Report to the 16th session of the Consultative Committee for Time and Frequency (CCTF), 1st - 2nd April 2004

Swiss Federal Office of Metrology and Accreditation (METAS)
Neuchâtel Observatory (ON)

1. Clocks for TAI (METAS)

1.1 Commercial clocks

The number of commercial cesium clocks forming the ensemble for the Swiss time scale has been significantly reduced over the last few years. From an initial ensemble of 9 clocks only 5 are still maintained. Nevertheless, the overall stability of the local timescale UTC(CH) has been increased, mainly for two reasons. First, a hydrogen maser was purchased and added to the ensemble and second the algorithm has been refined (cf. the section below). At present the data of 4 cesium tubes and 1 hydrogen maser are reported to BIPM and contribute to the two locally computed timescales UTC(CH) and TA(CH).

1.2 Cold continuous beam standard

The design and construction of the primary frequency standard based on a continuous beam of cold cesium atoms is now completed. The device, labeled FOCS-1 (which stands for FOntaine Continue Suisse) has been moved from the Observatory of Neuchâtel, where it was built, to its final location at METAS. Currently, the best achieved short term stability with FOCS-1 is $2.5 \cdot 10^{-13}\ \tau^{-1/2}$, limited by the signal to noise ratio of the atomic flux. For the accuracy evaluation three points have already been addressed: light-shift, second order Zeeman shift and the collisional shift. In the continuous fountain, collisional shifts can safely be neglected at the 10^{-16} level with present atomic flux. As for the second order Zeeman shift, tools have been developped to minimize magnetic field inhomogeneities, allowing to put an upper limit on this contribution to the error budget of $3 \cdot 10^{-16}$. The light-shift, finally, is brought under control by means of a rotating light trap that has been implemented. A detailed study of these points will be presented at the CPEM in June this year.
Simultaneously, METAS and ON collaborate on the construction of a second continuous fountain standard. Preliminary studies at ON have recently demonstrated the potential of degenerate-sideband Raman cooling for collimating the atomic beam of a continuous fountain. This will be implemented in FOCS-2 to reduce the 1-second instability below $1 \cdot 10^{-13}$ and simultaneously allowing an accuracy below $1 \cdot 10^{-15}$.

2. Timescales (METAS)

UTC(CH) is a computed timescale generated from the same ensemble of free running clocks and based on the same timescale algorithm as TA(CH). Since UTC(CH) is not a hardware clock the steering has to be performed by software by adding a common rate difference to each of the contributing clocks. Since summer 2001 (MJD 52100) the steering of UTC(CH) is performed monthly and based on an algorithm that predicts the state of UTC-UTC(CH) at the epoch of the next monthly steering on the basis of the most recent UTC-UTC(CH) data published in Circular T. The application of the new algorithm has improved the stability and the accuracy of UTC(CH) as shown on the figure 1.

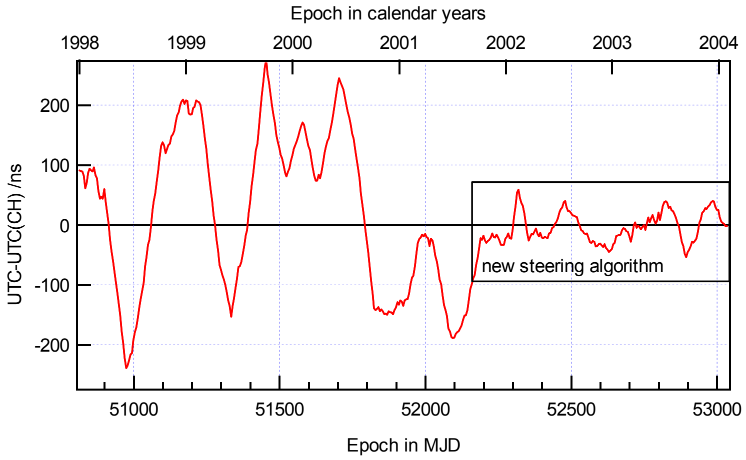

Fig 1: Difference UTC - UTC(CH) over the last 6 years. Since mid 2001 a new steering algorithm is in use.

2. Remote Comparisons (METAS)

2.1 GPS Common View

As for now, the main link of time transfer between METAS and other time centers remains the GPS Common View (CV) technique based on a NBS-type single-channel GPS receiver. At present two such receivers are in use at METAS but their operation will be discontinued as soon as a suitable substitute has been put in place. The link has been calibrated in 2003 by a travelling receiver from BIPM.

