The Future of the UTC Timescale (and the possible demise of the Leap Second) – A Brief Progress Report

A Summary of the "Final" Findings Report co-authored and produced by F. Arias, T. Bartholomew and W. Lewandowski working at the BIPM in June 2008

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Introduction

The work reported here is one of the activities of ITU-R Study Group 7 (Science Services), Working Party 7A (Standard Frequency and Time Signal Services (Time Signals and Frequency Standard Emissions))

•ITU-R – The International Telecommunications Union (Radiocommunications Bureau) establishes international standards for the global management and efficient utilization of the radio-frequency spectrum and satellite orbits - limited natural resources in demand from a growing number of services such as fixed, mobile, broadcasting, amateur, space research, emergency telecommunications, meteorology, global positioning systems, environmental monitoring and communication services.

•Study Group 7 – Science Services has responsibility within ITU-R for standards relating to:

- Systems for space operation, space research, Earth exploration and meteorology, including the related use of links in the inter satellite service.

- Systems for remote sensing, including passive and active sensing systems, operating on both ground-based and space-based platforms.

- Radio astronomy and radar astronomy.

- Dissemination, reception and coordination of standard-frequency and time-signal services, including the application of satellite techniques, on a worldwide basis.

•Working Party 7A – Standard Frequency and Time Signal Services has responsibility within ITU-R for the last sub-bullet listed under SG7 above. This responsibility gives WP7A purview over the definition of UTC. This is one of the major (if not the biggest) concerns of WP7A since UTC is built in to many international and national regulations, laws and treaties.

•Special Rapporteur Group on the Future of the UTC Timescale – a group established by WP7A to study and consider the definition of UTC. [deal with the leap second issue]

Background

As a result of technical timescale issues raised by Sector Members of the ITU-R over the last few years and a letter from the Director of the BIPM to the Secretary General of the ITU in 1999, a new question ITU-R 236/7 (2000) “The Future of the UTC Time Scale was generated by Working Party 7A (WP7A). Question 236/7 was structured to address the future definition and use of UTC in the ITU-R recommendations. Major technical changes to UTC clearly have a potentially significant impact on communications networks, navigation systems, time/frequency distribution systems and virtually all aspects of civil/military timekeeping. With that in mind WP7A established a Special Rapporteur Group (SRG) chaired by Ron Beard (note the plug for one of my sponsors) to consider the future of the UTC timescale with particular emphasis on the leap second and issues related to non-uniform timescales. The SRG was asked to study the following specific questions:

•What are the requirements for globally-accepted time scales for use both in navigation and telecommunications systems and for civil time-keeping?

•What are the present and future requirements for the tolerance limit between UTC and UT1?

•Does the current leap second procedure satisfy user needs or should an alternative procedure be developed?

The SRG held numerous meetings and a general colloquium in Torino on the subject over the period from 2000 to 2006. The SRG produced and provided WP7A with a number of reports and plans some of which are documented in this report. WP7A efforts also engendered a number of reports, studies, questionnaires and formal submissions from countries and administrations represented in the ITU. Those documents were also considered and are included in the work reported on here.

Description of our work in the Drafting Group

In response to a number of requests from administrations represented in WP7A a drafting group with about a dozen members from eight countries/administrations was formed in April 2008 to prepare a “final” report documenting and summarizing the data and materials produced by, submitted to and considered by WP7A and the SRG during their work on the UTC time scale during the study period 1999-2008. The drafting group was chaired by F. Arias of the BIPM.

The drafting group assembled and organized as many of those materials as available. A sub-group met in Paris at the BIPM in June 2008 to consider and analyze the body of documents gathered by the drafting group. We worked to provide a report comprising a brief statement of background, a list and summary of each of the documents as received, an analysis of the materials, an overall summary and finally a number of derived conclusions.

It should be noted that the subject SRG effort was conducted over an extended period of time with multiple meetings, many participants and contributions. As such, while we believe that the documents collected by the drafting group and provided to this sub-drafting group, offered a full and comprehensive perspective of the overall effort, they should be considered representative and not necessarily a complete compilation. We solicited and tried to incorporate further contributions, any missing items noted and pertinent comments received before the end of the drafting period on 30 June.

In a near “ITU first” we finished and published the report on time.

