



Chairman, Special Rapporteur Group 7A**UTC TIME SCALE****3-4 May 2001 Meeting Report**

This is the activities report of the Special Rapporteur Group 7A (SRG 7A) on the future of the UTC Time Scale, through May 2001. This meeting concluded the preliminary plan of action on this question developed and agreed to by ITU-R Working Party 7A (WP 7A) at their meeting in October 2000.

Background

A new question was generated by WP 7A concerning the future definition and use of Coordinated Universal Time (UTC) in the ITU-R Recommendations as a result of issues raised by sector members and a letter from the Director of the Bureau International des Poids et Mesures (BIPM) to the Secretary General of the ITU. The Question is ITU-R 236/7 (2000), "The Future of the UTC Time Scale". Determination and maintenance of the UTC time scale is conducted by the BIPM in conjunction with the International Earth Rotation Service (IERS). But the question was raised to the ITU-R due to its responsibility in the definition and use of time scales for radio and telecommunications purposes.

The implication of changes to the recommended UTC time scale in the current recommendations could have significant impact on scientific, governmental, commercial and regulatory interests. Accordingly, WP 7A on Standard Frequency and Time Signal Services established this Special Rapporteur Group (SRG) to address this significant question on the use of the UTC.

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Activities and Results (October 2000 – May 2001)

The objectives and activities of the SRG were originally determined at the formation of the group. The plan and results shown in italics are discussed below.

- 1) Identify Participating Organizations Points of Contact for coordination of materials.

The draft letter of the Director, ITU-R, sent to announce the formation of the SRG on the Future of UTC included a number of suggested participating organizations. The draft letter and clarifying information was submitted through SG7 to the secretariat for approval and release.

- 2) Generate clarification or additional material on Question ITU-R 236/7 for distribution and comment.

Additional information in the form of presentation materials was prepared for use at two conferences where these issues would be discussed. Some additional clarification was necessary. In general, the presentations were focused on issues and participation desired from other scientific and operational organizations.

- 3) Circulate a letter from Director, ITU-R, to the interested organizations by 1 November 2000.

The draft letter initiated by WP 7A was finalized and released from the ITU-R on 8 Jan 2001. The letter was distributed to the BIPM, CCTF, COSPAR, IAU, ICAO, ICSU, IMO, IUGG, IUPAP, URSI, and WMO. As a result of the ITU-R letter three

additional participants joined the SRG. These participants are Mr. Sigfriedo Leschuttia (CCTF), Mr. Dennis McCarthy (IAU), and Mr. Daniel Gambis (IUGG).

- 4) Introduce Question ITU-R 236/7 (2000) and ITU-R intentions to the timing community at the Annual Precise Time and Time Interval (PTTI) Meeting, 28 November 2000.

A special panel discussion session was held at the PTTI Dec 2000 meeting concerning the Leap Second. Short presentations were made by Mr. Dennis McCarthy (USNO), Mr. Steve Malys (NIMA), and Mr. Ronald Beard (SRG). The presentations and subsequent discussion will be published in the PTTI Proceedings. During the discussion period, Mr. Demetrios Matsakis (USNO) mentioned an URSI Study group that he chaired that was formed to also address the Leap Second issue. He provided the results of a survey they conducted. The survey report is attached.

- 5) Collect preliminary statements/comments from participating organizations as basis for the initial meeting to coordinate issues and ascertain the extent of required actions that may be necessary.

No preliminary statements or comments were received.

- 6) Conduct coordination meeting in conjunction with European Frequency and Time Forum, March 2001, Neuchatel, Switzerland.

Another special meeting was arranged in conjunction with the EFTF in lieu of a coordination meeting. In light of little response from organizations other than the IAU, a summary of the IAU considerations was presented and Mrs. Felicitas Arias, Head of the BIPM Time Section, was invited to present information on this issue. She gave a brief history of the formation of UT1 and UTC and the current procedures used for the formation of UTC and the Leap Second. She mentioned that systems, such as GLONASS and those using Network Time Protocol (NTP) have had difficulties with Leap Seconds. She also pointed out that other international organizations are starting to discuss the issue. She concluded that it might take some time for their deliberations to come to a definitive conclusion.

