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Commission 31: Time

PRESIDENT: Demetrios Matsakis
VICE-PRESIDENT: Pascale Defraigne
ORGANIZING COMMITTEE: M. Hosokawa, S. Leschiutta, G. Petit, and Z.-C. Zhai

1. Commission News

The most intensely discussed and controversial issue in time keeping has been the proposal before the International Telecommunications Union (ITU) to redefine Coordinated Universal Time (UTC) so as to replace leap seconds by leap hours. Should this proposal be adopted, the practice of inserting leap seconds would cease after a specific date. Should the Earth's rotation continue to de-accelerate at its historical rate, the next discontinuity in UTC would be an hour inserted several centuries from now. Advocates of this proposal cite the need to synchronize satellite and other systems, such as GPS, Galileo, and GLONASS, which did not exist and were not envisioned when the current system was adopted. They note that leap second insertions can be and have been incorrectly implemented or accounted for. Such errors have to date had localized impact, but they could cause serious mishaps involving loss of life. For example, some GPS receivers have been known to fail simply because there was no leap second after a long enough interval, other GPS receivers failed because the leap second information was broadcast more than three months in advance, and some commercial software used for internet time-transfer Network Time Protocol (NTP) could either discard all data received after a leap second or interpret it as a frequency change. The ambiguity associated with the extra second could also disrupt financial accounting and certain forms of encryption. Those opposed to the proposal question the need for a change, and also point out the costs of adjusting to the proposed change and its inconvenience to amateur astronomers and others who rely upon astronomical calculations published in advance. Reports have been circulated that the cost of checking and correcting software to accommodate the new definition of UTC would be many millions of dollars for some systems. In October 2005 American Astronomical Society asked the ITU for a year's time to study the issue. This commission has supported the efforts of the IAU's Committee on the Leap Second to make an informed recommendation, and anticipates considerable discussion at the IAU's 26th General Assembly in 2006.

Commission 31 joined Commissions 4, 7, 8, and 40 in proposing a Joint Discussion on Astronomical Timing at the General Assembly in Prague. Twenty papers had been planned on subjects relating to pulsar timing, relativity, atomic timing, and navigation. Unfortunately the proposal could not be accommodated, and therefore the commission is intending to use most of its internal time for scientific sessions. A request for increased internal time has been submitted.

2. Observatory Reports

2.1. *Time section, BIPM*

International reference time scales TAI and UTC have been maintained and disseminated as a part of the routine work of the section via monthly Circular T. 56 time laboratories are contributing their clock and time transfer data to the the International Bureau of Weights and Measures (BIPM). Participating clocks are about 300, 86auto-tuned hydrogen masers.

From January 2005, the uncertainties of [UTC ? UTC(k)] are also published in Circular T, as the result of the cooperation of the BIPM with the IEN and the USNO. The medium-term stability of TAI, expressed in terms of an Allan deviation, is estimated to be about 0.4 10?15 for averaging times of one month. The accuracy of TAI is based on the data from primary frequency standards (eleven in the period) that include, at present, six caesium fountains. The procedure of steering the frequency of TAI has been modified in July 2004; the bi-monthly correction of 1 x 10-15 has been replaced by a monthly correction of order 0.7 ? 10-15 at most. Since then, the scale unit of TAI has been estimated to match the SI second to within 2 10?15. An important part of the activity of the Time section deals with studies of time and frequency comparison using GNSS and other satellites. Common-views of GPS satellites with single and dual frequency receivers and TWSTFT links are routinely used in the calculation of TAI. The incorporation of dual-frequency geodetic type receivers and the TWSTFT observations on a sub-daily schedule have brought the uncertainty of some time links down to the nanosecond level or less. Extensive comparisons of techniques and methods of time transfer are conducted at the BIPM and published on the internet. Calibration programmes of GPS receivers have been organized and run by the section, with more then 50

Research work is also dedicated to space-time reference systems, particularly to the relativistic framework for defining and realizing coordinate times. The BIPM Time section and the USNO jointly provide the Conventions Product Centre of the International Earth Rotation and Reference Systems Service (IERS) with the responsibility of establishing conventions for space-time reference systems; the IERS Conventions (2003) have been published and updates are performed on the Conventions web site which is maintained at the BIPM.