Inventory & Summary - UTC Documents Reviewed by the Drafting Group

Contributed Documents

1. American Astronomical Society (AAS) Council – Document by the AAS division on Dynamical Astronomy Working Group and Coordinate System Standards (2005).
2. Report of the AAS leap second committee, 12 December 2007 – Membership included representatives from NOAO, University of Washington, USNO, JPL, University of Virginia and NRAO.
3. France – Report on the national survey conducted by CNES and the Paris Observatory in January 2005, and the results of a national meeting held in May 2005.
4. Letter from Judah Levine, Time and Frequency Division of NIST (USA) – This letter stresses the impact of retaining leap seconds.
5. Letter from Tom O'Brian, Chief of Time and Frequency Division of NIST (USA) – Supports and adds to Levine's letter:
6. Letter from Tom O'Brian, Chief of Time and Frequency Division of NIST (USA) to A. Vassiliev reporting on leap second experience at NIST at the end of 2005, 4 January 2006.
7. Letter from Anton Niessner, BEV (Austria)
8. Letter from Juan Palacio, Time Section ROA (Spain)
9. Letter from Teodoro Lopez Moratalla, Ephemeris Section ROA (Spain)
10. Letter from Andreas Bauch, Time Dissemination Working Group, PTB (Germany)
11. Letter from the IAU General Secretary to A. Vassiliev, 3 March 2006.
12. Report from IAU Working Group on the redefinition of UTC

Contributed documents (continued)

13. URSI Commission J Working group on the leap second
14. Seago and Storz – Paper on the redefinition of UTC.
15. Seago & Seidelmann – Paper for the American Institute of Aeronautics and Astronautics.
16. Royal Astronomical Society (RAS), UK (July 2005)
17. Royal Institute of Navigation (RIN), March 2005.
18. Jörg Hahn, Galileo Project Office, ESA.
19. ARC Electronic, Inc., company concerned with safety and survival technologies 2005.
20. Letter from EUMETSAT to A. Vassiliev, 16 February 2006
21. IETF document reporting experience at the leap second application end of 2006.
22. Letter from the chair of the International VLBI Service for Geodesy and Astronomy (IVS) to A. Vassiliev, 11 July 2006
23. JSAT corporation, ITU document 2006 on the insertion of the leap second
24. SAAB announcement on problems encountered with transponders, 15 September 2005.
25. USNO report on problems at the leap second insertion end of 2005, 2006
26. The leap second: its history and possible future,*Metrologia* 2001, **38**, 509-529, Nelson et al.

ITU-R Documents

1. UK, 28 October 2005
2. UK, 25 March 2008
3. Germany, 9 August 2006
4. Germany, France 5 March 2008
5. Japan, 20 September 2002
6. Japan, 22 August 2006
7. Japan, 4 September 2007
8. Russian Federation, 7 August 2006
9. Italy, 30 August 2007.
10. Bureau International des Poids et Mesures (BIPM) – Consultative Committee for Time and Frequency (CCTF), 5 September 2007
11. France, Bureau des Longitudes 25 March 2008
12. USA, 17 April 2001
13. USA, 26 September 2000
14. USA, September 2004
15. USA, 22 August 2006
16. ITU-T SG 15, 12 May 2008
17. Chairman's report of WP 7A, 8 October 2003 – [Contains the report of the Special Rapporteur Group on UTC including the results from the Torino meeting]

Summary

The documents listed above provide comments and arguments regarding the suppression of leap seconds that can be classified as follows: (a) favouring the change; (b) neutral or urging more study and consultation: (c) identifying potential difficulties to overcome if the change were made and; (d) opposing the change.
They are summarized as follows:

(a) Favouring -- for the proposal, but specifically proposing some significant delay in the effective date - most of the administrations and sector members represented in WP7A. For the proposal and ready for near-term put into force - the ESA, BdL and Galileo organizations are representative of this position. The submitted documents indicate:

•Activities that would benefit from suppression of the leap second include: geodesy - accurate access to UT1; networks; space activities - launch schedules; highly precise timing applications;

•Celestial navigation, space activities, global navigation satellite systems, telecommunications, network synchronization, and electric power distribution interests have all requested continuous time scales;

•Digital time distribution systems cannot deal efficiently with leap seconds;

•Impacts of the leap second in regions of the East are more significant and can be major;

•As systems become more complex and interdependent, the chances for significant disruptions increase;

Summary (continued)

•Reports on the December 2005 leap second event show that problems were detected at the hardware level for many NTP servers, but the most striking fact is that the official procedure for the application of the leap second was not universally followed. Different communities applied different methods that led to inconsistencies in time and frequency measurements during the 100-120 seconds before the event; moreover, some systems were interrupted several hours before and after the event to prevent operational mishaps;

•Misunderstanding of the definition and uses of time scales and time synchronization systems - even in the case of people with expertise in matters related to time and frequency, there is confusion on using and accessing TAI, UTC, GPS and GLONASS times. This situation is most probably compounded by the proliferation of continuous "pseudo time scales", leading to the erroneous concept that a user could select one of these without serious consequences;

•International and national organization experts in the different fields related to time-keeping (IAU, CCTF, ITU-T, BdL) support the change;

•Most national administrations that participate at the WP7A have provided documents recommending the suppression of leap seconds - France, Japan, Germany, Russian Federation, USA and Italy - in all cases they have recommended allowing sufficient time before the effective date of any new definition to allow any necessary changes in software, hardware and procedures;

Summary (continued)

(b) Neutral or recommending more consultation and study -- the documents indicate:

•Completely or more or less neutral regarding the proposal -- IAU, AAS, JPL, and the NRAO are representative of this position.

