Actions and developments related to GNSS

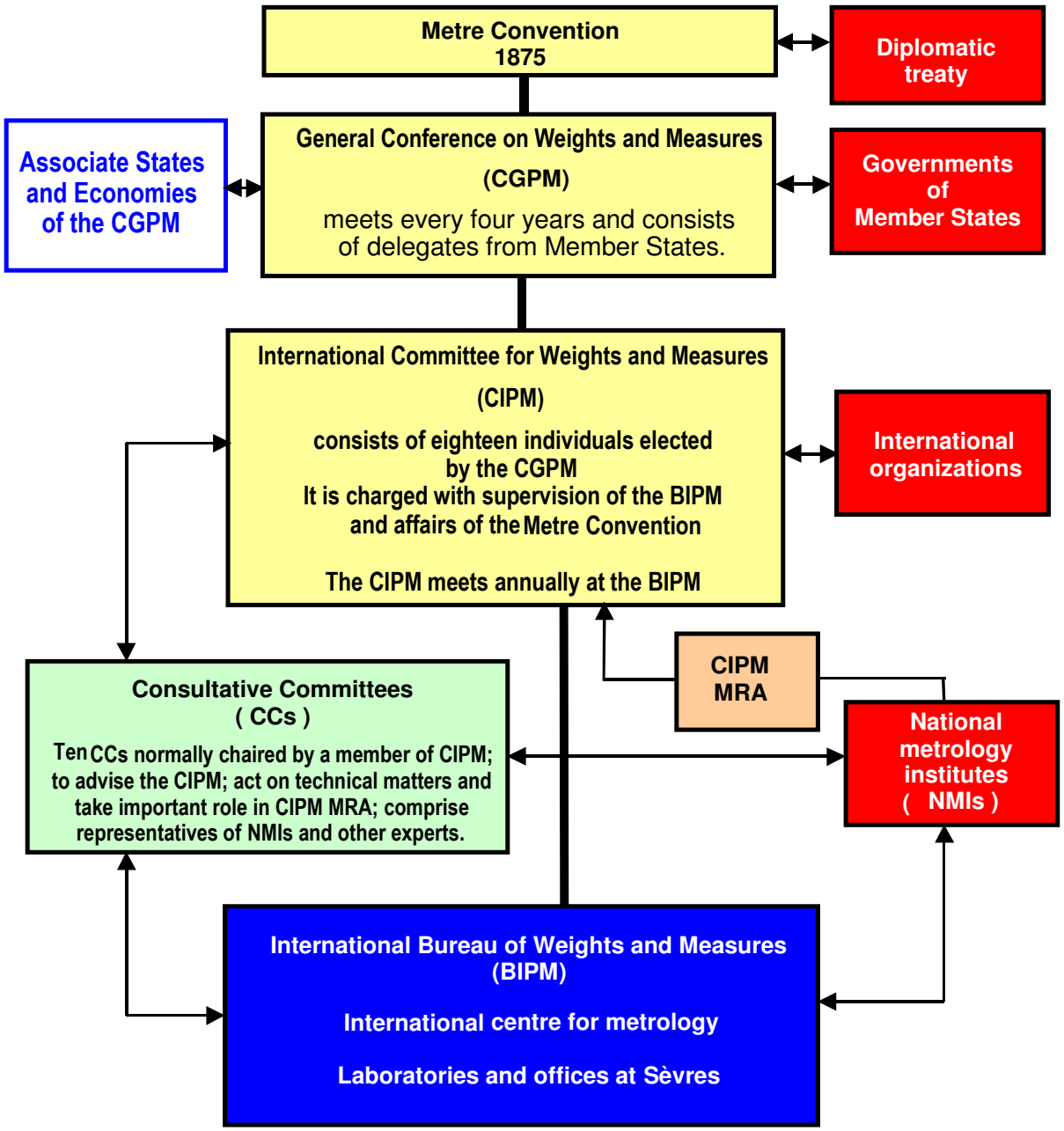
W. Lewandowski and E.F. Arias

Fourth Meeting of the ICG

14-18 September 2009 – St Petersburg, Russian Federation

Outline

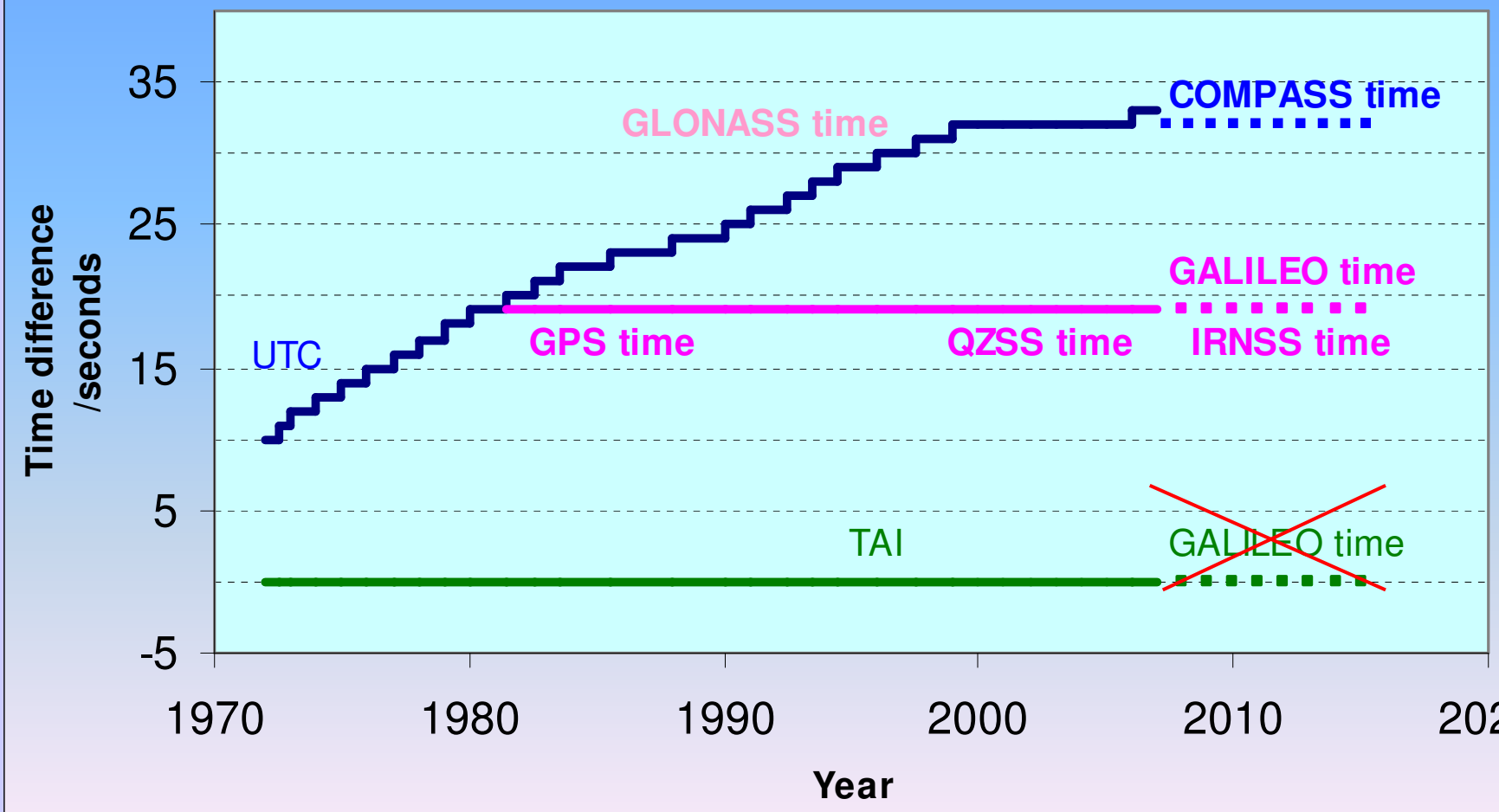
- Leap second of UTC
    - Recommendation 3, CCTF 2009
- Adoption of international references
    - Recommendation 5, CCTF 2009
- International Telecommunication Union (ITU)
    - Discussion and decision on a new definition of UTC at WP7A


Metre Convention
1875
Diplomatic treaty
Associate States and Economies of the CGPM
General Conference on Weights and Measures
(CGPM)
meets every four years and consists of delegates from Member States.
Governments of Member States
International Committee for Weights and Measures
(CIPM)
consists of eighteen individuals elected by the CGPM
It is charged with supervision of the BIPM and affairs of the Metre Convention
The CIPM meets annually at the BIPM
International organizations
CIPM MRA
Consultative Committees
(CCs)
Ten CCs normally chaired by a member of CIPM; to advise the CIPM; act on technical matters and take important role in CIPM MRA; comprise representatives of NMIs and other experts.
National metrology institutes
(NMIs)
International Bureau of Weights and Measures
(BIPM)
International centre for metrology
Laboratories and offices at Sèvres

