Report on the answers to the questionnaire on the leap second application

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Motivation

By the end of 2008 I have been contacted by some laboratories (participants and non-participants to UTC) requiring information either on the truthfulness of rumours on a leap second occurrence at the end of the year, or on the sign (positive or negative) of the leap second to be applied. This made me doubt about the access to first-line information coming from the authority deciding on the dates of application and sign of the leap second, that is, the International Earth Rotation and Reference Systems Service (IERS). In parallel, I was curious to learn on other systems and artefacts in other institutes, companies, etc. needing of this adjustment, and on the information that national contributing laboratories have on them.

I had also learnt in reports of administrations at the WP 7A of ITU-R, that the recommended procedure for application of the leap second was not always followed, as the case where the leap second resulted of a steering of the seconds over an interval around midnight UTC. I wondered whether all the contributing laboratories respected the procedure.

Another motivation was to have an idea of the amount of human work invested in each laboratory and globally, in aligning local UTC(*k*) to UT1.

When preparing the questionnaire, other "more classical" questions arose, as asking reports on disruptions and difficulties encountered, either potential or real.

Target and responses

As soon as the *IERS Bulletin C* announcing a leap second is published, a line is included in the header of Section 1 of *Circular T* with the relationship between TAI and UTC after the leap second introduction.

On 15 December 2008 a message was circulated from the BIPM with the information on the leap second on UTC at the end of the year, including the *IERS Bulletin C 36* of 4 July 2008 and the references for accessing this information via IERS.

On 9 January 2009 the questionnaire was distributed to the contributing laboratories requesting answer on a short deadline (30 January), since I wanted to have responses close to the event (the sooner, the better!).

The majority of responses came within the deadline, the late responders reacted in February and in the first half of March. From 70 laboratories contacted, 39 (56%) filled the questionnaire, which represents a good score.

Concerning the source of information of leap second application

All responses indicate been informed of the leap second application, but only 21 declare to be subscripted to the relevant IERS bulletins. 15 laboratories say having sources of information other that the IERS (mainly BIPM but also some NMIs and services). 15 laboratories declare that the only source of information is the BIPM, either *Circular T* or the e-mail of 15 December 2008 (the first and only released by the section).

Citation from questionnaires:

> I thought that IERS is the authority responsible for the introduction of leap seconds. Any other institution can only relay the IERS information. Are you suggesting that somebody else tries to introduce his own leap seconds ? There cannot be a "second source".

Conclusions:

I expected to have 100% of laboratories receiving first-line information from IERS, and this is not the case.
The BIPM is not the source of information on the application of leap seconds, unless this is decided in the future. Many laboratories declare been informed by *Circular T* (where the information is incomplete), or by e-mail messages from BIPM (only one has been sent, and as a reaction to received questions).
I would encourage laboratories to subscribe to the IERS publications, at least *IERS Bulletin C.*

Concerning the affected pieces of equipment and the staff resources

This question referred to the equipment on which the leap second is to be applied, directly or indirectly. They are clocks, time code generators, time scale generators, time servers, NTP servers, etc.

To quantify the human resources invested in this manipulation, information was requested on the man/hours required for the complete process, that is, preparation, application, checking, and eventually corrective actions. It is expected to find that this number is proportional to the size of the laboratory in equipment and services. The values range from 0.2 up to 80 man/hours, with 23 laboratories investing at most 10 man/hours, 6 laboratories between 10 and 30 man/hours, and 5 between 40 and 80. The total number of man/hours is of 444.

Citations from questionnaires:

"XXX is not in charge of the dissemination of the national official hour
So far, no name has been given to the signal 1pps."

"The initial design of the method described below took many months of design and testing. This system was introduced first for the leap second in 2000 and was fixed following the double-leap second event in 2005, which affected some of our newer NTP time servers that had not been in operation for the previous leap second. This fix took about a day to install and test. Introducing the leap second in 2008 took about 10 minutes during the first week of

December. The verification that all of the systems had executed the leap second properly took about 15 minutes on 31 December 2008. The entire verification process was completed by 1715 local time. (UTC- 7)"

Conclusions:

- In a general way, there is a correlation between the importance of equipment and services and the invested man/hours, but with exceptions.
- The total number of man/hours (444) indicates that a non-negligible effort is made in this operation.
- In some (big) laboratories the total procedure is heavy, starting by the preparation of the staff.

On the potential and real disruptions and problems

NTP servers, time dissemination services, time stamping are the most worrying. Laboratories operating TW stations reported on problems. About 15 incidents have been reported.

Citations from questionnaires:

Potential:
"Around 10 PCs logging data (including clock time offsets, GPS measurements and TWSTFT measurements), 2 phase comparators and 1 Satre TWSTFT modem are synchronised using NTP over the NPL internal network. There was considered to be a risk that the 1s step might cause the logging software to crash, although in practice no problems have been observed. …There is potential for errors in TWSTFT measurements following the leap second if one station has implemented the leap second but not the other, although again no problems have been observed."

