

DIVISION A / WORKING GROUP TIME METROLOGY STANDARD

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TRIENNIAL REPORT 2015-2018

1. Introduction

After the IAU decision of not maintaining a specific Commission on Time, the establishment of a working group in Division A to provide the link to time metrology standards was discussed and proposed during the IAU General Assembly in Hawaii in 2015. The proposal was based on the fact that time is an important element of fundamental astronomy, it is a coordinate in the space-time reference system, necessary for dating events, computing ephemerides, observation, modelling and prediction. The time metrology community provides the reference time scale, of atomic nature, related to the coordinate times used for space-time referencing in astronomy. Astronomers maintain time scales of different nature; the atomic reference time scale (UTC) is realized in a number of astronomical institutes; astronomers work on dynamical pulsar time scales which could complement atomic time with enhanced long-term stability.

The discussion on a possible change in Coordinated Universal Time (UTC) has taken place at the International Telecommunication Union (ITU) since year 2000 and a conclusion is expected by 2023. The IAU is one of the organisations involved in this process, requiring close coordination with other scientific communities, and in particular with metrology, in its role of defining and realizing the time reference.

A new definition of the SI second is forecast between 2026 and 2030. Clearly, the work of preparation of the future new definition of the second will call for mutual cooperation in the upcoming years.

Based on the previous considerations supported by members of the former Commission 31 on Time, the Working Group on Time Metrology Standards was accepted, and its membership completed by the end of 2016. Membership of the WG TMS includes astronomers and metrologists, and could be extended to include other experts in the time and frequency field if necessary.

The WG communicated by correspondence; there were no meetings in the period covered by this report.

The WG received a request from a young colleague, Dr Bess Fang (LNE-SYRTE, Observatoire de Paris) to become member of the WG. We have accepted a request for

membership, pending her induction into the IAU this year, and the continuation of this WG.

2. On the future of Coordinated Universal Time (UTC)

The World Radiocommunication Conference 2015 (WRC-15) met in Geneva, in November 2015, and adopted the Resolution 655 WRC15 (International Telecommunication Union 2016) inviting the relevant international organizations and scientific associations to cooperate submitting results of studies on the possible implementation of a continuous time scale. The IAU General Secretary received the invitation of the ITU to contribute.

Responding to the WRC, the Consultative Committee for Time and Frequency (CCTF) created a task group for preparing the text with formal definitions of reference time scales to be submitted as a resolution to the next General Conference on Weights and Measures (CGPM) in November 2018. Two members of the WG on Time Metrology Standards contributed to the elaboration of the text (F. Arias and G. Petit). The text was circulated to the members of the WG for comments, and also to the IAU representative to the CCTF, Dr D. McCarthy, who contributed to the improvement of the text. The metrological definition of International Atomic Time (TAI) is presented in the draft CGPM resolution (CIPM 2018) as defined from the coordinate-times adopted by IAU.

3. Meeting of the Consultative Committee for Time and Frequency (CCTF)

A meeting of the CCTF took place at the BIPM in June 2017. The IAU was represented by Dr D. McCarthy. The approval of the proposal of the text with time scales definitions was relevant to the IAU.

At the meeting Dr McCarthy questioned on the change of category of the international organisations in the Consultative Committees established by the International Committee for Weights and Measures (CIPM), and in particular the case of the IAU, which is no more considered as a member but as a liaison of the CCTF. This change of category requires clarification from the CIPM on the role of the liaisons.

4. On the possible future redefinition of the SI second

Discussions towards a possible redefinition of the SI second are progressing within the time metrology community, and they involve the IAU on various aspects:

(a) In the contribution of the IAU to the Consultative Committee for Units (CCU), where the strategy for the next years is under development;

(b) In the contribution of the IAU to the Consultative Committee for Time and Frequency (CCTF) and its Working Group on the Development of Advanced Time and Frequency Transfer Techniques.

