INTERNATIONAL TELECOMMUNICATION UNION

RADIOCOMMUNICATION STUDY GROUPS

Special Rapporteur Group 7A (SRG 7A) on the Future of the UTC Time Scale

UTC Timescale Colloquium 28-29 May 2003

Report

Table of Contents

Executive Summary 2

1. Introduction 3

2. The Colloquium on the UTC Timescale 3

3. Summary of Presentations 4

a) B. Guinot - Astronomical Background 4

b) S. Leschiutta - ITU-R Background 4

c) F. Arias - Considerations for International Timekeeping 4

d) R. Beard - Timescales and Navigation Systems 4

e) W. Klepczynski - Navigation Issues 5

f) J. Seago - Dependence of Satellite Tracking on UTC 5

g) D. Gambis - Prediction of Universal Time and LOD Variations 5

h) D. McCarthy - Different Options Concerning the Re-definition of UTC 5

i) D. Gambis - Results of the Leap Second Survey made by the IERS 5

j) P. Wallace - Software Implications of UTC) 6

k) F. Arias - Rotation of the Earth and Time Scales 6

l) R. Nelson - Telecommunications Issues 6

m) J. Levine - Internet Timing Issues 6

n) M. Kuhn -Considerations for Distributed Computer Systems 6

4. Roundtable Discussion Summary 6

5. Potential Alternative to the Leap Second 7

6. References 7

Executive Summary

The objectives of the Colloquium on the UTC Timescale may be stated as follows:

1. Address the future of the Leap Second and general technical issues related to the UTC Timescale.
2. Provide the basis for a final report on the issue to WP7A of the ITU-R.

Distinguished representatives in the areas of International Timekeeping, Navigation, Earth Rotation, Telecommunications and Internet Timing made Invited Presentations at the colloquium. The presentations covered subject areas considered to be significantly impacted by changes in the UTC Timescale. Contributed Presentations were also made to insure that additional viewpoints would be expressed. A roundtable discussion was held following the presentations. The results of this discussion were as follows:

1. There was no overwhelming consensus on whether the status quo should be maintained or an alternative should be pursued.
2. The preferred characteristics of a potential alternative emerged (see below).
3. The selected alternative proposal should be passed on to WP7A in draft form for detailed development of an opinion to be transmitted to the appropriate international organizations.
4. Advances in technology in communications, navigation and other fields would be enhanced in their interoperability by the adoption of a single, internationally recognized time scale for use in civil, engineering, and scientific applications.

During the roundtable discussion several alternative proposals concerning the Leap Second were discussed. If a change were to be made one alternative appeared to be preferred. The essence of this alternative was as follows:

1. Any change should slowly evolve from the current UTC Standard in transitioning to a uniform timescale, perhaps to be called *Temps International* (TI).
2. A suggested date for inaugurating any change would be 2022, the 50TH anniversary of the UTC timescale. The date suggested is influenced by the lifetimes of existing systems that would be expensive to change.
3. TI should be a continuous atomic time scale, without Leap Seconds, that is synchronized with UTC at the time of transition.
4. Responsibility for disseminating UT1 information should remain solely with the IERS.

UTC TIMESCALE COLLOQUIUM REPORT

1. Introduction

As a result of issues raised by sector members of the ITU-R (International Telecommunication Union - Radiocommunications) and a letter from the Director of the Bureau International des Poids et Mesures (BIPM) to the Secretary General of the ITU, a new question, ITU-R 236/7 (2000) "The Future of the UTC Timescale", was generated by ITU-R Study Group 7 (Science Services) Working Party 7A (Standard Frequency and Time Signal Services). The question considers the future definition and use of Coordinated Universal Time (UTC) in the ITU-R Recommendations.

Any *major change to the UTC timescale* as defined in the current recommendations could have a potentially significant impact on synchronization of communications networks, navigation systems and time distribution performance. Accordingly, Study Group 7, Working Party 7A established a Special Rapporteur Group (SRG) to specifically address the future of the *leap second and related issues*.