Coordinated Universal Time (UTC)

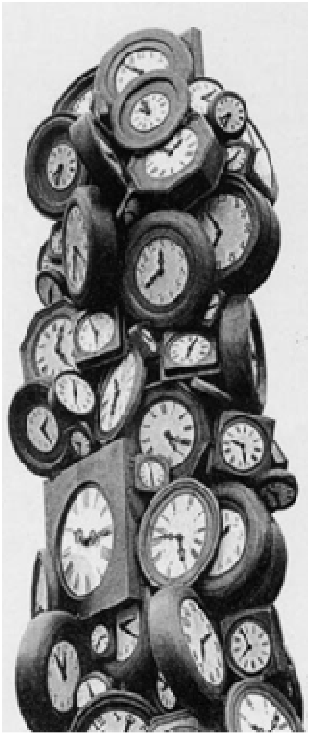
- UTC is computed monthly at the BIPM
- BIPM Circular T publishes [UTC-UTC(k)]
- TAI is based on the contribution of about 45 countries (about 350 clocks), it has only scientific applications, and is not represented by clocks
- Local realizations of UTC named UTC(k) are broadcast by time signals; they should approximate UTC better than 100 ns (recommended by CCTF)
- TAI and UTC differ in an integral number of seconds (34s today)
- UTC is the basis of legal times worldwide

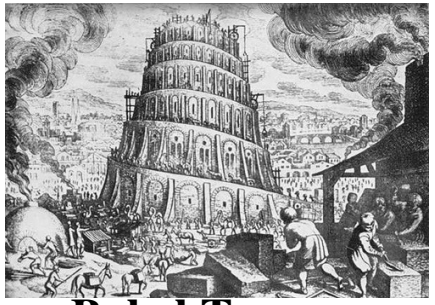
[*TAI - Time scale (i)*]



System times

- GPS time: steered to UTC(USNO) modulo 1s
  - ✓ [TAI – GPS time] = 19 s + C_0
  - ✓ [UTC -GPS time] = -15 s + C_0
  - ✓ $C_0 \leq 20$ ns
  - ✓ Tolerance is 1 μs
- GLONASS time: steered to UTC(SU) with leap second
  - ✓ [TAI – GLONASS time] = 34 s + C_1
  - ✓ [UTC – GLONASS time] = C_1
  - ✓ C_1 ~ some 100 ns
  - ✓ Tolerance is 1 ms
- Galileo time: steered to a set of EU UTC(k); using GPS time seconds, GGTO
  - ✓ [TAI – Galileo time] = 19 s + C_2
  - ✓ [UTC -Galileo time] = -15 s + C_2
  - ✓ Tolerance is 50 ns
- COMPASS time: will be steered to set of Chinese UTC(k)
  - ✓ [TAI –COMPASS time] = 33 s + C_3
  - ✓ [UTC -COMPASS time] = -1 s + C_3
  - ✓ Tolerance is 100 ns





Babel Tower

CCTF recommendation on the leap second (1)

RECOMMENDATION CCTF 3 (2009):
On the weakness of present definition of UTC

The Consultative Committee for Time and Frequency,

considering that

- The use of Coordinated Universal Time (UTC) as defined in 1972 is negatively affected by steps caused by the unpredictable insertion of an unpredictable number of leap seconds;
- This definition of UTC can not meet the requirements of many existing and future systems needing uniform time;
- Alternate time scales, not affected by leap seconds, are being developed and have started to proliferate;
- The need to represent the Earth's rotation angle in celestial reference systems for use in maritime celestial navigation is either no longer required or can easily be met through values of UT1-UTC as published by IERS;
- UT1 can fully satisfy needs related to the determination of Earth rotation angle;
- There must be sufficient lead time allowed for satellite and land based navigation system software developers to accommodate any change in the definition of UTC;
- Over the last ten years a number of national and international technical organizations have expressed increasing concerns about the present definition of UTC and the concomitant proliferation of alternate time scales.

