



## CCTF white paper

### Leap seconds in UTC: building a consensus for a continuous timescale

November 2022

The complete white paper is still in progress. Here we present the appendix dealing with the news reporting issues with UTC discontinuities.

#### 1 Annex 4: issues from users (public news)

This appendix contains extracts from public news where the impact of the UTC discontinuities is illustrated. A PDF file is also available here

<https://thebipm.sharepoint.com/:f:/r/sites/CCTFWGstrategicandCoChairs/Shared%20Documents/White%20paper/UTC%20continuous/PDF-%20Web%20pages%20quoted%20in%20the%20appendix?csf=1&web=1&e=wMH5hr>

containing the referred web pages. The numbering of the PDF files is reported in the captions.

##### 1.1 General



Figure 1 : <https://www.rolia.com/the-leap-second-problem/>



Figure 2 : <https://www.rolia.com/place-and-time-episode-3-the-leap-second-on-trial/>

## 1.2 Impact on transport

# AMADEUS ADMITS ALTEA CRASH WAS A RESULT OF LEAP SECOND BUG

A software failure at **Qantas** last week was not the result of slippery fingers by **Amadeus** engineers but was in fact due to the dreaded Leap Second bug.



The crash of the Amadeus ALTEA airline hosting system, the large platform used by hundreds of airlines for passenger check-in and ground control, hit Qantas and **Virgin Australia** on Sunday 1 July, just at the moment when many feared the Leap Second bug might make its mark felt across the digital world.

It wasn't a coincidence. And now Amadeus has admitted it got caught out by the bug.

Figure 3 : <https://www.phocuswire.com/Amadeus-admits-ALTEA-crash-was-a-result-of-Leap-Second-bug> (PDF n°5)

## Collins GPS & ADS-B Receivers Struck By Failure Modes



An update to a block of GPS satellites may have caused the widespread failure.

By Julie Boatman

June 11, 2019

An update to a block of satellites within the GPS constellation conducted by Collins Aerospace earlier in the weekend turned out to be the likely culprit, causing those in question to fail to work properly with a sensor and multi-mode receiver installed in the airplane.

Collins Aerospace notified its user base of a cascade of reports it had received beginning at 00:00Z on June 9 that certain GPS and GLU models were not operating properly. The specific models, the GPS-4000S sensor and the GLU-2100 multi-mode receiver (supporting ADS-B Out requirements), are installed in Collins Pro Line 21 and Pro Line Fusion avionics systems in many business jets, as well as in some aircraft used by regional and major airlines. In fact, *Forbes* reported on June 9 that a slew of airlines had cancelled flights on Sunday because of similar issues—including a group of Boeing 717s flown by *Hawaiian Airlines*.

When we contacted Collins Aerospace on the morning of June 10, we were sent the bulletin noted earlier, and advised that operators were encouraged to call in with their experience and contact information so that they could be informed of a resolution when it had been found. Later that day, Collins issued another letter to its user group, highlighting the exact problem: "We found that a software design error resulted in the system misinterpreting GPS time updates due to a 'leap second' event, which typically occurs once every 2.5 years within the U.S. Government GPS satellite almanac update. Our GPS-4000S-100 version software's timing calculations have reacted to this leap second by not tracking satellites upon power-up and subsequently failing. The U.S. Government distributed a regularly scheduled almanac update with this 'leap second' on 0:00GMT, Sunday, June 9, 2019, and the failures began to occur soon after."

Figure 4 : <https://www.flyingmag.com/collins-receivers-struck-by-failure-modes/> (PDF n°11)

## Leap second crashes Qantas and leaves passengers stranded

IT was a matter of a simple leap second, but it cost air travellers hours and left thousands of passengers stranded around the country.

Phil Jacob

less than 2 min read July 2, 2012 - 12:00AM DailyTelegraph

0 comments

Figure 5 : <https://www.dailytelegraph.com.au/leap-second-crashes-qantas-and-leaves-passengers-stranded/news-story/67e4354568ac8e5c491054c1aac1167> (PDF n°22)

## "Leap second" causes flight delays and internet problems

GlobalPost

July 1, 2012 - 3:34 PM EDT

By Amy Silverstein

On Saturday, the day was slightly longer than 24 hours--by one second, to be exact. While that might not seem like much, it was enough to wreak havoc on the internet.

Figure 6 : <https://theworld.org/stories/2012-07-01/leap-second-causes-flight-delays-and-internet-problems> (PDF n°20)

### 1.3 Impact on digital networks

# Leap Second Causes Sporadic Outages Across the Internet

Yesterday's leap second caused "sporadic outages" in more than 2,000 networks that link machines across the internet.

YESTERDAY'S LEAP SECOND caused "sporadic outages" in more than 2,000 networks that link machines across the Internet, according to a company that tracks the performance of online services.

Doug Madory, the director of internet analysis at the New Hampshire-based **Dyn Inc.**, says the outages occurred just after midnight **Coordinated Universal Time**, when the leap second was added (see graph below). Because no single Internet service provider was responsible for the outage, Madory says, the leap second was almost certainly the culprit. "This is pretty unusual," he says.

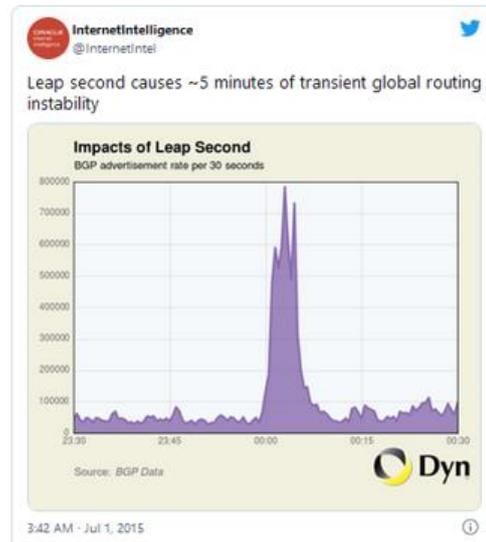


Figure 7 : <https://www.wired.com/2015/07/leap-second-causes-sporadic-outages-across-internet/> (PDF n°21)

## 2012-06-30 Leap Second

Quote of the day:

"There should be no noticeable affect or inconvenience on computers or any other technology that requires precise timekeeping because they adjust for these leap seconds"

AP Quoting [Daniel] Gambis [Director of the IERS].