The SRG has held several coordination and technical exchange meetings to generate, analyze and discuss alternative approaches to reduce or eliminate the operational impact of the leap second. These meetings were held as follows:

1. Dec 2000, PTTI
2. Mar 2001, EFTF,
3. May 2001, ITU-R, Geneva, Switzerland
4. Dec 2001, PTTI
5. Mar 2002, BIPM, Sevres, France

The result of these meetings and other related efforts had not produced a consensual opinion. However, the SRG wanted to present results and discuss viable alternatives with representative parties that had come forth as a result of these meetings. In support of that purpose, the SRG organized a Colloquium for deliberating and drafting a report on the issue to WP7A of the ITU-R.

2. The Colloquium on the UTC Timescale

The Colloquium was hosted by the Istituto Elettrotecnico Nazionale (IEN), Torino (Italy), whose members had played a significant role in the original formulation of the current UTC procedures and policies. Two days were devoted to presentations and discussions. The SRG members then discussed the results of the Colloquium in executive session, which were used to produce this report.

At the Colloquium, distinguished representatives in the areas of International Timekeeping, Navigation, Earth Rotation, Telecommunications and Internet Timing made invited presentations. These areas were considered those that would be impacted by changes in the UTC Timescale. Additional contributed presentations were made to insure that additional viewpoints would be expressed.

The program for the Colloquium included invited presentations by

a. B. Guinot on the Astronomical Background of the Leap Second;
b. S. Leschiutta on the ITU-R Background of the Leap Second;
c. F. Arias on Considerations for International Timekeeping;
d. W. Klepczynski on Navigation Issues;
e. D. Gambis on Earth Rotation Issues;

f. R. Nelson on Telecommunications Issues; and

g. J. Levine on Internet Timing Issues.

Contributed presentations were also made by:

a. R. Beard on Timescales and Navigation Systems;

b. J. Seago on the Dependence of Spacecraft and Satellite Tracking on UTC;

c. P. Wallace on Astronomical Software Implications of UTC; and

d. M. Kuhn on Leap Second Considerations in Distributed Computer Systems.

3. Summary of Presentations

A brief synopsis of the main points covered by each of the speakers follows. Copies of all presentations given at the Colloquium are attached to this report.

a) B. Guinot - Astronomical Background

This paper restated the definitions of UT1 as being proportional to the Earth rotation angle around a moving rotation axis and remains approximately in phase with Greenwich solar time. It also reviewed the various attempts to definite a uniform time reference ranging from early efforts to use paleontological data up to modern efforts that use Atomic Time.

Guinot also gave a history of the various frequency offsets in UTC that had occurred prior to 1972 as well as a history of the evolution of the UTC time steps that occurred. He also showed the results of two and three year linear moving window predictions that could be used to model UT1-TAI to within one second.

b) S. Leschiutta - ITU-R Background

This paper presented a brief history of the ITU-R background in the formulation of the current UTC system adopted by the ITU-R in 1972.

c) F. Arias - Considerations for International Timekeeping

Arias presented a review of the current status of UTC as a key aspect of International Timekeeping and pointed out the observation that Leap Seconds are becoming increasingly inconvenient due to the proliferation of the development of unique time scales to meet the needs of different applications. If a change in the present system were deemed desirable, two possible ways to achieve a change were described. One way would insure continuity by aligning UTC to TAI at the moment of application and the other would interrupt the application of Leap Seconds in favour of a Leap Hour. However, any change would necessitate the broader dissemination of UT1 data.

d) R. Beard - Timescales and Navigation Systems

This paper emphasized the point that time in satellite navigation systems is used to insure that the offset between different satellite clocks is relatively small. This synchronization of the satellite clocks provides the basis for measuring the signal propagation time, and hence the range, from multiple satellites, accurately and simultaneously. Synchronization to a standard reference time is not necessary for the system to be an effective navigation system. What is necessary is that all the clocks in the system be precisely synchronized. Satellite navigation system time has been referenced to an external reference time standard for the purposes of using the satellite navigation system as a means of transferring time from the reference to another external clock or timing system. Even without an external time reference satellite navigation system time could be used effectively as a time standard because of it’s precision and universal availability. This utility of the satellite navigation systems could lead to a proliferation of time standards and time scales.

