25ᵉ Conférence générale des poids et mesures
Rapport du Comité consultatif du temps et des fréquences (CCTF)

Luc ERARD
Président du CCTF
Metrological areas/Achievements: Time scales

- **BIPM**
  - UTC (CCTF-K001.UTC) monthly, post-processed
  - UTCr (rapid solution) weekly, post-processed
  - TT(BIPMyy) yearly (post-processed)
  - Calibration of receivers (BIPM/RMOs)

- **NMIs, DIs and others**
  - Real-time local realizations UTC(k)
  - Local atomic time scales TA(k)
  - Primary/secondary frequency standards
  - Time/frequency transfer (i.e. optical fibres)

**Unique Key comparison CCTF-K001.UTC**

- **BIPM Circular T**
  - Ongoing, monthly, 74 participants
  - Two comparisons in one:
    - local time scales: traceability of UTC (k) to the SI
    - realizations of the second: comparison of the primary and secondary frequency standards for confirmation of the quality of the local realization of the SI second
  - Information of the access to UTC via GNSS > broad dissemination of UTC
Metrological areas/Achievements: The SI second

♦ **Primary realization: caesium**
  - 16 Cs frequency standards operated in NMIs have contributed since 2011:
    2 thermal beams, 14 fountains
  - Accuracy 2-3 parts in $10^{16}$ (fountain), $10^{-20}$ parts in $10^{15}$ (thermal beam)
  - One under consideration (October 2014)

♦ **Secondary representations of the second**
  - Recommended list of frequencies/wavelengths (CI-2013)
  - Microwave (Rb fountain, accuracy 2-3 parts in $10^{16}$)
  - Optical transitions (accuracy parts in $10^{18}$), ratios of optical frequencies

♦ Trapped single ions and neutral atoms trapped in optical lattices (Hg, Sr, Yb, Al, Ca, In, Mg,..)
Major challenges

- **Redefinition of the SI second**
  - Developing optical standards with $10^{-18}$ frequency accuracy at NMIs;
  - Comparing optical standards with the highest accuracy over long distances (optical fibres, TWSTFT, microwave and optical links, VLBI,..);
  - Operating optical standards over long intervals for reporting to the BIPM.

- **BIPM and contributing laboratories**
  - Improving UTC stability, accuracy and dissemination; providing prediction on a shorter delay;
  - Algorithms.
### Stakeholders/Inter-disciplinary issues

<table>
<thead>
<tr>
<th>Organization/Activity</th>
<th>Stakeholder</th>
<th>Inter-disciplinary issues</th>
</tr>
</thead>
<tbody>
<tr>
<td>CCL</td>
<td>Length metrology</td>
<td>Wavelength</td>
</tr>
<tr>
<td>Time scales</td>
<td>NMIs, observatories, universities, space agencies</td>
<td>Traceability to UTC</td>
</tr>
<tr>
<td>Telecommunications Radiocommunications</td>
<td>ITU</td>
<td>Dissemination of UTC Synchronization to UT1</td>
</tr>
<tr>
<td>Global Navigation Satellite Systems (GNSS)</td>
<td>GPS, GLONASS, Galileo, BeiDou, ...</td>
<td>Dissemination of UTC GNSS System Times Time transfer for UTC</td>
</tr>
<tr>
<td>Earth and space sciences GNSS civil applications</td>
<td>IAU, IUGG/IAG, URSI, IERS, IGS ICG, CGSIC</td>
<td>Space-time references Conventions Time transfer for UTC</td>
</tr>
</tbody>
</table>
Future strategy

Frequency standards

- Assist to the decision of a new definition of the second by
  - Determining the best representation of the SI second and its uncertainty: which physical standard(s)
  - Developing portable highly accurate primary standards for confirming the innovative long-distance comparison methods

Time scales

- Stronger coordination work on upcoming time scales developed for different applications (GNSS, dynamical-pulsar time scale, etc.)
- Adapting algorithms following clock and frequency standard improvement
- Providing the reference UTC on a shortest delay for supporting new applications

Time and frequency transfer

- Implementing ground-based techniques (optical fibres) targeting $10^{-18}$ frequency transfer accuracy
- Extending to novel space-based techniques targeting 0.1 ns time transfer uncertainty and to allow $10^{-18}$ frequency transfer accuracy over all distances