### Notable Twitter messages

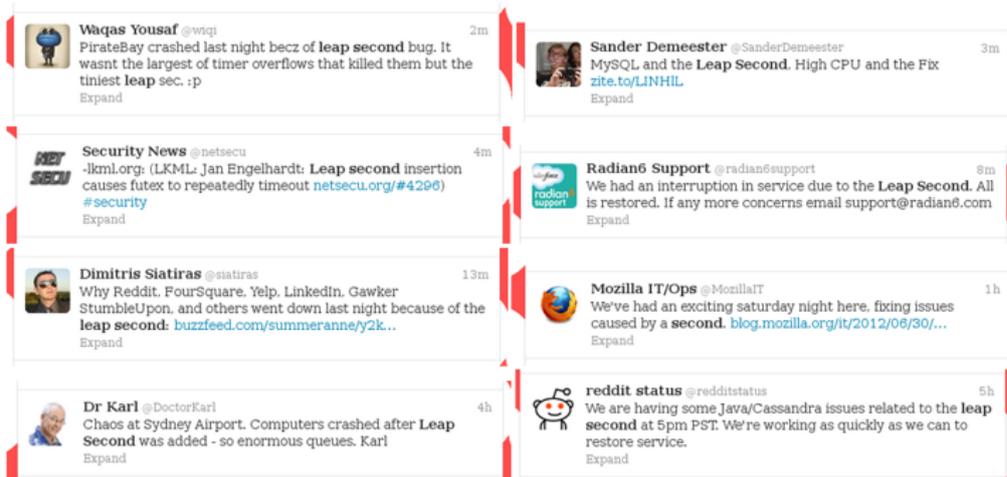


Figure 8 : [http://phk.freebsd.dk/hacks/leap\\_20120630/?highlight=leap%20second](http://phk.freebsd.dk/hacks/leap_20120630/?highlight=leap%20second) (PDF n°1)

# 'Leap second' knocked key city radios offline New Year's Eve

Jon Willing

Jan 03, 2017 • January 3, 2017 • 2 minute read • [Join the conversation](#)

A unique systems patch designed so the City of Ottawa could absorb the "leap second" failed on New Year's Eve, knocking out radios for OC Transpo and public works.

Figure 9 : <https://ottawacitizen.com/news/local-news/leap-second-knocked-key-city-radios-offline-new-years-eve> (PDF n°24)

DAVID METZ BUSINESS JUL 1, 2012 3:48 AM

## 'Leap Second' Bug Wreaks Havoc Across Web

Reddit, Mozilla, and several other big name web outfits experienced brief technical problems on Saturday evening, when software unpinning their online operations choked on the "leap second" that was added to the world's atomic clocks.



Figure 10 : <https://www.wired.com/2012/07/leap-second-bug-wreaks-havoc-with-java-linux/> (PDF n°19)

# Leap Second confuses Twitter and Android

Users reported problems with Android and Twitter as the leap second was added to atomic time

By Sarah Knapton  
01 July 2015 • 10:20am



Twitter users were among those who encountered issues with the leap second | CREDIT: Photo: PA

Figure 11 : <https://www.telegraph.co.uk/news/science/science-news/11710148/Leap-Second-confuses-Twitter-and-Android.html>

## 1.4 Impact on finance

How did Alibaba spend the 27th leap second on January 1, 2017?

Jiang Yi | Alibaba Cloud Infrastructure | 2017-03-24 18:05

When it comes to "leap second", most people may be a little unfamiliar. Maybe everyone knows that there are "leap year" and "leap month", but they may not have thought of "leap second". The fact is In recent years, with the development of science and technology, especially the rise of IT and financial industries, in the field of fine calculation, one second cannot be ignored, so the concept of "leap second" is also known by more and more people. For a large-scale Internet company like Alibaba, the challenges it faces are always huge. Let's talk about how Alibaba deals with leap seconds.

Figure 12 : [https://mp.weixin.qq.com/s/bBecGJrTn5HCx7\\_92a9uWQ](https://mp.weixin.qq.com/s/bBecGJrTn5HCx7_92a9uWQ) (PDF n°4)

## There are 61 seconds in a minute? Understand the computer and the stock market enemy "leap second" in seconds

2015/07/01 06:27  
Text/Reporter Liu Jiqing



The impact of leap seconds - computer systems, financial market preparations

Leap seconds don't have much of an impact on the life of the average person, but they are a formidable foe to financial markets, where transactions are measured in seconds, and to many computer systems. The last leap second occurred in 2012. In addition to the impact of well-known websites such as Yelp, FourSquare, LinkedIn, Reddit, Mozilla, and RedHat, the check-in systems of Qantas and Virgin Australia also crashed, causing delays for hundreds of passengers. . These sites all crashed because the software platform couldn't handle the extra 1 second.