Potential:
"Some measurements in the time and frequency field are performed according to strict schedules; for examples TWSTFT measurements. If the leap second is not properly introduced in the computer that controls this setup, the measurements will start 1 s too early or too late"

Real:
"Both NTP servers used at VSL have no provision in the firmware to program a leap second in advance. The NTP servers use a 1PPS reference signal which is directly derived from UTC(VSL). Time and date information have to be entered manually at start up and will then follow the normal time and calendar onwards. For the introduction of a leap second, the time has to be re-entered manually"

Potential:
"Time stamps for data may differ 1 s for 30 minutes due to slow time correction. process (Computers follow NTP time)…..

Real:
" Our time display was filmed (02:00 Local time) and put to you tube. This display is connected to our above mentioned (slow) NTP server, which have not automatic leap second corrections"

Real:

“Large display clock (commercial product) failed to adjust for leap second
NTP not available for 30 minutes
A web clock designed to update once every 10 seconds at a user’s display updated 0-10 seconds late
TWSTT modems placed offline for the period of the leap second
LORAN monitor receivers required recalibration”

Real:

“*It wasn’t incident I would say a misunderstanding,*

In the beginning of December 2008 some Bulgarian newspapers published information for leap second introduction on 1 January 2009 but I didn’t have this information from BIPM. Immediately I saw into web address of the International Earth Rotation and Reference Systems Service and there weren’t information yet.

So while I was looking for information my telephone was ringing and every body was asking me for that.”

Potential:

“A December leap second occurs on January 1 at 11 am local time in Sydney, which is a public holiday but otherwise causes no complication. The introduction of the leap second does not cause any disruption to equipment or services operating in the laboratory.”

Real:

“A software bug on one system caused a momentary loss of output due to a false error condition. The dialup time service did not make the leap second transition due to a bug in the software but this was automatically detected and system output inhibited. Both faults were immediately rectified and had no impact outside of the laboratory. We are not aware of any issues caused by the introduction of the leap second for users of our timing services.”

Potential:

“

NTP service, TDS time code service, HBG time code service…..
Everything that displays or uses a time code……………………..”

Real:

“

NTP servers introduced the leap second a bit late because of software problems in the IRIG/B time code generators. The NTP servers were configured OK it is the IRIG/B time code that drives the NTP servers that had a problem. The incident originated from an unforeseen urgent Windows XP security update followed by a reboot of the computers that erased the leap second pre-programming in the IRIG/B time code generators. We are confident that next time a leap second is introduced we will be successful if we can manage to avoid running standard MS Windows OS on critical computers. ”

Conclusions:

- No serious problems reported, but indeed problems.

- Most problems are of the same kind.

Concerning the procedures applied

The aim of this question was to learn whether the ITU-R rules for application of leap seconds on UTC are respected, and to have an idea of the extent of work involved.

In many cases preset/automated procedures in the equipment are applied, operation manual is followed. Some laboratories apply the leap second to some pieces of equipment after the event, other before. Some descriptions show that there is a lot of preparation work.

Citations from questionnaires

“ Written procedures are reviewed about a month before, over what must be done.
Computer files that can be updated in advance are updated.
Tests are made of relevant adjustment equipment before 3 weeks of the event.
Six or even individuals are present a few hours before and after the leap second
The teams implement the procedures and then monitor the behavior
The Department Head communicates about problems, with people world-wide”

“

A 61th second had to be added in the time code sequences at the end of the last minute UTC of 31.12.2008 (leap second is second UTC 23:59:60).

TDS time code generators are programmable in advance for any epoch (easy)

IRIG B generators are programmable in advance for any epoch (easy)

HBG time code generator is programmable in advance for any epoch (easy)

Our NTP servers must be specially configured in advance (firmware) with encoded NIST leap second file. The NTP daemon will acknowledge the introduction of a leap second by its reference clock only if it is notified in advance via the driver or a proper software mechanism (for instance the NIST leap second file). If properly configured, NTP servers introduce the leap second at the correct epoch specified by IERS. However only Linux kernel can handle a leap second properly. Windows cannot. It is difficult to test in advance how the NTP daemon configuration will behave in a given particular environment. It is easier to manage NTP servers that rely on radio controlled receivers (GPS, HBG or DCF) because the time code and the NTP clock driver have a built-in leap second notification mechanisms. However in our case we drive the NTP servers with an IRIG/B code derived autonomously from our atomic clocks and, unfortunately, the IRIG/B format does not include an impending leap second notification mechanism. Software testing is very time consuming.

Technically the introduction of a leap second has nothing to do with metrology. It is only a peculiar calendar event. So basically the problem is to introduce a calendar leap second in the time code, in real time and at the correct epoch, using the available software which is not necessarily well adapted to handle such an event.

Our equipment was configured in mid-December. The time code epochs (TDS, NTP, IRIG/B, HBG) transmitted from a few hours before until a few hours after the leap second event were logged every second for traceability. If something goes wrong we can look at the log files and a posteriori tell exactly what went wrong.