e) W. Klepczynski - Navigation Issues

This paper introduced the problem of the proliferation of different time scales being developed for satellite-based navigation systems. The GPS navigation system has GPS Time as its basis. Galileo will have TAI as its basis. GLONASS has UTC as its basis. Because the designers of systems using these navigation aids may not be totally familiar with the fundamental concepts of modern timekeeping, there is danger of an error or confusion causing a catastrophe, either in the air or on the ground resulting from using different time scales or reference times. It is essential that the time of an aircraft's position be correctly identified and recorded. Air traffic controllers, using UTC, must insure that the time used by an aircraft's navigation system to record its position is the same. The differences between UTC and GPS Time of 13 seconds and between UTC and TAI of 32 seconds could potentially create large positional errors between aircraft and ground controllers. Such a difference could have very unfortunate results.

f) J. Seago - Dependence of Satellite Tracking on UTC

This paper concerned the use of UTC as an approximation of UT1 for input into the calculation of approximate satellite orbits. Because UTC is kept within a second of UT1 many computer programs have been programmed to utilize this fact in the initial determination of an approximate orbit for spacecraft. These approximate orbits are applied to such tasks as pointing high gain antennas and the initial estimate of more precise orbit determination programs. A principle thrust of this paper was that it would be extremely costly to re-program these systems.

g) D. Gambis - Prediction of Universal Time and LOD Variations

Gambis, Director of the International Earth Rotation Service (IERS), presented a brief discussion on the causes for variations in the Length of the Day (LOD). He went on to describe the current IERS products, including their current prediction capabilities and statistics. The IERS can currently predict UT1 with an accuracy of about 300 ms out to 3 years. Using a simple model that includes a seasonal term, a bias and a drift, it is possible to obtain an accuracy of about 1 second over 4 years. Such a capability would enable an table of corrections to be determined well in advance so that a user could use a table look up technique to correct UTC to UT1 rather than relying on the broadcast of DUT1.

h) D. McCarthy - Different Options Concerning the Re-definition of UTC

A review of past suggestions concerning the re-definition of UTC was the subject of this paper. The different possibilities were sorted into three categories:

1) Status Quo,
2) Change Current Definition, and
3) Switch to some form of Atomic Time.

The pros and cons in each category were discussed.

i) D. Gambis - Results of the Leap Second Survey made by the IERS

Gambis reported on the results of a survey made in the spring of 2002 through the IERS website. There were 243 responses - 21% were astronomers, 16% from the timing community, 15% navigators, and 13% geodesists. The remaining 35 % consisted of space scientists, others in the timing community, telecommunications industry, and geophysicists. 88% of those who responded indicated that they were satisfied with the current UTC determination method. However, Gambis was not sure if the opinions of those who responded was representative of all subscribers to IERS publications.

j) P. Wallace - Software Implications of UTC)

This paper recognized that there are many applications that implicitly assume that UTC is approximately equal to UT1. It also stated that UTC as presently defined is not sustainable into the future. Therefore, three time scales were proposed for three prospective levels of service, high accuracy (TAI), approximate UT1, and UTC (to be continued only for a short time).

k) F. Arias - Rotation of the Earth and Time Scales

Arias continued to elaborate on the earlier discussion that pointed out the observation that Leap Seconds are becoming increasingly inconvenient due to the proliferation of unique time scales to meet the needs of different applications. She again presented two possible proposals. The first of which would insure continuity by aligning UTC to TAI at the moment of application and the other would interrupt the application of Leap Seconds in favour of a Leap Hour. However, any change would necessitate the widespread dissemination of UT1 data.

l) R. Nelson - Telecommunications Issues

This paper discussed the characteristics of modern telecommunications systems and advances in other systems require the availability of a uniform time scale for their interoperability. It proposes the continuation of UTC without leap seconds.