Figure 13 : <https://3c.ltn.com.tw/news/18985/2> (PDF n°3)

### 1.5 Impact on IT applications

```
Subject Leap Second, nohz, and ABSOLUTE timers problem
```

```
John,
```

```
We've identified an issue with ABSOLUTE timers and the leap second that effects, AFAICT, all kernels.
```

```
This is the scenario. Suppose you have a userspace program that has an ABSOLUTE timer that will expire @ midnight (00:00:00) UTC. The timer expiry should occur at the end of the leap second event but it does not always occur at the end. In fact it may occur during the leap second event and effectively one second too early.
```

Figure 14 : <https://lkml.org/lkml/2015/5/27/458> (PDF n°25)

```
Date Fri, 2 Jan 2009 18:21:14 -0600
From Chris Adams <>
Subject Re: Bug: Status/Summary of slashdot leap-second crash on new years 2008-2009
```

```
Once upon a time, Linas Vepstas <linasvepstas@gmail.com> said:
> Below follows a summary of the reported crashes. I'm ignoring the
> zillions of "mine didn't crash" reports, or the "you're a paranoid
> conspiracy theorist, its random chance" reports.
```

```
Basically (to my untrained eye), the leap second code is called from the
timer interrupt handler, which holds xtime_lock. The leap second code
does a printk to notify about the leap second. The printk code tries to
wake up klogd (I assume to prioritize kernel messages), and (under some
conditions), the scheduler attempts to get the current time, which tries
to get xtime_lock => deadlock.
```

Figure 15 : <https://lkml.org/lkml/2009/1/2/373> (PDF n°36)

## Cisco Bug: CSCub38654 - N5K: Switch hang/lock up may occur due to Leap second update

### Description (partial)

#### Symptom:

There are periodic leap second events which can add or delete a second to global time.

When the leap second update occurs N5K NX-OS 5.0, 5.1 5.2 versions run an affected version of the Linux kernel. A Nexus 5010/5500 running affected code could experience a lock up condition.

If the N5K was stuck in hung state, mgmt0, in band management will not be possible. On console messages such as following will be seen

Setting: rc 5 BUG: spinlock lockup on CPU#0, adj\_x86s.bin/5926, lock=c793a6e0 pc=c013c560

```
SMI: System watchdog timed out
NXOS_WATCHDOG: ffff [#1] SMP
Cpu: 0 Watchdog timer NMI occurred (0)
SMI: System watchdog timed out
SMI: System watchdog timed out
```

If switch is hung in this state, the switch will need to be manually power cycled to recover.

Figure 16 : <https://quickview.cloudapps.cisco.com/quickview/bug/CSCub38654> (PDF n°7)

## Cisco Bug: CSCvb01730 - leapsec 3.10.7: deadlock test may intermittently cause wdog timeout - rtr crashes

### Description (partial)

#### Symptom:

The router may reset unexpectedly with the following message: Kernel panic - not syncing: Watchdog timeout

#### Conditions:

This error can only occur during a leap second event, which will only occur at June 30th 23:59:60 or Dec 31st 23:59:60, and only when dictated by the International Earth Rotation and Reference Systems Service (IERS). The next leap second add event is scheduled for Dec 31st, 2016, at 23:59:60.

Figure 17 : <https://quickview.cloudapps.cisco.com/quickview/bug/CSCvb01730> (PDF n°8)

# How and why the leap second affected Cloudflare DNS

01/01/2017

 John Graham-Cumming

At midnight UTC on New Year's Day, deep inside Cloudflare's custom [RRDNS](#) software, a number went negative when it should always have been, at worst, zero. A little later this negative value caused RRDNS to panic. This panic was caught using the recover feature of the Go language. The net effect was that some DNS resolutions to some Cloudflare managed web properties failed.

The problem only affected customers who use CNAME DNS records with Cloudflare, and only affected a small number of machines across Cloudflare's 102 data centers. At peak approximately 0.2% of DNS queries to Cloudflare were affected and less than 1% of all HTTP requests to Cloudflare encountered an error.

This problem was quickly identified. The most affected machines were patched in 90 minutes and the fix was rolled out worldwide by 0645 UTC. We are sorry that our customers were affected, but we thought it was worth writing up the root cause for others to understand.

**Figure 18** : <https://blog.cloudflare.com/how-and-why-the-leap-second-affected-cloudflare-dns/> (PDF n°10)

## Leap seconds

When a [leap second](#) occurs, the UTC day is not exactly 86 400 seconds long and the Unix time number (which always increases by exactly 86 400 each day) experiences a [discontinuity](#). Leap seconds may be positive or negative. No negative leap second has ever been declared, but if one were to be, then at the end of a day with a negative leap second, the Unix time number would jump up by 1 to the start of the next day. During a positive leap second at the end of a day, which occurs about every year and a half on average, the Unix time number increases continuously into the next day during the leap second and then at the end of the leap second jumps back by 1 (returning to the start of the next day).

**Figure 19** : [https://en.wikipedia.org/wiki/Unix\\_time](https://en.wikipedia.org/wiki/Unix_time) (PDF n°39)

## Five different ways to handle leap seconds with NTP

June 1, 2015      Linux

 Miroslav Lichvar

A leap second is an adjustment that is once in a while applied to the Coordinated Universal Time (UTC) to keep it close to the mean solar time. The concept is similar to that of leap day, but instead of adding a 29th day to February to keep the calendar synchronized with Earth's orbit around the Sun, an extra second 23:59:60 is added to the last day of June or December to keep the time of the day synchronized with the Earth's rotation relative to the Sun. The mean solar day is about 2 milliseconds longer than 24 hours and in long term it's getting longer as the Moon is constantly slowing down the Earth's rotation.

UTC is based on the International Atomic Time (TAI) and it is currently 35 seconds behind TAI. The first leap second was inserted in 1972 and 25 seconds were inserted so far. The next one is scheduled for 30 June 2015, when the offset from TAI will increase to 36 seconds. Leap seconds are scheduled only about 6 months in advance.