- 7) Based on the actions defined in steps 1) - 6), determine if additional efforts are necessary to evaluate potential changes to ITU-R Recommendations. If determined necessary, formulate final plan of action and time required.

Based on the results of the activities discussed above and the insufficient information available, it was not yet possible to come to any conclusions or formulate any recommendations.

- 8) Meeting of the Special Rapporteur Group 3-4 May 2001.

The results of this SRG meeting are reported below. An additional phase to the effort was determined to be necessary. The course of action developed is described below and is believed to be sufficient to study the question and provide definite suggestions on revision of the recommendations.

Results of the Meeting of Special Rapporteur Group, 3-4 May 2001

The agenda of the meeting that was held at the ITU-R in Geneva follows:

- I. Introduction and Purpose
- II. Recognition of Participants and Representatives
Reports from Representatives
- III. Preliminary Review of uses of UTC

National and International

IV. Time Scale Considerations

Proposed changes to UTC

TAI and Alternatives

Comments from SRG Members

V. Discussion of Views by the Group

VI. Study Plan Discussion

VII. Summary & Action Items

Attendees

Mr. Ronald Beard (USA), Chairman

Mr. William Klepczynski (USA - IAU), Secretary

Mr. Jacques Azoubib (BIPM)

Mrs. Francoise Baumont (France)

Mr. Michel Brunet (France)

Mr. Daniel Gambis (IUGG)

Mr. Donald Hanson (USA)

Mr. Sigfriedo Leschiutta (CCTF)

Mr. Dennis McCarthy (IAU)

After introduction of new members and general discussion of the objectives of the SRG, comments by representatives were invited and they took the form of short presentations. Mr. Gambis summarized the role of the IERS and its contribution to Earth rotation monitoring that determine Leap Seconds for maintenance of the international UTC time scale. After his comments, there was a discussion of the areas that use UTC in national and international systems. There were five areas discussed. These areas were satellite navigation systems, telecommunications systems, computer networking, broadcast services, and scientific uses. The dominance of GPS systems in these areas was mentioned. Since GPS disseminates UTC (USNO), there is considerable investment in GPS equipment serving these systems and this may create a considerable reluctance to change. This factor should be considered in the SRG deliberations. The SRG needs more information on use and investment in these areas. Procedures to effectively gather data in these areas were discussed extensively by the members. Conclusions on new procedures were incorporated into the final course of action described later.

Before discussing time scale considerations and the presentation by Mr. McCarthy on IAU studies, Question ITU-R 236/7 was reviewed in greater detail and the three study areas mentioned in the Question were discussed. From this discussion the SRG concluded that clarification of these areas would be necessary in the information provided by the contributing groups. The additional factors to be considered by the SRG are outlined below.

Point 1. Clarify requirements by identifying the following additional information.

- a. Accuracy of timing information;
- b. Stability of references;
- c. Basis for the second used in the time scale;

- d. Uniformity and accessibility of references;
- e. Reliability;
- f. Relation to legal time;
- g. Coverage needed.

A special query should be directed to the international timing centers to clarify the uses of UTC in the area of civil and legal timekeeping.

Point 2. The definition of future requirements on tolerance limits between UTC and UT1 may be very difficult for users to foresee. Information on the sensitivity of changing the tolerance on operations may be a better indicator.

Point 3. Possible alternative procedures and specific changes being considered should be clarified for the user. As an example, better explanation of current procedures detailed in a handbook might satisfy user needs rather than making major system changes.

The relationship of internal system time references to the requirements that determined their design and operation needs to be better understood by the SRG. In other words, why did a system not adopt a standard time scale as its reference.

The presentation by Mr. McCarthy discussed the options and changes under considerations by the IAU working group on this issue. The various options were discussed by the SRG and were categorized into three major areas of options. These options for the UTC time scale are discussed below.

Option 1: Maintain the Status Quo

In order to maintain the system and operations as they are currently, it was apparent to the SRG that additional information is necessary for users to effectively use current time scale information. UTC would continue as the recommended time scale and its relation to other time scales, such as TAI, should be better explained for system designers and operators. Design for use of time scale information should be explained and understood by system users. Implementation of more advanced notice of Leap Seconds that is more widely available, could significantly aid current users in their operations. It may be necessary within this option to consider the creation of new, lower accuracy time scales to meet the needs of users who do not require high accuracy, e.g. celestial navigation needs.