2.2 TAI-P3

METAS participates in the TAI P3-project conducted by BIPM, aiming at using the data of geodetic type receivers for CV time links. At METAS an Ashtech ZXII-T receiver is operated and driven by the METAS reference clock. The collected data are pre-processed by the software of P. Defraigne (Royal Observatory of Belgium) to conform with the CCGTTS common view format. This setup shall replace the one-channel CV receiver as the TAI-link of METAS in the near future.

2.3 IGS-Station

After several years of collaboration between the Astronomical Institute of the University of Bern and METAS in which time and frequency transfer by means of GPS Carrier Phase has been studied, a permanent IGS-station has now been set up at METAS. This station shall primarily serve as link for frequency comparison of the primary frequency standard with similar devices of other NMIs.

2.4 TWSTFT-Station

Finally, METAS is on the way of installing a TWSTFT-station. The assembly of the station shall take place throughout the year 2004 and it is planned to operate the setup on a regular basis early 2005.

3. Time dissemination services (METAS)

As responsible body for the dissemination of the legal time in Switzerland, METAS distributes coded time information over three channels: the longwave timecode transmitter HBG, a stratum-1 NTP-server and the dissemination of the European Telephone Time code over the public telephone lines.

4. Clocks for space (ON)

4.1 Space Hydrogen maser for the ACES experiment (ON)

The Atomic Clock Ensemble in Space (ACES) experiment consists in flying one cold-atom Cs clock and an H-maser on the International Space Station. The cold-atom clock (PHARAO) is designed to take advantage of micro-gravity to reach both an inaccuracy and a 1-day instability in the low 10^{-16}. The hydrogen maser (SHM), built by ON, will contribute its low instability between 1 s and 500 s to perform the following tasks:

i) Operate as a flywheel oscillator for the metrological evaluation of PHARAO
ii) Enhance the precision of comparisons between ACES and ground clocks
iii) Optimize the short time stability in joint operation of the PHARAO-SHM clock.

The goals of the mission are the demonstration of a micro-gravity enhanced atomic clock, world-wide time dissemination from space, and improved T/F comparisons with ground clocks and between distant ground clocks for metrology and tests of relativity (improved measurements of the gravitational red-shift, of the isotropy of c, and of a possible drift of the fine-structure constant). Miniaturization of the maser relies on a very compact, sapphire-loaded microwave cavity. This allows the same performance level as state-of-the-art, ground masers at one-third of the mass. The development of the SHM proceeds according to schedule. Delivery of the engineering model will take place in 2005. Launch of the ACES experiment is scheduled for 2008.

4.2 Space clocks for GALILEO, 1st generation (ON, TNT)

The 30 satellites of the first generation will be equipped each with two lamp-pumped Rb-cell clocks and two Space Passive Hydrogen Masers (SPHM). The Rb clock, initially developed at ON, is now in the final stage of industrial development at TEMEX Neuchâtel Time (TNT). It will be tested in the first experimental satellite of the Galileo system test bed (GSTB), to be launched from Russia by end of 2005. An engineering model of the SPHM (physics package developed by ON and electronics package by Galileo Avionica in Italy) has been delivered to the European Space Agency (instability $8 \cdot 10^{-13} \tau^{-1/2}$, mass 17 kg). TNT are now in charge of the industrialization of the atomic resonator, while Galileo Avionica are responsible for the electronics package and for the instrument. A qualification model is planned for testing in the second GSTB satellite.

4.3 Space clocks for GALILEO, 2nd generation (ON)

ON is completing the first phase of the development of a laser-pumped Rb-cell clock for ESA (Elegant Breadboard). This first demonstration phase has allowed to put precise constraints on the pumping laser frequency stability, to demonstrate efficient techniques of light-shift reduction (factor 40), to determine optimum buffer gas composititon for laser-pumped operation, and to develop a compact, frequency stabilized, extended-cavity diode laser system for space applications. ON has also recently resumed the development of a space-qualified, optically pumped thermal Cs beam clock with short-term instability $3 \cdot 10^{-12} \tau^{-1/2}$ between 1 s and 1 day. The goal for the mass of the entire clock is 7 kg, intermediate between the 3 kg Rb-cell clock and the 17 kg SPHM.