There is a possibility that leap seconds will be abolished in the future. A discussion about this topic has been going on for a long time, but so far no agreement has been reached. The current plan is that the International Telecommunication Union (ITU) will decide at the World Radiocommunication Conference in November 2015.

**Figure 20** : <https://developers.redhat.com/blog/2015/06/01/five-different-ways-handle-leap-seconds-ntp> (PDF n°14)

## Time, technology and leaping seconds

September 15, 2011

*Google's Site Reliability team is responsible for keeping Google's services and data centers up and running 24/7. In this post, you'll hear about a project our Site Reliability Engineers took on to make sure that the fluctuations of time don't adversely affect Google's products and services. If you like this (detailed) glimpse at the tech behind the scenes, come back for more about this team's work in the future. -Ed.*

Figure 21 : <https://googleblog.blogspot.com/2011/09/time-technology-and-leaping-seconds.html> (PDF n°38)

## Google turns on free public NTP servers that SMEAR TIME

With a leap second coming up, smearing's quite a good idea

Simon Sharwood

Fri 2 Dec 2016 // 03:31 UTC

61 

Google's turned on a set of public network time protocol (NTP) servers.



You'll find the servers at `time.google.com` – which resolves to `216.239.35.0`, a rather less pretty IP address than the `8.8.8.8` and `8.8.4.4` Google uses for its public domain-name system (DNS) servers. There's also `time2.google.com` at `216.239.35.4`, `time3.` at `.8` and `time4.` at `.12`.

Google **says** the new services is for "anyone who needs to keep local clocks in sync with VM instances running on Google Compute Engine, to match the time used by Google APIs, or for those who just need a reliable time service."

If the servers are as reliable as Google's DNS servers, they'll be more than adequate.

Figure 22 : [https://www.theregister.com/2016/12/02/google\\_public\\_ntp\\_servers/](https://www.theregister.com/2016/12/02/google_public_ntp_servers/) (PDF n°15)

## Facebook Switches to New Timekeeping Service > The upgrade should help millions of the company's servers keep more accurate time

BY AMY NORDRUM | 18 MAR 2020 | 4 MIN READ | 

Facebook recently switched millions of its own servers and consumer products (including Portal and Oculus VR headsets) over to a new timekeeping service. The company says the new service, built in-house by the company's engineers using open-source tools, is more scalable than the one it used previously. What's more, it will improve the accuracy of device's internal clocks from 10 milliseconds to 100 microseconds.

Figure 23 : <https://spectrum.ieee.org/facebook-new-time-keeping-service> (PDF n°13)

## Building a more accurate time service at Facebook scale

By Oleg Obleukhov



UPDATE: To continue our support of this public NTP service, we have open-sourced our collection of NTP libraries on GitHub.

Almost all of the billions of devices connected to the internet have onboard clocks, which need to be accurate to properly perform their functions. Many clocks contain inaccurate internal oscillators, which can cause seconds of inaccuracy per day and need to be periodically corrected. Incorrect time can lead to issues, such as missing an important reminder or failing a spacecraft launch. Devices all over the world rely on Network Time Protocol (NTP) to stay synchronized to a more accurate clock over packet-switched, variable-latency data networks.

Figure 24 : <https://engineering.fb.com/2020/03/18/production-engineering/ntp-service/> (PDF n°6)

## Precision Time Protocol

From Wikipedia, the free encyclopedia

The **Precision Time Protocol (PTP)** is a protocol used to synchronize clocks throughout a computer network. On a local area network, it achieves clock accuracy in the sub-microsecond range, making it suitable for measurement and control systems.<sup>[1]</sup> PTP is currently employed to synchronize financial transactions, mobile phone tower transmissions, sub-sea acoustic arrays, and networks that require precise timing but lack access to satellite navigation signals.

The original version of PTP, **IEEE 1588-2002**, was published in 2002. **IEEE 1588-2008**, also known as PTP Version 2 is not backward compatible with the original 2002 version. **IEEE 1588-2019** was published in November 2019 and includes backward-compatible improvements to the 2008 publication. IEEE 1588-2008 includes a *profile* concept defining PTP operating parameters and options. Several profiles have been defined for applications including telecommunications, electric power distribution and audiovisual. **IEEE 802.1AS** is an adaptation of PTP for use with Audio Video Bridging and Time-Sensitive Networking.

Figure 25 : [https://en.wikipedia.org/wiki/Precision\\_Time\\_Protocol](https://en.wikipedia.org/wiki/Precision_Time_Protocol) (PDF n°33)

## PTP Timescale (and what the heck is Arb time?)

April 15, 2019 by Douglas Arnold — 2 Comments

Most application which use PTP to distribute time, don't actually need standard time, as understood by national laboratories. All that is needed is for the clocks in a network to have the same time. However, there are several reasons to use a standard timescale when distributing PTP:

1. It can be useful if the network time can easily be converted to human readable standard local time.
2. If two live networks, that already have a sense of time, are connected together, then it causes less transient chaos if they start with approximately the same time. It is easier to achieve this if a standard timescale is used.
3. Some government regulations and technology standards specify standard time tied to national labs.

To start with, every timing network should use the standard **SI second**. IEEE 1588 doesn't actually require that, but many parts of the standard nevertheless assume it. Also not using the SI second makes it very difficult to convert the network time into any kind of standard time. So don't even consider putting time into any network which is not based on the SI second. You're thinking of a corner case where this isn't needed. Don't!

Figure 26 : <https://blog.meinbergglobal.com/2019/04/15/ptp-timescale-and-what-the-heck-is-arb-time/> (PDF n°34)

## The Inside Story of the Extra Second That Crashed the Web

The "leap second" crash -- which hit several web operations on Saturday evening -- can be traced to a single glitch in the Linux operating system. Here's the inside story on what happened.