Collaboration is maintained with radio-astronomy groups observing pulsars and analyzing pulsar data provided that it is of interest for us to study the potential capability of millisecond pulsars as a means of sensing the very long-term stability of atomic time. The Time section provides these groups with its post-processed realization of Terrestrial Time. The collaboration continues with the Observatoire Midi-Pyrenees (OMP), Toulouse, on a programme of survey observations. A cooperation with LNE-SYRTE (Paris Observatory) research activities are conducted on linking clocks in space and atom interferometry.

2.2. *NICT*

The National Institute of Information and Communications Technology (NICT) changed its name from CRL at April 2004, has covered the wide area of time and frequency research activities. NICT currently maintains 18 cesium beam standards and 5 Hydrogen masers in the headquarters in Tokyo. Since October 2002, UTC(CRL) or UTC(NICT) has been mostly kept within 20 ns from UTC. The UTC(NICT) generation software was upgraded in June 2004, which has greatly reduced the impact of the withdrawal of a clock from the clock ensemble to the average atomic time. A primary frequency standard NICT-O1 has contributed to the determination of TAI scale unit several times for these three years with the accuracy around 7E-15. A Cs atomic fountain has been developed. Now its stability reaches 4E-13 at one second. A Ca+ ion optical standard has also been developed. NICT has established the Two Way Satellite Time and Frequency Transfer link network in Asia-Pacific region. A type of modem developed at NICT is now used in several Asia-Pacific T&F Institutes. Timing measurement of the Pulsars 1937+21 and 1713+07 has been made almost every week by using Kashima 34 m antenna, with accuracies 2 micro second and 5 micro second, respectively.

2.3. *Time Service Department, USNO*

To provide accurate and precise time, U.S. Naval Observatory (USNO) currently maintains an ensemble of 73 cesium-beam frequency standards and 21 cavity-tuned masers in three buildings in Washington, DC and at Schriever Air Force Base in Colorado. A non-operational cesium-based atomic fountain has reached stabilities of 1.0E-15 at one day, and a rubidium-based fountain has generated Ramsey fringes and short ?term stabilities consistent with a white frequency noise of 1.4E-13 at 1 second. An improved time scale algorithm involving Kalman-based hourly characterization and steering of the Master Clock against the USNO ensemble was installed in 2004. Since September 1, 2002 UTC(USNO) stayed within 4.6 ns RMS of UTC; the RMS of UTC-UTC(USNO) since January 1, 2005 was 2.8 ns. USNO has participated in Two Way Satellite Time Transfer (TWSTT) for the generation of TAI, and has calibrated its transatlantic timing link with the PTB in Germany on a biannual basis. It has participated as a contributor of clock information to the International GPS Service (IGS) via time-stable Ashtech Z123Ts at all three of its buildings, and contributes to two real-time GPS networks.

2.4. *Time Lab., ROB*

The Royal Observatory of Belgium (ROB) presently maintains 3 Cesium clocks HP5071A with standard tubes, one active H-maser CH1-75 and one passive H-maser CH1-76. The time scale UTC(ORB) is generated from the frequency of the active H-maser, of which the auto-tuning is adjusted by the passive H-maser. UTC(ORB) remains within 0.06 microsecond of UTC. The steering of UTC(ORB) is performed only using the circular T, but UTC(ORB) is also monitored on a daily basis using a comparison with the IGS time scale and with several UTC(k)'s produced by time laboratories collocated with IGS stations. This last comparison is done using a RINEX-CGGTTS conversion software using the P3 ionosphere free combination and IGS rapid and ultra-rapid orbits. This tool has been developed by the ROB staff and has been proposed to the time community for using dual frequency geodetic receivers for time transfer, in agreement with the standards used for the realization of TAI (project named TAIP3). The ROB staff also studies the combined code-carrier phase GPS data analysis for time and frequency transfer, looking for higher stability and precision.

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