5. Time developments relevant to astronomical work

Seventeen astronomical/research institutions officially maintained local representations of UTC for applications in astronomy, geodesy and/or space navigation in the triennium. They include ten astronomical observatories and centres (AOS Poland, CAO Italy, HKO Hong-Kong, NAO Japan, NTSC China, ONBA Argentina, ONRJ Brazil, OP France, ORB Belgium, ROA Spain, USNO United States of North America), two metrology

institutes (NICT Japan, SP Sweden supporting Onsala geodetic station), one university (APL United States of North America), three space agencies (CNES France, DLR Germany, ESA/ESTEC Europe) and one fundamental station (IFAG Germany). Many observatories maintain unofficial realizations of UTC for time domain astronomy, time-tagging of data for analysis, telescope pointing, etc.

Other the maintenance of local realizations of UTC, some of these institutions operate primary and secondary frequency standards (OP, NICT, AOS), and the USNO currently maintains four continuously running rubidium fountains at its Washington DC facility, with two fountains expected to become operational in 2019, at its Alternate Master Clock.

Researchers at the BIPM, working with colleagues in other institutions, have published an analysis of relativistic effects affecting timescale generation at the 10^{-18} level. The USNO has derived upper limits for violations of relativity by comparisons of clocks reporting data to the BIPM worldwide, and is also improving previous-reported limits using its rubidium fountains and other internal clocks. USNO is also contributing to the development of ideas using circumlunar orbits to test relativity, as well as quantum mechanics. The use of pulsars for navigation has been revitalized as a matter of active study due to NASAs successful deployment of an X-ray telescope on the International Space Station, for the NICER and SEXTANT missions. Searches for short-term correlated variations in GPS clocks, as an indicator of dark matter or unusual particles, have reported negative results.

The BIPM Time department released TT(BIPM17), the BIPM realization of terrestrial time calculated until end 2017, available on (BIPM 2018). The computation parameters are similar to TT(BIPM16) (BIPM 2017). The integration of TT(BIPM17) has been performed over the last 7 years (end 2010 to end 2017), in order to account for the revised 2017 values of the transition frequencies of secondary standards.

6. Toward a pulsar-based dynamical timescale

The pulse trains received from pulsars, particularly millisecond pulsars, have great period stability. On long timescales, years and decades, this stability can rival that of the best terrestrial time standards. It is therefore practical to envisage a timescale based on precision timing observations of millisecond pulsars. At least three consortia around the world have set up Pulsar Timing Arrays (PTAs) that are making the necessary observations. Data from the individual PTAs are being combined under the umbrella consortium, the International Pulsar Timing Array (IPTA). As well as searching for nanoHertz gravitational waves, the IPTA consortium is using the data sets to establish a pulsar-based timescale. This timescale is independent of the terrestrial timescales that are used as a reference for pulsar timing and can be compared with these. Current results are consistent with the best terrestrial timescale, TT(BIPM16), but are able to detect the intentional rate changes in TT(TAI). This demonstrates that pulsar timescales can rival the best terrestrial time standards on timescales of years and also that TT(BIPM16) (and its successors) are the most uniform timescales currently available. Being based on entirely different physics and essentially independent of all terrestrial factors, pulsar-based timescales provide a valuable independent check on the long-term stability of timescales based on terrestrial atomic frequency standards.

7. Closing remarks

The WG TMS started its task of maintaining the communication between the IAU and the time metrology community. A lot is still to be done in the next years, particularly on two issues involving not only the IAU and the metrology system, but other communities.

The decision on the adoption of a continuous time scale as the world reference (or leap second issue) will be made at the ITU World Radiocommunication Conference in 2023 (WRC-23). The ITU asked the cooperation of the international organisations and scientific unions, including explicitly the IAU. This cooperative work has already started and the WG TMS and the IAU have been consulted. More activities are expected in this direction in the next triennium.

Another important issue is the redefinition of the second. The Consultative Committee for Units (CCU) is starting to move on this discussion, and the international organisations will be included. In the case of the IAU, the contribution would be at the CCU and also at the CCTF. Clearly, the link of astronomers with time metrology standards is to be maintained during the period of the work for coming to a new definition. Also contact will be made by the working group of the CCTF on advanced time and frequency transfer techniques to explore with other communities on the possible exploitation of techniques (VLBI is one).

The members of the WG TMS are supportive to the proposal of continuing the activities in the next triennium, and a formal request will be submitted to consideration.

Elisa F. Arias
chair of Working Group

References

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- Comité International des Poids et Mesures 2018, in: Convocation de la Conférence Générale des Poids et Mesures (26 réunion), *Draft Resolution B*, 32, 33
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