WHEN SATURDAY NIGHT'S [leap second glitch](#) hit Reddit, Jason Harvey didn't realize it was the leap second glitch. He thought it was some sort of Internet slowdown related to the [massive Amazon cloud outage](#) that brought down some of the web's most popular services less than 24 hours earlier.

"It looked like the network was just moving really poorly," says Harvey, one of the system administrators who oversee the operation of Reddit, the popular news aggregation and discussion site. "With Amazon going down, a network problem just made sense."

Figure 27 : <https://www.wired.com/2012/07/leap-second-glitch-explained/> (PDF n°37)

## 'Leap second' snafu affects Oracle clusterware



By Chris Kanaracus

U.S. Correspondent, IDG News Service | JAN 6, 2009 12:00 AM PST

The additional second that time-tracking scientists added to 2008 to adjust for the slowing of the earth's rotation is causing problems with Oracle's Cluster Ready Services (CRS) clusterware, but a pair of fixes are available, said an Oracle document dated Monday.

CRS is used in conjunction with Oracle's Real Application Clusters software, which allows one Oracle database to be deployed on a group of servers or "nodes," providing fault tolerance and scalability.

The "leap second event" is causing CRS nodes to reboot, according to an Oracle document detailing the problem. Among the affected platforms are Oracle Server Enterprise Edition Version 10.1.0.2 to 11.1.0.7; Sun Solaris SPARC (64-bit); and Oracle CRS and patchsets 10.2.0.1 to 11.1.0.7.

Figure 28 : <https://www.networkworld.com/article/2271654/-leap-second--snafu-affects-oracle-clusterware.html> (PDF n°27)

# Leap second bedevils Web systems over weekend

Reddit, LinkedIn and other sites were knocked offline by an extra second added to the official time



By Joab Jackson

U.S. Correspondent, IDG News Service | JUL 2, 2012 11:32 AM PST

Despite precautions by system providers, an extra second added to the official timekeeping record Saturday triggered several popular Internet services to crash over the weekend, including LinkedIn, Reddit and Quantas airline's reservation system.

Among systems that reportedly experienced difficulty with the extra second were unpatched Linux OS kernels, Hadoop instances, Cassandra databases and Java-based programs. Enough problems were documented around the globe that some even [likened](#) leap second change to another Y2K.

Figure 29 : <https://www.computerworld.com/article/2505309/leap-second-bedevils-web-systems-over-weekend.html> (PDF n°17)

## 'Leap second bug' causes site, software crashes

The addition of an extra second to the world's atomic clocks was apparently too much for some popular Web sites and software platforms to take.



Steven Musil

July 1, 2012 11:19 a.m. PT



Figure 30 : <https://www.cnet.com/tech/services-and-software/leap-second-bug-causes-site-software-crashes/> (PDF n°18)

TECH / FAIL

## Y2K 2.0: How A Second Brought Down Half The Internets

The "leap second" was a one second adjustment made to the atomic clock tonight at 23:59:59 UT (just before 8pm ET). After it went into effect tonight, half the internet -- including Reddit, FourSquare, Yelp, LinkedIn, Gawker StumbleUpon, and more -- came crashing down. The outages were mostly (thankfully) brief. Here's how it happened.



by Summer Anne Burton  
BuzzFeed Staff

Posted on July 1, 2012, 4:46 am

Figure 31 : <https://www.buzzfeednews.com/article/summeranne/y2k-20-how-a-second-brought-down-half-the-intern> (PDF n°16)

### 1.6 Impact on GNSS receivers



*The next leap second will be added to the official time scale on December 31, 2016. It is the first end of year leap second since 2008. No doubt many GPS receivers, software and systems in current production have not experienced an end of year leap second event. For these reasons, it is strongly recommended to test the upcoming leap second event for all GPS receivers and systems to determine if algorithms and software successfully manages the leap second event and to uncover any detrimental effect of the leap second discontinuity.*

**Figure 34** : [https://www.rolia.com/wp-content/uploads/2021/07/GPS-Receiver-Leap-Second-Testing\\_AN06-101\\_revC-1.pdf](https://www.rolia.com/wp-content/uploads/2021/07/GPS-Receiver-Leap-Second-Testing_AN06-101_revC-1.pdf) (PDF n°40)

## Leap Second Implementation Confuses Some Receivers

February 2, 2015 - By [GPS World Staff](#)

Est. reading time: 1 minute 

The United States Civil GPS Service Interface Committee (CGSIC) has issued a notice about a problem some receivers are having implementing the correct time. The U.S. Coast Guard Navigation Center has received reports of synchronization issues since the implementation of a leap second on Jan. 21. Users experiencing this problem should contact the receiver manufacturer for a firmware or software update.

**Figure 35** : <https://www.gpsworld.com/leap-second-implementation-confuses-some-receivers/> (PDF n°23)

## 1.7 Impact on the electrical power distribution

Recent timing events – principally the leap second shifts of 2012 and 2015 and the January 2016 GPS constellation error – have revealed many different impacts and means of failure for the timing devices that serve synchrophasor systems, and the interaction between the timing systems and the devices they connect to. This technical paper summarizes those impacts and failures without identifying either device vendors or models nor the affected companies.

