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Best Practices for Leap Second Event Occurring on 30 June 2015

Sponsored by the 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 the 30-June 2015 Leap Second event.

Entities using precision time should be mindful that no leap second adjustment has occurred on a non-holiday weekday in the past decade. Of the three leap seconds implemented since 2000, two have been scheduled on 31 December and the most recent was on Sunday, 1 July 2012.

Please report operational challenges you experience to the United States Coast Guard Navigation Center (NAVCEN), via the NAVCEN Website, http://www.navcen.uscg.gov/ under "Report a GPS Problem"

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1. **Leap Second Introduction**

The Coordinated Universal Time (UTC) time standard, based on atomic clocks, is widely used for international timekeeping and as the reference for time in most countries. UTC is the basis of legal time for most of the world.

UTC must be adjusted at irregular intervals to maintain its correlation to mean solar time due to irregularities in the Earth's rotation. These adjustments, called leap seconds, are pre-determined. The next leap second will occur on 30 June 2015 at 23:59:59 UTC.

Specifically, a positive leap second will be inserted between second 23:59:59 of 30 June and second 00:00:00 of 1 July. 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 used by most industrial nations, but it is often also referred to approximate military time, Zulu time or Greenwich Mean Time (GMT). This approximates the time zone of the prime meridian, zero longitude. Local time zone offsets apply as needed. For example, the 30 June leap second will occur at 7:59:59 PM Eastern Daylight Savings Time on the East coast of the United States.

NOTE: Systems that do not receive time via external reference *may* require manual resetting/synchronization of clocks to maintain accuracy to UTC.

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

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2. **Leap Second Preparation**

    a. Check and verify leap second insertion procedures on all systems dependent on precise time (UTC) to verify leap second insertion will not disrupt normal operation.
    b. Verify Global Positioning System (GPS) *receivers are built in accordance with GPS interface specifications IS-GPS-200H* (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.

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3. **Leap Second Implementation**

The Leap Second occurs simultaneously worldwide based on UTC day transition 30 June/1 July, irrespective of your local time zone.

To implement the positive leap second, all UTC clocks will be display an extra second. The date sequence of the UTC markers will be:

30 Jun 2015 23H 59M 59S
30 Jun 2015 23H 59M 60S * (extra second)

Followed by:
01 Jul2015 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 vice the 60s scheme above or even just freeze the time for one second.

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4. **Leap Second and Global Positioning System (GPS)**

    a. Systems that receive UTC via GPS should be unaffected by the addition of a leap second. GPS *receivers built in accordance with IS-GPS-200H* should adjust for this leap second change without user intervention.

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b. The leap second correction information is broadcast by GPS and is contained within the GPS navigation 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.

c. No physical adjustments will be required for the GPS internal navigation time scale (GPS time).

d. Systems that receive UTC via GPS should be unaffected by the addition of a leap second if designed properly to account for this extra second.

e. Ensure the GPS receiver has been turned on at least once since Feb 2015, and prior to 2359 on 30 June, for at least 15 minutes to make sure the latest almanac is uploaded; this almanac will contain the leap second notification information in the navigation message.

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5. **Leap Second and Network Time Protocol (NTP)**

Care should be taken with NTP.

a. The NTP server 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.

b. There is a probability that some NTP servers may either not implement or incorrectly set their leap second flag.

c. As a result of the missing or incorrect leap second flag, many NTP servers broadcast the wrong time for up to a day after a leap second insertion. Clients systems may not properly account for seconds and not reflect UTC time.

d. Perform an update to the NTP software on the day prior to or day of the leap second event at http://www.ntp.org/downloads.html.

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.

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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.

Following the procedures in the cesium manual, perform the following actions within 24 hours of the leap second (after 0000 UTC 30 June and prior to 2359 UTC 30 June):

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 30 June.

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7. **Leap Second Problem Resolution**

If you know your system will not work through the leap second on 30 June 2015:
   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 July 2015.

If a problem occurs after 23:59:59 on Tuesday, 30 June the following actions should be taken:

   a. Verify the time on the system by calling the time voice announcers at the National Institute of Standards and Technology (NIST) at **(303) 499-7111** and **(808) 335-4363** or the United States Naval Observatory (USNO) at **(202) 762-1401** or **(719) 567-6742**.
   b. If the time is off by 1 second, then reset the time to the correct time indicated by the voice announcer and if necessary, restart the system.

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8. **Leap Second Reporting**

Historically leap second changes have created significant operational problems. All coordinated time scales will be affected by this adjustment.

Please report operational challenges you experience to the United States Coast Guard Navigation Center (NAVCEN), via the NAVCEN Website, http://www.navcen.uscg.gov/ under "Report a GPS Problem"

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

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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 International System (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 time 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 January 2015) 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 defines 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. Local realizations of UTC exist at the national time laboratories around the world. The two national timing standards for the U.S. are maintained at NIST, providing UTC(NIST), and at USNO, providing UTC(USNO). These standards are kept within 50 nanoseconds of each other.

Climatic, geological, and cosmic events affect the Earth's irregular rotation speed. This irregular motion of the earth's rotation rate is accounted for by the introduction of "leap seconds". Without such a correction, time reckoned by Earth's rotation (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 time keeping 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 maintaining the UTC time of day and changes of UTC date 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 (35 seconds in July 2012). The most recent leap second was added on June 30, 2012 at 23:59:59 UTC. A leap second will again be inserted at the end of June 30, 2015 at 23:59:59 UTC.