"

"Preparation: Talk with all people depending on the time and frequency system at the observatory. Introduce new/young people with some interesting details. Pre-program the cesium clocks according the device manual.
Introduction: The cesium clocks introduces the leap second automatically as pre-programmed. Manual adjustment of every Clock Module: Clock Modules receiving the frequency (5MHz) from the time keeping building must be re-adjusted. There is some manual interaction with these devices necessary concerning the "time of the day" (and the MJD). Adjustment of the GPS receivers: wait enough long time (in this case the receiver is automatically re-adjusted) or hard reset the device or update the almanac.
Verification: Using different Clock Modules (in different buildings) the "time of the day" and MJD are compared by phone and the 1PPS differences are measured using counters.
We have already introduced leap seconds in the past years successfully and we know exactly what we must do. Due to public holidays between Christmas and the new year, we are forced to do some manual tasks sometimes later than needed. During the critical time interval, no measurements are made and no data is send"

"The preparation for leap second introduction usually began 10 minutes prior to the moment a leap second will be inserted, then at Greenwich Time 23:59:59, insert a second 23:59:60s. During the process, the atomic clock runs freely and continually, the only affected parts are the time display units. After leap second insertion, a verifications are made. »

« First, we simulated the event to determine how our equipment responds. After following the user manual, in the control panel we scheduled the cesium clock to make the change at 0 h with a minute of 61 seconds

Then we correct the NTP server before leaving the laboratory (closer to 19 hours UTC) because their only source of time reference is the 1 PPS signal from our master clock and any adjust is can be done only manually

We decided to do it in this way, because since the days 1 and 2 of January were holidays and we returned on Monday 5."

"*Cs clocks are easy to program but masers not.*."

“When it was 23:59:59(UTC time), we stopped the equipment. And then the equipment was started again with next second according to GPS time. Finally we verified it by UTC time that was acquired by our GPS receiver”

“The leap second is inserted manually into the NIST ACTS servers. This is done during the first week of the month where a leap second is scheduled. (At the beginning of December, 2008 in this case). These servers act as the reference for all of the NIST NTP servers, and the advance notice is transmitted to the NTP servers about 1 hour after it is inserted into the ACTS system. The NTP and ACTS servers then set the advance notice flag for the leap second. The measurement system for the time scale receives the advance notice flag using NTP link to the time servers. All of this happens during the first week of December. All of the systems are programmed to execute the leap second at the end of the month once the advance notice flag has been received. No special commands are needed for this to happen. The ACTS servers implement the leap second by transmitting a time of 23:59:60. The NTP servers implement the leap second by transmitting a time corresponding to 23:59:59 two times – once for that time and a second time for the leap second. The ACTS servers also increment the dUT1 correction automatically during the leap second.…The measurement system for the time scale measures the time differences between the clocks in our ensemble every 12 minutes (720 seconds). As result of the leap second, the last interval of the month with a leap second is 721 seconds long. This introduces a small glitch into the prediction algorithm, since the time scale estimates the frequency of each clock assuming that the interval is 720 seconds, where it is actually 721 seconds. This glitch is generally too small to matter for the cesium devices, but it produces a time step that is observable for the masers, since the measurement noise floor is smaller than the time dispersion of a maser over 1 second.
The operation at the radio stations is similar – the leap second flag is set manually by the operators and the time code generators implement the leap second automatically during the last second of the day.”

Conclusions:

- The value of the answers is not on finding how properly the ITU rules are followed, but moreover to show how cumbersome this process may be.
- Some anecdotic answers have been cited, such as laboratories closed for some days, allusion to “Greenwich Time” instead of UTC …

On the process applied by other laboratories/institutes…

In general there is no knowledge on who is applying the procedure. There were just a few positive answers containing information. Many colleagues took the opportunity to express their feelings on the leap second and related matters.

Citations from questionnaires:

“The following information has been supplied to me regarding the insertion of the leap second into the BBC's timing systems:

a) The BBC experienced no significant problems, although technical staff were monitoring the timing systems around the insertion to deal with any problems that arose.

b) The main UTC feed is derived from 3 sources: a rubidium clock (which was programmed in advance), an MSF clock that updated at 00:02:02 UTC, and a DCF77 clock that updated at 00:04:00 UTC.
c) The insertion of the leap second into the time code distribution at BBC Television Centre was delayed until approximately 04:30 UTC on 1 January (a quiet period) to minimise the risk of disruption, and performed manually.
d) Some discrepancies were reported due to different time feeds updating at different times."

"*As a rule people are not interested in one second corrections. They have used to boring one hour jumps (summertime / normaltime), which causes much extra work for all population and for nothing.*
First we have to drop out summertime, then leap seconds"

"Panama no have laws to make the UTC realizated by CENAMEP the legal hour. The companies, institutes, observatories and people in general are not aware for the importance of the exact time. Is a very common practice in Panama to have a delay of 5 minutes in their clocks. Their think that the leap second is a purely scientific matters"

Final remarks

The results show that

- Not all time laboratories responsible for maintaining a local UTC take the information on the leap second application from IERS; many rely on the BIPM;
- There is a significant investment of manpower in the process of a leap second implementation in laboratories;
- The complete process may be heavy in laboratories with large responsibilities;
- There is a potential risk of disruptions coming from some specific equipment;
- Real disruptions occur, but without serious consequences.

I acknowledge the laboratory staff who dedicated a part of their time for responding to this questionnaire.