The purpose of this paper is to document these problems to accelerate their resolution, and to warn synchrophasor system owners and other members of the electric industry that they cannot assume that timing delivery systems and synchrophasor equipment will operate smoothly through future leap second events. The next leap second is scheduled for December 31, 2016. Other leap second adjustments have not been announced yet, but a comparable timing event will occur on April 16, 2019 with the GPS epoch roll-over.<sup>1</sup>

Figure 36 :

[https://www.naspi.org/sites/default/files/reference\\_documents/naspi\\_2016\\_tr\\_008\\_leap\\_second.pdf](https://www.naspi.org/sites/default/files/reference_documents/naspi_2016_tr_008_leap_second.pdf) (PDF n°30)

## Investigation of PMU Response to Leap Second: 2015

Allen Goldstein  
Dhananjay Anand  
Ya-Shian Li-Baboud

This publication is available free of charge from:  
<http://dx.doi.org/10.6028/NIST.IR.8077>

Between 22:30:00 June 30, 2015 and 00:30:00 July 2, 2015 UTC, the National Institute of Standards and Technology (NIST) tested 8 Phasor Measurement Units (PMUs) to investigate their response to the leap second adjustment to UTC which occurred following 23:59:59 UTC on June 30, 2015. At this time, the offset between TAI and UTC time incremented by 1 second from 35 seconds to 36 seconds. The UTC Time of Day (TOD) during an added leap second can be represented by either repeating 29:59:59 or inserting 23:59:60 for one second. This report shall represent the TOD during the leap second as 23:59:60

Figure 37 : <https://nvlpubs.nist.gov/nistpubs/ir/2015/NIST.IR.8077.pdf> (PDF n°31)

## 2 Annex 5: standards and papers dealing with UTC discontinuities in different applications

### 2.1 IT applications

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## Leap Smear 🔖

Since 2008, instead of applying leap seconds to our servers using clock steps, we have "smeared" the extra second across the hours before and after each leap. The leap smear applies to all Google services, including all our APIs.

### Our proposed standard smear

Many organizations use smeared clocks, and it would be helpful if the smears were the same. After all, the purpose of clocks is to read the same time in different places.

We encourage anyone smearing leap seconds to use a **24-hour linear smear from noon to noon UTC**.

This smear combines the features that experience has shown to work well for many distributed computing applications:

- The long duration keeps the frequency change small. The change for the smear is about 11.6 ppm. This is within the manufacturing and thermal errors of most machines' quartz oscillators, and well under NTP's 500 ppm maximum slew rate.
- Centering the smear on the leap second, instead of having it begin or end at the leap second, minimizes the maximum offset.
- Compared to a cosine smear, the linear smear is simpler, easier to calculate, and minimizes the maximum frequency change.
- The 24-hour duration has been widely adopted by others implementing smears. We previously used a 20-hour smear duration, but changed to align with this more popular noon-to-noon interval.

We plan to use this smear for all future leap seconds. Amazon [uses this smear](#) in AWS. One way to use it in your systems is to configure them to use [Google Public NTP](#).

**Figure 38 :** <https://developers.google.com/time/smear> (PDF n°28)

## Re: [PATCH 0/2][RFC] Potential fix for leapsecond caused futex issue (v2)

[Posted July 2, 2012 by corbet]

- \* Leap second occurs, `CLOCK_REALTIME` is set back one second.
- \* As `clock_was_set()` is not called, the `hrtimer base.offset` value for `CLOCK_REALTIME` is not updated, thus its sense of wall time is one second ahead of the timekeeping core's.
- \* At interrupt time (T), the `hrtimer` code expires all `CLOCK_REALTIME` based timers set for T+1s and before, causing early expirations for timers between T and T+1s since the `hrtimer` code's sense of time is one second ahead.
- \* This causes all `TIMER_ABSTIME CLOCK_REALTIME` timers to expire one second early.
- \* More problematically, all sub-second `TIMER_ABSTIME CLOCK_REALTIME` timers will return immediately. If any such timer calls are done in a loop (as commonly done with `futex_wait` or other timeouts), this will cause load spikes in those applications.
- \* This state persists until `clock_was_set()` is called (most easily done via `settimeofday()`)

Figure 39 : <https://lwn.net/Articles/504658/> (PDF n°32)

```
Subject: [PATCH 075/109] ntp: Correct TAI offset during leap second

When repeating a UTC time value during a leap second (when the UTC
time should be 23:59:60), the TAI timescale should not stop. The kernel
NTP code increments the TAI offset one second too late. This patch fixes
the issue by incrementing the offset during the leap second itself.
```

Figure 40 : <https://github.com/Angstrom-distribution/meta-ti/blob/master/recipes-kernel/linux/linux-ti33x-psp-3.2/3.2.24/0075-ntp-Correct-TAI-offset-during-leap-second.patch> (PDF n°12)

## Resolve Leap Second Issues in Red Hat Enterprise Linux

Updated August 3 2021 at 12:36 AM - English ↕

### Handling of the Leap Second

The leap second will be handled in two primary ways, depending on how the system clock is configured.

The system clock is keeping time with UTC and synchronized via NTP or PTP

As mentioned previously, the leap second must be skipped when the system is using UTC, as this second does not exist. Therefore, to prevent the system clock from being one second ahead of UTC, the clock must be corrected after the leap second occurs. This correction may occur in a variety of ways, outlined below:

The system clock is keeping time in TAI-10 seconds, is not synchronized, and is using a `right/*` timezone

Systems may also be configured to report time corrected for leap seconds by updating the `tzdata` package to the latest version available, copying the appropriate file from the `/usr/share/zoneinfo/right` directory hierarchy to `/etc/localtime`, and resetting the clock to the correct local time. The files in `/usr/share/zoneinfo/right` contain local time information corrected for all leap seconds that have occurred since the beginning of the Epoch on 1970-01-01 00:00:00 UTC. The other time zone files in `/usr/share/zoneinfo` do not have leap second corrections added. After the 2008 leap second, there were 24 leap seconds added since the Epoch. Any application that expects the time to be in UTC will have issues if a `right/*` timezone is used.

