.g., mean solar time] will differ slightly from UTC.) Local time zone offsets apply as needed. For example, the 31 December 2016 leap second will occur at 6:59:59 PM Eastern Standard Time on the East coast of the United States and 3:59:59 PM Pacific Standard Time on the West coast of the United States.

NOTE: Systems that do not receive time via an external reference *may* require manual resetting or synchronization to maintain consistency with UTC.

For more information on Leap Seconds, please see the background following the best practices.

---

2. Leap Second Preparation

a. Check and verify leap second insertion procedures on all systems dependent on precise time to verify leap second insertion will not disrupt normal operation.

b. Verify Global Positioning System (GPS) ***receivers are built in accordance with GPS Interface Specification IS-GPS-200H.*** The time disseminated by GPS is UTC (USNO). The latest specification may be found at http://www.gps.gov/technical/icwg/. These receivers should automatically adjust UTC time of day outputs to reflect leap second changes.

c. Verify Network Time Protocol (NTP) servers and clients systems are built to account for leap seconds. Some vendors may offer tests than can be run prior to the leap second event.

---

3. Leap Second Implementation

The Leap Second occurs simultaneously worldwide based on UTC day transition 31 December/1 January, irrespective of your local time zone.
To implement the positive leap second, all UTC clocks will display an extra second. The date sequence of the UTC markers will be:

31 Dec 2016 23H 59M 59S
31 Dec 2016 23H 59M 60S * (extra second)

Followed by:
01 Jan 2017 00H 00M 00S
Note: If your clock is set to local time zones, then the above example will need to be adjusted to your local time zone.

Time on NTP clients and Stratum 2 servers should be verified after the leap second insertion. Systems receiving time over NTP may have delayed responses to the leap second update depending on the software version installed.

NOTE: Not all clocks implement leap seconds in the same manner as UTC above. Some may use multiple 59s or 00s verses the 60s scheme above or even just freeze the time for one second.

---

4. Leap Second and Global Positioning System (GPS)

a. GPS receivers should be unaffected by the addition of a leap second. ***Those built in accordance with IS-GPS-200H*** should adjust for this leap second change without user intervention. However, systems that use embedded GPS receivers as time references must be designed to accommodate the occurrence of leap seconds.

b. Leap seconds should not affect the use of GPS for navigation. Location is computed using GPS System Time, a time scale that is referenced to UTC as it was in 1980, without subsequent leap seconds. Only the conversion of GPS System Time to the conventional UTC time scale is affected by leap seconds.

c. The GPS signal provides advanced notice to the receiver that a leap second will occur. To receive this message, ensure that a GPS receiver has been turned on at least once since 19 July 2016, and prior to 2359 on 31 December 2016, for at least 30 minutes—the cycle time of the suite of messages. This will ensure that the latest almanac is downloaded, which will contain the leap second notification information.

    i. Reports indicate that some receivers not built in accordance with the standard (IS-GPS-200H) have experienced problems since the notice of the scheduled future leap second was uploaded to the GPS NAV message on 19 July 2016. A one second UTC time error appeared on some receivers following this notice as the receivers effectively introduced the leap second early. The receiver manufacturer and POCs listed in this document should be notified if this problem has occurred.

d. The leap second correction information is broadcast by GPS and is contained within the GPS navigation (NAV) message, sub frame 4, page 18. IS-GPS-200H sections "3.3.4 GPS Time and SV Z-Count" on page 40; "20.3.3.5.2.4 Coordinated Universal Time (UTC)" on page 123; and "30.3.3.6.2 UTC and GPS Time" on page 180 provide detailed information related to the leap second.
e. The leap second correction contained within the UTC data of subframe 4, page 18 of the navigation message transmitted by satellites will change from 17s to 18s.

---

5. Leap Second and Network Time Protocol (NTP)

Care should be taken with NTP.

a. Network managers should verify their networks are utilizing a traceable NTP source. These include the NTP servers provided by NIST (see http://tf.nist.gov/tf-cgi/servers.cgi) and USNO, at:

DNS	IP address	Location
ntp.usno.navy.mil	192.5.41.40	Washington, D.C.
ntp.usnogps.navy.mil	204.34.198.40	Colorado Springs, CO

These NTP servers will correctly implement leap seconds.

b. NTP data packets may include a leap second flag, which informs the user client software that a leap second is imminent. This allows the user client software to automatically adjust for leap seconds.

c. Certain computer systems are not designed to handle the existence of leap seconds—that is, other than 86,400 seconds in a day. When leap seconds occur, they handle them in various *ad hoc* ways. Some IT providers plan to spread the extra second out over many hours before or after the actual leap second. Others duplicate the time stamp of 23:59:59 or 00:00:00 over two seconds. Others ignore the leap second and resynchronize to UTC at some later time. NTP servers hosted on such computer systems may disseminate inaccurate data that follow from these *ad hoc* approaches. These data include both the time and the leap second flag. The time may be in error for up to a day after leap second insertion.

d. Users with computer systems that rely on NTP to obtain or disseminate the correct time to better than one second should take two steps. First, ensure that your NTP software is up to date. (See, e.g., http://www.ntp.org/downloads.html .) Second, ask the operators of any NTP servers that you use how their systems handle leap seconds. Verify that their solution will meet your requirements.