Option 2: Modify Leap Second Procedures or Occurrence

To lessen the impact of Leap Seconds on systems requiring continuity in their operation, the tolerance between UTC and UT1 could be modified. Various modifications were discussed. However, specific values would be dependent upon the information gathered from users. Alternatives to modifying $|\text{UTC}-\text{UT1}|$ tolerance could be to vary or fix the interval of occurrence. In this case, multiple Leap Seconds would be necessary and could be applied at fixed intervals. Another alternative discussed along this line was to increase the prediction interval based on a longer-term deceleration model of the earth rotation rate for time scale correction at fixed prediction intervals. The difficulty is the un-predictability of the deceleration rate over long periods of time. The adoption of this alternative would need to be carefully considered.

Option 3: Use, or transition to another time scale

The sole use of the TAI time scale in current systems would need a carefully developed transition plan. Immediate use would introduce considerable operational problems. As part of a transition plan the availability and maintenance of TAI for general use would need to be improved. A handbook explaining its use and transition details would be necessary prior to implementation. As

discussed above in Option 1, a lower accuracy time scale for general-purpose use should be considered in this option as well. The formation of a totally new time scale based on a redefinition or modification of the SI second was considered to be possible. However, redefinition of the SI second would be highly dependent upon technological advancement and many other complex issues beyond time scale considerations. Such a change is considered by the SRG to have a very low probability of occurring in the near future.

Plan of Action

Having discussed the results of the SRG activities to this point and identifying the possible alternatives, a plan of action was developed. To remain within the original scope of effort in producing definitive suggested recommendations on the future of the UTC time scale for consideration by Working Party 7A, a plan, for completion by their 2002 meeting, was developed.

The approach followed in the preliminary plan of action in contacting organizations for participation and obtaining necessary information on time scale usage has not been very productive. An alternative plan was developed to produce an increased awareness within the ITU and other scientific and technical organizations. It is felt that this plan will develop the sources of information necessary to base a recommendation for WP 7A.

The two aspects of this plan are to increase the awareness within other organizations of the existence of the SRG and to the Question of the future of the UTC time scale, through:

- (1) Release of a general circular letter to both sectors of the ITU announcing the SRG and its objectives; and
- (2) Publication of articles and notices in the newsletters and general information journals of scientific and technical organizations.

This new approach should increase awareness and participation in this effort. In addition, the SRG will directly follow up and contact the sector members who received the original letter from the Director, ITU-R. Additional correspondence and contacts with other potentially interested organizations will also be pursued.

E-mail will be the primary means for coordination and exchange between SRG members between meetings. The consideration of an ITU e-mail mirror site, as was discussed in earlier sessions, was held in abeyance pending the results of contacts and response of organizations involved.

Two SRG meetings were scheduled for the coming year. They are currently planned as one-day sessions concurrent with the PTTI meeting during the last week of November 2001, and the EFTF meeting in mid March 2002.

With these planned efforts and meetings it is anticipated that a final report with *suggestions on the recommendations*, will be available for WP7A meeting in 2002 and the mission of the SRG will be completed.

ATTACHMENT A

Report of the URSI Commission J Working Group on the Leap Second

Date: July 2, 2000

Abstract and Conclusions

An e-mail survey to find possible adverse effects of a redefinition of UTC has identified some possibly expensive or unsolvable problems involving software rewriting or checking, which are listed below. Although it was not possible to quantify the financial scale of resolving the software problems, the largest expenses appear to be for satellite systems, of which one estimate of several hundred thousand dollars was supplied. The quantity and quality of the responses opposed to a change indicate that those who favor any change must be prepared to make a very convincing argument to people and groups who initially will disagree with them.

To further discuss this issue and inform the community of any developments, an archived electronic listserv has been set up. Anyone wishing to join can do so using <http://clockdev.usno.navy.mil/archives/leapsecs.html>.

Introduction

UTC (Coordinated Universal Time), which the public commonly confuses with Greenwich Mean Time, is computed by occasionally adding leap seconds to International Atomic Time (TAI). Since 1972, these leap seconds have been added on December 31 or June 30, at the rate of about one every 18 months, and serve to keep atomic time in step with the Earth's rotation. Although it is recommended that users use only TAI or UTC, as their needs indicate, many major navigation systems have used times offset from TAI by fixed amounts. The most important of these is GPS, which is offset by 19 seconds from TAI.