Figure 41 : <https://access.redhat.com/articles/15145#handling> (PDF n°35)

### 3 Annex 6: Petition from the ITSF 2021 from synchronization industries

Date: 30th of January 2022

To  
Director, ITU Radiocommunication Bureau  
Mr. Mario Maniewicz

Dear Mr. Maniewicz,

On behalf of the ITSF (The International Timing & Sync Forum) group of sponsors and exhibitors, and the OCP-TAP (The Open Computing Project – Time Appliances Project), we are sending attached signed petition addressed to ITU Radiocommunication, with a question to consider discontinuation of the *UTC leap seconds*.

The International Timing and Sync Forum (ITSF) sponsors and exhibitors signed on petition represents over 90% of global market of manufactures of commercial time & frequency appliances, test and measurement equipment.

The The Open Computing Project – Time Appliances Project (OCP-TAP) is newly operating since 2020, a group of timing experts related to cloud computing and IT industry. The OCP has been funded by Facebook and groups trade names: Google, Amazon, Microsoft, NVIDIA, Intel, Oracle, CISCO, IBM etc. The OCP-TAP handles open hardware repository of synchronization hardware, important for state of the art CLOUD, FOG, EDGE computing.

We, the commercial timing community, deeply understand that, the further continuation of handling *UTC leap second* introduces a high risk of failure for modern IT and Industry4.0 (OT). Although the leap-second problem has always existed, currently with exponentially growing automation and the close interdependence of entire Industry4.0 systems, there is recommendation for immediate suspension of the *UTC leap-second*. Currently considered the first in history negative UTC leap-second makes us especially worry.

The attached petition was signed during the ITFS2021 conference Brighton UK (November 2021), by a major group of exhibitors and sponsors. The OCP-TAP and Facebook were main speakers during this conference.

Best regards,



Tomasz Widomski  
in behalf of ITSF group of sponsors



Ahmad Byagowi  
in behalf of OCP-TAP project

Attn:  
The Petition, signed by the group of ITSF2021sponsors and OCP-TAP leader

Copy to attention of:  
Mr. Joseph Achkar (Chair, ITU-R WP-7A)

Figure 42 : Letter to ITU radiocommunication Bureau (PDF n°29)

Figure 43 : Petition from the ITSF 2021 from synchronization industries

## 4 Annex 7: Contribution from other organizations and international groups

### 4.1 statement from Civil GPS Service Interface Committee

#### CGSIC opinion on the redefinition of UTC now under consideration by the International Telecommunications Union (ITU)

**Prepared by CGSIC Timing Subcommittee and endorsed by the CGSIC Executive Committee on 8-9 September 2014**

The Civil GPS Interface Committee,

Considering that

- In 1971, the ITU-R (formerly CCIR, International Consultative Committee for Radiocommunications) proposed the present form of Coordinated Universal Time (UTC), which is based upon the SI second but remains linked to the variable rotation of the Earth through the introduction of leap seconds, which are inserted preferentially at the end of December 31 or June 30 in such a manner that  $|UT1-UTC|$  will always be less than 0.9 second.
- This proposal was accepted after discussions with BIH (Bureau International de l'Heure), URSI, IAU, IUGG, and other bodies active in positioning and navigation.
- At the time of introduction, the future implementation of satellite and other systems which cannot easily incorporate the leap second was not foreseeable.
- A proposal on the redefinition of UTC is under consideration by ITU, about which the ITU has solicited the opinion of several international bodies.

And further considering that,

- leap second insertions have increasingly been associated with failures of navigational as well as timing systems, among them the ground, transmission, or accounting systems of GPS, LORAN, and commercial air travel,
- in one instance uncorrected mis-programming of a GPS receiver was responsible for a failure in mid-month, at a time when no leap second would have been expected,
- approximately 10% of the world's Network Time Protocol (NTP) servers, which provides an internet-based timing structure upon which many navigational systems depend, failed to correctly handle the leap second insertion of 2012,
- never as long as NTP servers have been monitored has every one correctly predicted the presence or absence of leap second on a December 31 or June 30,
- some systems have been mis-programmed to insert leap seconds after 23:59:59 local time instead of 23:59:59 UTC,
- many corporations, governments, providers of navigational systems, and other groups do not report failures as a matter of policy,
- and in the interests of safety some systems cease operations at the time a leap second is to be introduced,
- although navigational systems must and do continue operating through leap second insertions.

Concludes

- That many navigational and timing systems are at risk of failure due to possible leap second insertions,
- which although numerically few can pose an unacceptable danger to travelers.

And is therefore of the opinion that

- Leap seconds should cease to be inserted in the near future,
- UTC should become a unique and continuous reference time scale,
- and that a period of at least 5 years be allowed so that operators of navigational systems can make adequate preparations.

And therefore requests that

- The co-chairs of the CGSIC Timing Subcommittee forward this opinion to the ITU.

Figure 44 : <https://www.gps.gov/cgsic/timing/2014-resolution/> (PDF n°9)

## 4.2 ITU - T

### Radiocommunication Study Groups



Source: SG15-LS354

Reference: SG15-TD780/PLEN-Annex I

Questions: ITU-T 13/15

**Document 7A/38-E**  
**23 December 2021**  
**English only**

### ITU-T Study Group 15

#### LIAISON STATEMENT ON USE OF CONTINUOUS TIMESCALES IN TELECOM APPLICATIONS

**For action to:** -  
**For comment to:**  
**For information to:** ITU-R SG 7 WP 7A  
**Approval:** ITU-T SG15 meeting (E-meeting, 17 December 2021)  
**Deadline:** -  
**Keywords:** timescales

We understand that Resolution **655 (WRC-15)**, "Definition of time scale and dissemination of time signals via radiocommunication systems", is under study in your group with the aim to arrive at a consensus at the WRC in 2023 on the modernization of the UTC to meet the needs of the current and future user communities. In particular with proposals to modify the leap second recommendation.