   NTP software updates should be checked on a recurring basis. The most current NTP software updates are located at http://www.ntp.org/downloads.html in accordance with service network policy. Some vendors integrate NTP updates into their comprehensive software updates. Other useful archived information can be found at http://www.ntp.org/.

---

6. Leap Second and Frequency Standards

Manual intervention may be required on some cesium and rubidium atomic frequency standards, as well as some quartz standards, that display the time of day (TOD). These standards' TOD display may be incorrect after the leap second, thus requiring an adjustment for the leap second. NOTE: the frequency accuracy of these standards will not be affected by the leap second.

Some commercial cesium clocks (e. g., the 5071) and similar devices can be programmed in advance to handle the leap second in the time display and outputs. The programming can be done in advance from the front panel as shown in the example below.

Following the procedures in the cesium manual, perform the following actions within 24 hours of the leap second (after 0000 UTC 31 December and prior to 2359 UTC 31 December):

a. The leap second flag may be set by using the control panel on the front of the cesium.

b. Verify the leap second occurred at 23:59:60 on 31 December.

---

7. Leap Second Problem Resolution

If you know your system will not work through the leap second on 31 December 2016:

a. Isolate the system from any external timing sources and manually insert the additional second at 23:59:59 UTC. Then reconnect the system after 00:00:00 UTC 1 January 2017.

If a problem occurs after 23:59:59 on Saturday, 31 December 2016 the following actions should be taken:

a. Verify the time on the system with respect to the website http://www.time.gov , or by calling the time voice announcers at the United States Naval Observatory (USNO) at **(202) 762-1401** or **(719) 567-6742** (DSN 762-1401 or 560-6742) or NIST at **(303) 499-7111**.
b. If the time on the system is off by 1 second, then reset the time to the correct time and, if necessary, restart the system.

---

8. Leap Second Reporting

Historically leap second changes have created significant operational problems. Please report operational challenges you experience to the following organizations:

GPS – United States Coast Guard Navigation Center (NAVCEN) 703-313-5900 or via the NAVCEN Website, http://www.navcen.uscg.gov/ under "Report a GPS Problem"

NIST Time Dissemination Services — Michael Lombardi at NIST, Boulder, Colorado at 303-497-3212, or michael.lombardi@nist.gov.

Thank you for supporting this effort to better understand leap second issues.

---

9. Leap Second History

UTC uses the International System (SI) definition of the second, based on atomic clocks.

a. **Definition of a Second** - In 1967 the General Conference on Weights and Measures (CGPM) defined the length of the second to be based on the atomic clock as follows. The second is the duration of 9,192,631,770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the cesium 133 atom. This defines the SI second.

b. **Definition of a Leap Second** - A leap second is a one second adjustment that is applied to Coordinated Universal Time (UTC) in order to keep its time of day close to the mean solar time standard (UT1). UT1 is based on precise measurement of the Earth's rotation.

c. **Determination of Leap Second Insertion** - Insertion of each UTC leap second is usually decided several months in advance (in this case was in July 2016) by the International Earth Rotation and Reference Systems Service (IERS), when needed to ensure that the difference between the UTC and UT1 readings will remain within +/- 0.9 second.

International Atomic Time (TAI) is the uniform time scale based on the atomic clock; its unit interval is defined by the SI second. Coordinated Universal Time (UTC) is derived from TAI, to provide a reference scale in step with the irregular rotation of the Earth. The timing standard for the DoD, UTC (USNO), is maintained at USNO. Official time for civilian use is maintained at NIST, providing UTC (NIST).

Meteorological, geological, and astronomical phenomena affect Earth's irregular rotation speed. This irregular motion of Earth's rotation rate is accounted for by the introduction of "leap seconds." Without such a correction, UT1 drifts away from UTC. Leap seconds are irregularly spaced and unpredictable. In fact it is possible that leap seconds may be either positive or negative, but so far, all leap seconds have been positive.
In 1972, the present definition of timekeeping was adopted that include the insertion of leap second so that the broadcast UTC seconds could be made exactly equal to the standard SI second, while still allowing the UTC time of day and changes of UTC date to be synchronized with those of UT1. By then, the UTC clock was already 10 seconds behind TAI, which had been synchronized with UT1 in 1958, but had been counting true SI seconds since then.

After 1972, both clocks have been ticking in SI seconds, so the difference between their readouts at any time is 10 seconds plus the total number of leap seconds that have been applied to UTC (36 seconds in July 2015). The most recent leap second was added on June 30, 2015 at 23:59:59 UTC. A leap second will again be inserted at the end of 31 December 2016 at 23:59:59 UTC.