

FUTURE OF UTC: CONSEQUENCES IN ASTRONOMY: REPORT ON THE UTC WORKING GROUP AND THE LATEST DEVELOPMENTS

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ABSTRACT. The International Telecommunications Union Radiocommunications section (ITU-R) Working Party 7A has created a Special Rapporteur Group on the Future of the UTC Time Scale, and it presented its final report in September, 2004. This report suggests potential alternatives to the current relationship between the UTC time scale and the Earth's rotation angle as described by UT1. It is expected that this may lead to formal proposals to re-define this relationship. Possible consequences for the astronomical community are reviewed.

1. BACKGROUND

Coordinated Universal Time (UTC), the basis for worldwide civil timekeeping is an atomic time scale with a rate corresponding to the internationally accepted definition of the length of the second. However, it is adjusted in epoch by the occasional insertion or deletion of an integral second in order to keep it within 0.9s of UT1, the angle, expressed in terms of time, which is used to measure the rotation angle of the Earth in a celestial reference frame. This definition was implemented in 1972, principally to accommodate celestial navigation. The definition of UTC follows recommendation 460 of the International Radio Consultative Committee (CCIR) in 1970.

Stephenson and Morrison (1995), from their study of solar eclipse information, have shown that the average rate of increase in the length of the day is about 1.7ms per century in the long term. Although this might seem insignificant, the integrated effect on the difference between a uniform time scale and one based on the Earth's rotation can be very significant. For example, a time scale based on the Earth's rotation has lost more than three hours with respect to a uniform time scale over the past 2000 years. (Stephenson 1997). This deceleration of the Earth's rotation indicates that leap seconds will be inserted with increasing frequency in the future.

Since 1972 the use of electronic means to navigate has overtaken celestial navigation. This fact along with increasing public dissatisfaction with the possible disruption to modern electronic communications and navigation systems caused by the insertion of a leap second has called into question the current definition of UTC. An extensive review of the background and issues relating to the leap second can be found in Nelson *et al.* (2001).

2. CONSIDERATION OF A POSSIBLE REDEFINITION OF UTC

In 2000 the International Telecommunications Union Radiocommunications Section (ITU-R), the follow-on organization to the CCIR, adopted Question 236/7 “Future of the UTC Timescale” for discussion and possible future action. The issues addressed in this question were:

- What are the requirements for globally-accepted time scales for use both in navigation/telecommunication systems, and for civil time keeping?
- What are the present and future requirements for the tolerance limit between UTC and UT1? and
- Does the current leap second procedure satisfy user needs or should an alternative procedure be developed?

The question stipulated that results of the above studies should be included in recommendation(s), and that the above studies should be completed by 2006. It further required that this question should be brought to the attention of the Bureau international des poids et mesures (BIPM); the International Earth Rotation Service (IERS), now called the International Earth rotation and Reference system Service; Study Group 13 of the Telecommunication Standardization Sector; and ITU-R Study Group 8.

The question was referred to Working Party 7A (WP 7A) (Time Signals and Frequency Standard Emissions) of Study Group 7 (Science Services) for their action. In response WP 7A created a Special Rapporteur Group (SRG) to gather information and prepare a report with possible recommendations. The SRG met in December 2000, March 2001, May 2001, December 2001, and March 2002. A colloquium on the subject was held in Torino, Italy in 2003. During this time independent surveys on the topic were also conducted by the IERS, The International Union of Radio Sciences (URSI), the Communications Research Laboratory of Japan (CRL), and the National Institute of Standards and Technology of the USA (NIST). The SRG presented its report to the ITU-R WP 7A in September, 2004. At that meeting the USA WP 7A members proposed formally a recommendation to change the definition of UTC to modify its definition so that in the future, adjustments would be made to keep the difference between UTC and UT1 within one hour.

The International Astronomical Union (IAU) Working Group on the Definition of Coordinated Universal Time was created in compliance with IAU Resolution B2 of the 24th IAU General Assembly. The members were F. Arias, W. Dick, E. Fedoseev, D. Gambis, W. Klepczynski, S. Leschiutta, J. Luck, Z. Malkin, D. Matsakis, P. Paquet, J. Vondrak, P. Wallace, and S. Ye. D. McCarthy served as Chairman of the Group and as IAU representative to the ITU-R Special Rapporteur Group (SRG) on the Definition of Universal Time.

The IAU Working Group carried on its work by electronic correspondence and occasional meetings of opportunity. It contacted groups using celestial navigation and found no interest in continuing the use of leap seconds. It also identified the possible problems with existing software should a change be made in the current definition of UTC. Some members recommended the greater use of International Atomic Time (TAI) as a uniform time scale, but others argued that TAI would have to become more accessible to be widely used. Its report was submitted to IAU Division 1.

At the next IAU General Assembly it was decided to extend the lifetime of the Working Group to formulate a draft response to the possible recommendation of the ITU-R. The membership was revised at that time, and its new members are F. Arias, W. Dick, D. Gambis, M. Hosokawa, W. Klepczynski, S. Leschiutta, J. Laverty, Z. Malkin, D. Matsakis, R. Nelson, J. Vondrak, P.

Wallace, N. Capitaine (ex officio), and D. McCarthy (chair). Its response to any official action by the ITU is to be submitted through Division 1 to the General Secretary for IAU approval.

3. OPTIONS DISCUSSED

Options that have been discussed for the future of UTC include:

- Maintain the status quo
- Increase the tolerance between UT1 and UTC
- Periodic insertion of leap seconds
- Variable adjustments in frequency
- Redefine the second
- Substitute TAI for UTC
- Discontinue leap seconds in UTC

None of the options beyond (1) has received significant acceptance in discussions and surveys to this point. Also discussed has been the feasibility of establishing a low-cost low-precision UT1 service for any applications that need approximate mean solar time. The Internet would be a possible way to accomplish this and the IERS is taking steps to implement that service.