•Consultation should continue with other relevant international organizations, but a number of contributors feel that ample opportunity has already been provided to virtually every concerned user community, organization and administration to present their opinions and/or positions

;

Summary (continued)

(c) Identifying potential difficulties to overcome – a new definition of UTC as a uniform continuous time scale, without leap seconds would require users to cope with various potential difficulties that were listed as:

•Existing software and methodology based on 35 years of experience - changing procedures and legacy software may be challenging;

•Discontinuing leap seconds will affect those that have to maintain such software;

•Formats for transmitting the offset UT1-UTC would need to be modified;

•Astronomical systems based on earth orientation could be affected, but, compared to other operators, the astronomy community is seen as more technically sophisticated and should be able to cope with complex timing issues;

•Costs of changing software and hardware could be significant;

•Keeping the name UTC could be confusing;

•Educational aspects and existing literature could be invalidated by the change

•Loss of publicity when these events occur

Summary (continued)

(d) Opposing the change -- against the proposed removal of leap seconds no matter what effective date might be established

•There is one national administration represented in WP7A that opposes the change. Their arguments include some technical elements, but are mostly cultural and social issues and they provide statements of technical support from a two of their national professional societies.

•There are other organizations such as URSI that have significant segments of their membership in opposition.

It should also be noted that a significant fraction of those responding to the questionnaires circulated in 2002 by NICT were opposed, and that this position changed in another questionnaire reported in 2007 by the Japanese administration. This questionnaire was circulated to a larger population of users and they now find that a majority supports the suppression of leap seconds.

Conclusions

We saw an evolutionary drift of opinion over the duration of the effort. Some organizations like the AAS, while initially opposed to the proposal, are in the neutral camp. Japan, while initially in opposition or neutral regarding the change has shifted to a position of clear support.

Even though there have been many opportunities, it is clear that there are major organizations that have not yet publicly weighed in on this subject. Their lack of response could be interpreted as a neutral position.

It is also clear that we have little or no information on quantitative costs either way. The few estimates that were offered seem to be guesses at best. A number of observers note that there are costs associated with maintaining the status quo that may or may not be mitigated by the proposed change.

While there are pro, con or neutral opinions in the user communities, experts in time metrology agree on the necessity for the change and offer technical support for it. This is the unequivocal position of the CCTF, which brings together experts from the most relevant national metrology institutes maintaining local representations of UTC. They strongly recommended that if the final decision is made to suppress leap seconds in UTC, that enough time should be given to allow for any necessary software and systems modifications.

Conclusions (continued)

The documents produced primarily over the last two years of this effort appear to indicate that the timing community has realized that this seemingly interminable ITU process may not be the most effective technical mechanism for the definition and maintenance of the international timescale. This again raises fundamental questions about the respective roles of the ITU and CCTF/CGPM and related agencies with international T/F responsibilities.

Many of the documents demonstrate a clear misunderstanding of the definitions and applications of time scales and system times for internal synchronization. It was frequently indicated that users have the choice between UTC, TAI, UT1, GPS time for their applications. However, UTC is the only practical time scale, represented by local approximations in time laboratories, that is broadcast and can be used for worldwide time coordination. Therefore, for applications needing a continuous reference, TAI is not an option, as it has no means of dissemination, and it is not represented by clocks. GPS time is not a reference, it is simply an internal time for GPS system synchronization, as GLONASS time is and Galileo time will be.

A variety of continuous time systems and scales have proliferated to provide a deceptively simple solution to the problems associated with discontinuities in UTC. Experience has shown that these solutions propagate their own problems as well as conceptual confusion on the proper definition and role of time references.

Comments

Recently the USDOD put out a statement, white paper and questionnaire on this subject on the web. Their questionnaire is quite detailed with numerous questions regarding impacts and costs. They are soliciting inputs before the end of September. WP7A meets in October. Questions on this – see Bill Bollwerk (USNO).

The path from here – if WP7A were to agree on this change in UTC in 2008, sent it to SG7 in 2008, then the Radio Assembly (RA) in 2009 could send the proposal to the World Radio Conference (WRC) in 2011. Approved recommendations have to percolate for a year after the WRC, so if the delay delta stays at five years, that would put the recommendation into effect not earlier than 2017-2018.

Any detailed explanation of the technical aspects and history of this issue is well beyond the scope of this talk. For a comprehensive review of the subject, I recommend that you read The leap second: its history and possible future, *Metrologia* 2001, **38**, 509-529, Nelson et al.

Questions?

Backup Slides

- None – I had planned to provide the detailed inventory and our summary of each of the documents described in the preceding epistle, but ran out of time. I can make them available via email as a Word document for anybody who might be interested.