A segment of the international timing community has proposed a revision of the definition of UTC to avoid the discontinuities due to intermittent leap seconds. A discussion of the motivations for a change and of possible solutions has been published by McCarthy and Klepczynski in the Innovations Section of the November, 1999 issue of GPS World. The authors consider the most significant reason for a change to be keeping spread-spectrum communication systems and satellite navigation systems compatible with each other and with civil times. Another reason is the emerging need in the financial community to keep all computer time-stamps synchronized.

In order to survey the effects of any action, an URSI Commission J Working Group (WG) was formed, whose purpose was to prepare this report and propose further actions.

Methodology

A questionnaire (Appendix I) was distributed as widely as seemed appropriate (Appendix II). The goal of the questionnaire was to find and categorize those operations that would be adversely affected should a change in UTC's computation be made. The questionnaire focused on the possibility of simply inserting no new leap seconds, although alternative solutions were also solicited. Over 200 responses were received, and no effort was made to separate the responses of URSI members from those of nonmembers.

The principal object of the questionnaire was to find what systems would be adversely affected should a change be made in leap second procedures rather than to convince users of the need for a change or to take a vote. However, so many queries on these matters were received that a "standard reply" (Appendix III) was developed and distributed as appropriate. In the spirit of full disclosure,

the number of responses in each category is given, but we caution that this was by no means an unbiased sampling of all who would be affected by the change. All responses were counted only once, with preference to the most practical grounds for objection. About half the responses that were received were opposed to any change, while one-fourth were in favor of a change, and one-fourth indifferent.

I. Responses Opposed to Changes in the Status Quo

A. The expense of rewriting software.

Five responses suggested that contractors would have to be hired to scrutinize and adapt large amounts of code for operational satellite systems. Efforts were made to contact these responders for specific dollar amounts, and one off-the-cuff estimate of "several \$100,000" was received. The impact on such systems would be lessened if any decision to redefine UTC were announced several years in advance.

Twenty-six others indicated that software would be a serious problem – a very few of these were from people who did not seem to understand the proposal. There were 9 responses involving telescope control; one of these, from the Keck Observatory, provided a rough estimate of a few programmer-months. Others pointed out the problems computing eclipses and occultations, for telescope pointing by amateurs, or with code they had themselves written for professional-level projects such as speckle interferometry. One observatory indicated its station clock can not accommodate a large UT1-UTC correction.

Fourteen more indicated that software issues would be a problem, but that they are probably solvable. Some of these actually indicated support for the change.

B. Inherent inability to rewrite software to allow for $|\text{UT1-UTC}|$ exceeding .9 seconds.

Ten responses involved navigational software. Taking the example of a software product of the US Naval Observatory (USNO), pilots and sailors are given the option to input UT1-UTC. However, it is expected that many users would not understand this and enter 0, leading to noticeable errors within a decade. These are similar to the telescope-control problems covered above, except that one could not and should not expect the general public to ever understand these issues. Problems amateur astronomers might have are also included here, and were brought up by many responders in other contexts.

One of the problems anticipated is that UT1-UTC could be applied with the wrong sign, just as the leap second is occasionally applied with the wrong sign. An example of "buffer overflow" problem would happen in NIST's WWV, WWVH and WWVB transmissions, which do not allow enough space for $|\text{UT1-UTC}|$ to exceed .9 sec. Any users of these broadcasts who might need this information and who are unaware of the problem, decoding in hardware, or relying on old software would be adversely affected. Under the best of future circumstances only the sub-second (tenths) digit would be available, requiring the user to keep track of the digits to the left of the decimal point.

Not tabulated is an informal comment seriously made to the Working Group's Chairman, by a respected and competent scientist from a non-western nation, that astrologers would be adversely affected.

C. Philosophical Objections

Eight thought this would confuse or antagonize the public, religious authorities, or even scientists - in essence because solar time is "true time". (In contrast, one responder in favor of a change thought this would help educate the public to the fact that Earth rotation is not "true" time).