m) J. Levine - Internet Timing Issues

Internet timing is predominately used with the NTP protocol. This paper pointed out the difficulties that computers have with leap seconds. Computers cannot represent a leap second and are effectively stopped when it occurs. Furthermore, because leap seconds can occur in the middle of a working day in some parts of the world, electronic commerce and digital transactions can be affected. Four proposals were put forward for discussion as follows:

1) Abandon leap seconds
2) Use TAI instead of UTC
3) Change leap second name and its representation
4) Move the leap second epoch to only a single event on 1 January

n) M. Kuhn -Considerations for Distributed Computer Systems

This paper discussed the problems with computers in dealing with leap seconds. As a possible fix to the problem, it was suggested that the leap second be ignored and that the duration of the second within a computer be changed at the time that a leap second is to be introduced. Three other proposals were put forward that were similar to those that had been introduced earlier.

4. Roundtable Discussion Summary

At the conclusion of the formal presentations a roundtable discussion with all participants was held. Most users with real time requirements for UT1 came from the astronomical community and those who needed low precision values of UT1 for non-precision orbits of Earth orbiting objects. McCarthy proposed that, in the future, these users be urged to use the more accurate difference values of UT1-UTC as published by the IERS and not assume that UTC = UT1. While there was a proposal to have a low precision UT1 and a high precision TAI transmitted, it was pointed out that this could be considered a step backward to the time when there was both ET and UT. One additional point was raised concerning UT1. UT1 is really a measure of the Earth's orientation and is not a true time scale. Therefore, the ITU-R should not be concerned with transmitting it. Time should be decoupled from the rotation of the Earth.

While surveys have been made by several organizations, it was not clear that the small percentage of responders really represented an adequate sample on which to base conclusions.

The inability of computer protocols to handle Leap Seconds led to a proposal, which tried to hide the leap second by varying the length of the second via special subroutines within the computer. There was strong opposition to such a proposal because it introduced a non-SI frequency for that second.

The proposal to introduce a Leap Hour in place of the Leap Second faced considerable opposition because it would necessitate an increasing change in time and frequency standard transmission that could not be currently handled. Consequently, the discussion revolved around the premise that if the Leap Second is not abandoned, then the current system should remain.

The results of the roundtable discussion were:

1. There was no overwhelming consensus on whether the status quo should be maintained or an alternative should be pursued.
2. The characteristics of a potential alternative emerged (see below).
3. This draft alternate proposal should be passed on to WP7A for detailed development of an opinion to be transmitted to the appropriate international organizations.
4. Advances in technology in communications, navigation and other fields would be enhanced in their interoperability by the adoption of a single, internationally recognized time scale for use in civil, engineering, and scientific applications.

5. Potential Alternative to the Leap Second

During the roundtable discussion several alternative proposals concerning the Leap Second were discussed. If a change were to be made, one proposal seemed to be preferred. The essence of this proposal is:

1. Any change should slowly evolve from the current UTC Standard by transition to a uniform timescale,
2. The final timescale should have a new name to distinguish it from Universal Time, since Universal Time is general understood to Solar Time and the earth's rotation. A new name suggested and discussed was International Time, *Temps International* (TI).
3. A suggested date for inaugurating any change would be 2022, the 50TH anniversary of the UTC timescale. The date suggested was remarked as being influenced by the beyond the lifetimes of currently existing systems that would be expensive to change.
4. TI should be a continuous atomic time scale, without Leap Seconds, that is synchronized with UTC at the time of transition.
5. UT1 information would continue to be made available under the sole responsibility of the IERS.

6. References

1. **Letter** from Director of Bureau International des Poids et Mesures (T. J. Quinn) to the Secretary General of the ITU, 10 June 1999.
2. **Letter** from Director of the Radiocommunication Bureau of the ITU (R. W. Jones), 8 January 2001
3. **Question ITU-R TF.236/7**, *The Future of the UTC Time Scale*.
4. **Recommendation ITU-R TF.460-5**, *Standard-Frequency and Time-Signal Emissions*