4. ISSUES

In the time since the ITU-R adopted Question 236/7 it is clear that analyses of Earth rotation lead to the conclusion that, at some future point, multiple leap seconds per year will be required to maintain the currently defined tolerance between UT1 and UTC. While advances in telecommunications, navigation and related fields are moving toward the need for a single, internationally recognized uniform time scale, no overwhelming consensus has emerged regarding maintaining the status quo until change is essential or actively seeking an alternative in anticipation of that change.

Continuation of the current definition has also led to concerns regarding the timing sequence to be followed during the actual implementation of a leap second. The convention is to number the leap second with the label “60” in the minute in which it has been inserted. Unfortunately many timing system do not permit a second to be labeled “60.” In the past, this may have resulted in 2 seconds labeled 59 or even a second without a label. A conventional means to resolve this problem has not been adopted.

Yet another concern is that the traditional model of generating internal system time scales for operations could produce multiple *de facto* time scales. These “pseudo time scales” could lead to confusion and potentially serious consequences.

On the other hand some members of the astronomical community have expressed concerns over any change to the current system. These concerns are based on existing software that takes advantage of the current definition and uses UTC as a substitute for UT1. Their requirements for precision are such that the current 0.9-second tolerance is adequate, and their software has been designed accordingly. Should the definition of UTC be modified in any way that would permit this tolerance to be exceeded, they would anticipate substantial cost to make non-trivial changes in existing software. Similarly, the astrodynamics community has similar concerns regarding legacy software used in the determination of orbital parameters of artificial satellites that again utilizes UTC as a substitute for UT1.

However, although UT1 is expressed as a time, it is not used practically as a time scale. It is used as an angle that is related to the rotation angle of the Earth in the celestial reference frame. Knowledge of UT1 is essential in relating celestial and terrestrial reference systems and is obtained observationally for that purpose. The IERS provides daily values and predictions for up to a year in the future. It is conceivable that the systems served by legacy software based on the current UTC definition could benefit from using more realistic values for UT1 as opposed to the UTC approximation.

The reference of UTC to UT1 does provide a means to keep UTC vaguely in synchronization with the position of the Sun in the sky. It is generally agreed that a change in the definition of UTC that would cause legal time to depart from a solar connection would be unacceptable.

5. TORINO COLLOQUIUM

Although there was no overall consensus on this topic, findings from the official report of the Torino Colloquium, held in 2003, were the following.

- The definition of UTC is likely to evolve from the current UTC standard by transitioning to a uniform time scale, perhaps to be called Temps International (TI).
- If a change were to be made, a date suggested to inaugurate that change could be 2022, the 50th anniversary of the institution of the UTC timescale. This date was influenced by the anticipated lifetimes of existing systems that would be expensive to change.
- TI would likely be a continuous atomic time scale, without leap seconds, synchronized with UTC at the time of transition.
- The responsibility for disseminating UT1 information should remain solely with the IERS.

6. SPECIAL RAPPORTEUR REPORT

Following the Torino Colloquium and after further discussion, the SRG prepared a final report outlining a possible transition to a new definition of UTC. The final report of the SRG was submitted to ITU-R Working Party 7A. It contained the following recommendations.

- The creation of a new name was not recommended because it would add significant complications in the process of defining a new time scale. A name change alone could cause great confusion and complications in the ITU-R process and systems attempting to implement the new standards.
- The radio broadcast of DUT1 information should be discontinued since UT1 is available via IERS.
- The redefinition of a new “UTC” is not necessary
- Divergence from solar time, a possible issue in “civil” timekeeping is considered to be insignificant as an error of approximately 1 hour would result in 2600. Subsequent step adjustment could maintain approximate agreement and that advances in time keeping may lead to other solutions.
- The recommended date for change is 2010.

7. RECOMMENDATION PROPOSED TO ITU-R WP-7A

In order to work toward a final decision on the matter, the U. S. Working Party 7A prepared a proposal that was submitted to ITU Working Party 7A in September, 2004. In that proposed recommendation the Operational Rules for the formation of UTC after 0000 UTC December 21, 2007 would be modified so that the difference of UT1 from UTC should not exceed 1 hour. It further proposed that adjustments to the UTC time scale should be made as determined by the IERS to ensure that the time scale remains within the specified tolerances and that the IERS should announce the introduction of an adjustment to the UTC time scale at least five years in advance. At the time of that announcement the IERS should provide directions regarding the details of the implementation of the adjustment. The broadcast of DUT1 would be discontinued. Analysis of historical observations of the Earth's rotation currently indicates that such an adjustment would not be required for at least 500 years.

This proposal was rejected by the Working Party largely because of its early proposed date for implementation.

8. FUTURE

Discussion continues on this subject. It is important that final resolution is obtained as new navigation and communication systems are being planned that need to be able to plan on a future means to obtain a standard uniform time scale.

If formal recommendation were to be referred to ITU sector members, the IAU would be expected to respond. The draft response would be prepared by IAU Working Group that includes F. Arias, W. Dick, D. Gambis, M. Hosokawa, W. Klepczynski, S. Leschiutta, J. Lavery, Z. Malkin, D. Matsakis, R. Nelson, J. Vondrak, P. Wallace, N. Capitaine (ex officio), D. McCarthy (chair). It would be submitted through Division 1 to General Secretary for IAU approval

9. REFERENCES

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