CCTF recommendation on the leap second (2)

recommends that

National and international agencies and relevant scientific unions concerned with the definition of international time scales urgently consider decisions regarding the future definition of UTC so that international agreement can be reached as soon as possible.

modulo 1s

Fundamental for multiple GNSS interoperable

- Unique terrestrial reference system
  - ITRS, recommended by IAU, IUGG for application in space and Earth sciences
  - Access to ITRS is possible through its different realizations, ITRF (primary), WGS84, PZ-90, GTRF, CGS'2000, plus regional densifications
- Unique reference time scale for steering GNSS times
  - Independent from any GNSS time
  - Reliable, enjoying the highest metrological quality (frequency stability and accuracy)
  - UTC, as constructed by the BIPM on the basis of national metrology institutes contribution that maintain real-time approximations UTC(k)
  - Unique reference should be continuous

Recommendation CCTF 4 (2009) (1)

RECOMMENDATION CCTF 4 (2009):
Concerning adoption of a common terrestrial reference system by the CGPM

The Consultative Committee for Time and Frequency,

considering that

- there exists at present only a few global satellite navigation systems but that new ones are being created and in the future there may be many more,
- different time and geodesy reference systems, which are in use in these navigation systems, produce additional ambiguities for users regarding interpretation of navigation and timing solutions and render systems interoperability more difficult,
- although the international terrestrial reference system ITRS is recommended by relevant scientific unions, it has not yet been adopted by an intergovernmental organization,
- such an adoption by the appropriate intergovernmental organization would lead to more user convenience regarding unification of navigation and timing solutions and systems interoperability;

Recommendation CCTF 4 (2009) (2)

noting that

one of the key factors that led to the creation of the BIPM and the Metre Convention was the recommendation of the Second International Conference on Geodesy for the Measurement of Degrees in Europe held in Berlin in 1867 that a European international bureau of weights and measures be set up in order to unify European geodesy standards.

recommends that

after agreement with the relevant scientific unions, the Director of the BIPM formally discuss with the CIPM the steps so that the 24th CGPM be asked to adopt the ITRS, as defined by the IUGG and realized by the IERS and IGS, as the international standard for terrestrial reference frames used for all metrological applications.

Recommendation CCTF 5 (2009) (1)

RECOMMENDATION CCTF 5 (2009)
Alignment of Geodetic References and synchronization of Time References to international standards

The Consultative Committee for Time and Frequency,

considering that

- the International Terrestrial Reference System (ITRS) has been recommended by the International Astronomical Union (IAU) and the International Union of Geodesy and Geophysics (IUGG) for applications in space and Earth sciences,
- access to the ITRS is primarily achieved through the International Terrestrial Reference Frame (ITRF), and with an approximation ranging between 3 and 40 cm by WGS84, PZ-90, the Galileo Terrestrial Reference Frame (GTRF), the China Geodetic System 2000 (CGS'2000), and regional densifications,
- the time scale endorsed by the 15th General Conference of Weights and Measures (1975) for worldwide time coordination and dissemination is the Coordinated Universal Time (UTC),
- the BIPM provides coordination for the maintenance and dissemination of UTC,
- GPS time is steered to UTC (USNO) (modulo 1 s), GLONASS time is steered to UTC (SU). Galileo time will be steered to an ensemble of European realizations of UTC, keeping the seconds of the GPS time,
- the BIPM participates to the International Committee on GNSS (ICG) as observer;

Recommendation CCTF 5 (2009) (2)

aware that

- new global navigation satellite systems (GNSS) are being designed and developed,
- interoperability of the various GNSS would be facilitated by the adoption of international geodetic and time references in the various GNSS,
- civil and scientific activities worldwide need to refer to common internationally recognized geodetic and time references;

recognizes that

- the ICG is a unique structure to enable GNSS Service Providers to align their Geodetic and Time References to the ITRS and UTC for the operation of their systems;

recommends that

- the geodetic references for GNSSs be aligned as closely as possible to the ITRS,
- the internal System Times (ST) of GNSS be synchronized as closely as possible to UTC (modulo 1 s),
- the GNSS broadcast, in addition to their own ST:
  the time difference between the ST and a real-time realization of UTC,
  the time differences between various STs;

Recommendation CCTF 5 (2009) (3)

and

requests

- the BIPM to coordinate actions within the ICG for the accomplishment of this recommendation.

Conclusion

- All GNSS should provide UTC timing service
- Each GNSS system should align its navigation time scale to UTC
- All GNSS systems should align to a common geodetic reference frame (ITRF)
  - Recommendation CCTF 2009, requesting the BIPM to coordinate actions with the ICG for accomplishing with this recommendation
- Elimination of leap second would be helpful to GNSS
  - Recommendation CCTF 2009, requesting actions from organizations
- The two new proposed task forces in WGD will address these issues


THANK YOU!