Three pointed out that legal complications might occur in countries where laws are specified in terms of solar time, or GMT (which has not existed for thirty years). Although one of these responders feared governments would not follow the scientist's lead, we find it difficult to believe that governments would, on their own, choose to add leap seconds. Others thought that any legal system flexible enough to handle daylight savings time and the past abandonment of GMT in favor of UTC would easily accommodate a seamless change in UTC's computation, especially if no other time standard were available. Some of the history of legal issues concerning past changes in time definition can be found in the book "Greenwich Time and Longitude" by Derek Howse.

Three thought we should not adopt a system which will fail in the long run, even if that is a very distant time in the future. (It could be pointed out that all current time systems will eventually fail. Well before 2050 we could be routinely adding more than one leap second per year, and when we reach the point where a day is 48 hours long we would have to add a leap second every second. Even the Gregorian calendar will eventually need revision because in a few million years the Earth will rotate less than 365 times per year, and leap days will not be necessary.)

Two thought this would deprive the timing community of free publicity when leap seconds are inserted.

Thirty-eight expressed opposition, but gave no specific reason. Eleven of those also indicated that a problem would exist with their system, but did not specify it. Some of these pointed out that TAI was readily available, or indicated that they had seen no justification for a change. (We had intentionally provided no justification in the initial questionnaire, but two responders replied that they still believed there was not enough reason to change even after having read "standard response".)

Four were against it because they thought problems would happen if some systems did not use the new system, and because they thought one would have to separate analyses based upon whether data were recorded with the current system or the old system. (We believe these to be based upon a misunderstanding of the "no new leap seconds" proposal, but entirely possible if the more drastic measure of re-defining SI, the International Second, were adopted.)

II. Alternative Suggestions

Five suggested that it would be better to redefine the second to be longer, add 1 second every 18 months forever, change on leap years or century-ends, or change when the number exceeded a fixed amount. These possibilities are also discussed in the GPS World Article.

A suggestion was received to add enough "negative leap seconds" to bring UTC in line with GPS. However, a different responder pointed out that many of NASA's programs assume UT1-UTC always grows and that problems would happen with any change that would sometimes lead to a "negative leap second". (According to Dennis McCarthy of the USNO, this is possible even with the current system, but unlikely).

It was also pointed out that rubidium atomic fountains or optical standards could lead to a redefinition of the second using an element other than cesium. If so, it could be redefined using a scale factor of sufficient magnitude to avoid the short-term need for leap seconds (As noted in the GPS World article, such a change would alter the values of those physical quantities that depend upon time.)

One suggested that a redefined UTC should have a new name.

III. Responses in favor of changing the current leap second procedures

Forty-eight responses in favor were received, several from people who experienced minor problems now in handling leap seconds, such as confusion due to GPS time being currently 13 seconds offset from UTC and computer errors at the time of the leap seconds. Along with responses based upon reasons already covered in the GPS World Article, there were also three from the highly undersampled group of computer programmers, which pointed out the growing need to synchronize diverse computers to one second accuracy and the difficulties of doing so in an when dates of future leap seconds were unpredictable. Many of the responses indicated that periodic addition of leap seconds on a scheduled basis would also be acceptable. One of the responders, who was opposed to a change, suggested that leap seconds were not a problem because computer users could program an automatic extraction of the needed information from some publicly available source; however it must be pointed out that no one can guarantee that a given file, whether it be for leap seconds or for daily values of UT1-UTC (see part IV, below), will remain forever available in a given format or given IP address.

Four responses were from people who indicated that the convenience in not having to update files every 18 months outweighed the expense and problems rewriting software. One of these suggested the use of sufficient negative leap seconds to bring UTC in line with TAI, and several noted that UT1-users easily incorporate the offsets due to time zones and daylight time.

IV. Other Responses

Forty-seven responders checked the "indifferent" option. Most indicated that there would be no problems with their system, or that the problems were small enough that they were indifferent to a change.

Seven other responders indicated that the change would be okay if they could somehow reliably obtain UT1-UTC. (The USNO, as a sub-bureau of the IERS, freely provides this information on its web site, <http://www.maia.usno.navy.mil> , and via weekly emailings. Other organizations also provide this information.) Some responses tabulated here were phrased in the negative because the responders were apparently unaware that the information was available. One responder was concerned that the GPS system itself would be degraded for this reason, however this is not the case because GPS currently uses UT1-UTC values derived from USNO products.