#### Figure 45 : ITU-T SG15Q13

## 4.3 URSI



## GASS 2021 : Vote on URSI Resolutions and Recommendation

### R1. Resolution on the need for a continuous reference time scale

The URSI Council,

considering that

- a) the current practice of maintaining the Coordinated Universal Time (UTC) within 0.9 s of the Earth's rotation angle (UT1) by occasional leap second adjustments has been under discussion since the late 1990s;
- b) the Radiocommunication Sector of the International Telecommunication Union (ITU-R) discussed the realization of time scales and dissemination of time signals via radiocommunication systems during its World Radio Conference 2015 (WRC-15) and resolved in Resolution 655 to further and more widely study the various aspects of current and potential future reference time scales, including their impacts and applications, in cooperation with URSI and other relevant international organizations;
- c) in 2018 the 26<sup>th</sup> General Conference of Weights and Measures (CGPM) formally confirmed in its Resolution 2 the definitions of International Atomic Time (TAI) and Coordinated Universal Time (UTC), and asked all relevant scientific unions and organizations to work together to develop a common understanding on reference time scales and their realization and dissemination, with a view to considering the present limitation on the maximum magnitude of UT1 - UTC so as to meet the needs of the current and future user communities;
- d) URSI Commission A organized a wider consultation with experts from various fields to request their opinions on the adoption of a continuous reference time scale,

**Figure 46 : URSI Resolutions and Recommendation (PDF n°41)**

## 4.4 IERS Response to WRC

### Impact of a Continuous International Reference for Time on the IERS

If a continuous time scale was established, the need for leap seconds would be eliminated. This would allow the value of UT1 – UTC to grow unbounded, which would have the following impacts on the IERS.

1. The format of any IERS data set containing UT1 – UTC would need to be changed to account for an increased number of digits to the left of the decimal place instead of the single digit that is currently in place.
  - a. Note that the format for TAI – UT1 would not need modification because it already assumes an arbitrarily large number left of the decimal place.
2. There will be conventional routines that will need to be modified to account for any assumptions that the difference between UT1 and UTC will be sufficiently small (e.g. solid earth tide models). However, these are issues that can be addressed well in advance of any change to a continuous time scale.
3. There will be an increased interest in UT1 – UTC, especially for applications that used UTC as a proxy for UT1. IERS have to make UT1 – UTC more easily available, e.g. in the form of a web service.
4. There may be an increased interest in longer-term predictions, particularly of UT1 – UTC. This would necessitate research efforts into different algorithms for long-term predictions and may necessitate the creation of additional data sets.

In general, the change to a continuous international reference for time should have a minimal impact on the IERS or the way in which we deliver our products.

**Figure 47 : IERS Response to WRC**

## 5 Annex 8: Statement received from users on the impact of leap seconds

In the first month of 2022, after a talk to the Time Appliance Project given by P. Tavella of the BIPM [https://www.opencompute.org/wiki/Time\\_Appliances\\_Project](https://www.opencompute.org/wiki/Time_Appliances_Project) [https://www.opencompute.org/wiki/Time\\_Appliances\\_Project#IC\\_Presentations](https://www.opencompute.org/wiki/Time_Appliances_Project#IC_Presentations) a comment was posted on LinkedIn, and a great discussion started among IT and Timing industries.

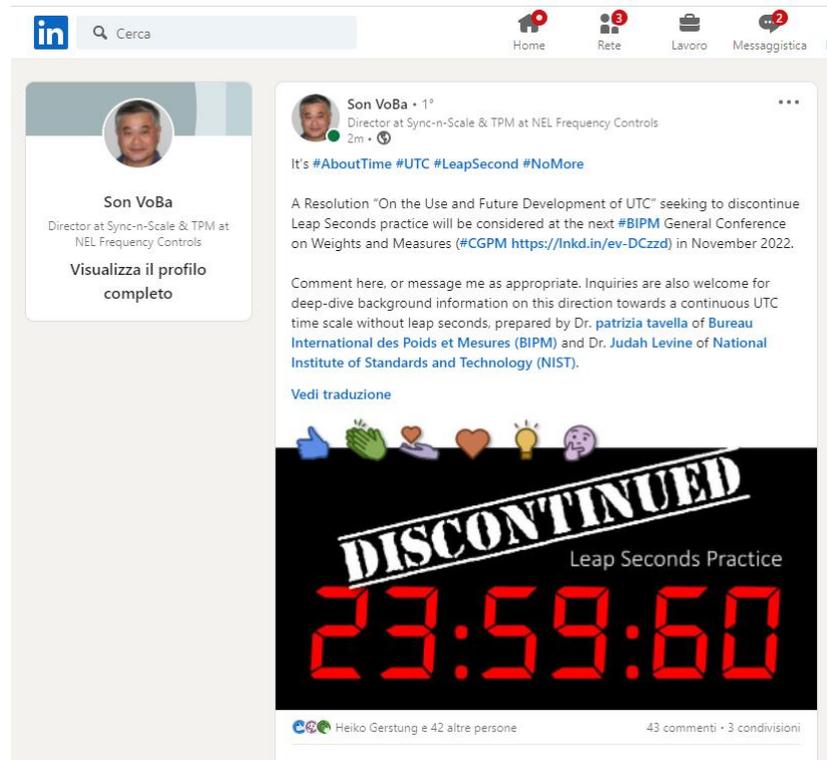


Figure 48 : LinkedIn comment appeared in 2022 and announcing the CGPM draft resolution D. [LinkedIn post on Leap Seconds practice.](#)

Those industries were asked to provide information on the possible issues of the UTC discontinuities and technical insights on how a continuous UTC time scale would affect their products and services. After a couple of months, several industries had provided a contribution which is collected and added here as received by the coordinator Son VoBa (Sync-n-scale) [b-svoba@microsoft.com](mailto:b-svoba@microsoft.com) on May 2<sup>nd</sup>, 2022