Use and future development of UTC and impact on GNSS

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The Consultative Committee for Time and Frequency (CCTF) is currently concentrating on hot topics

that have an impact on

- time and frequency metrology,
- related research activity,
- technological complex systems as digital networks and GNSS
- everyday timekeeping accomplishments

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https://www.bipm.org/en/committees/cc/cctf

The four hot topics are

- **Updating the roadmap for the redefinition of second**
- **Leap seconds in UTC and building a consensus for a continuous timescale**
- **Promoting the mutual benefit of UTC and GNSS**
- **Sharing Resources and Capacity Building to Improve the International Timekeeping**

Task groups have been created in 2020 under the CCTF Strategic Planning WG coordination
A **survey** was carried out online to get the feedback from National Metrology Institutes, Liaisons, and Stakeholders. More than 200 answers were received

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Leap seconds in UTC and building a consensus for a continuous timescale

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Coordinated Universal Time UTC is kept in agreement with the rotational angle of the Earth UT1 by the insertion of leap seconds

UTC is obtained from the International Atomic Time (TAI) plus leap seconds.

When the difference between the Earth rotational angle UT1 time scale and UTC reaches a 0.9 second, an integer second is inserted to UTC to keep it within 1 s of UT1.

|UTC - UT1| < 1 second

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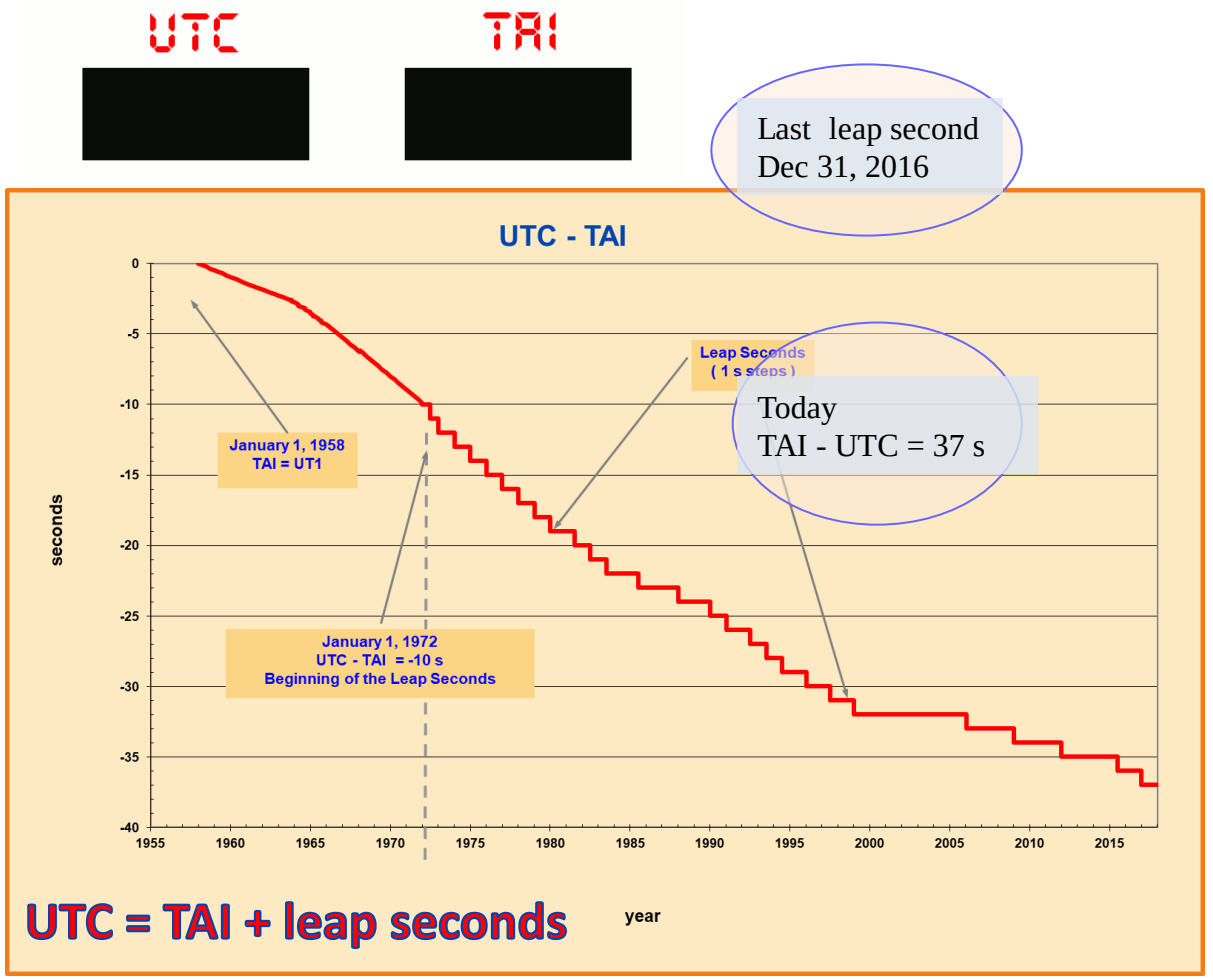


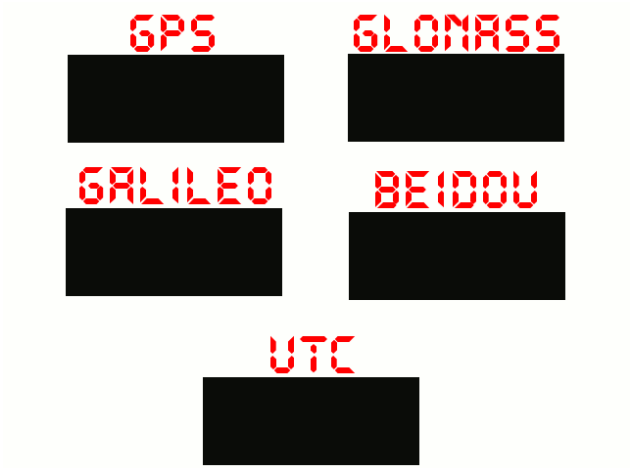
The digital networks cannot cope with the leap second

Time travels on the network

Computer operating systems are not easily able to handle a minute with 61 seconds

Different methods: Time in GNSS

Navigation using GNSS signals prefers a continuous time scale, and the GNSS system time does not use leap seconds (except GLONASS which applies leap seconds). These time scales are easily available all over the world, are commonly used as time and frequency references, and differ from each other and from UTC by several seconds



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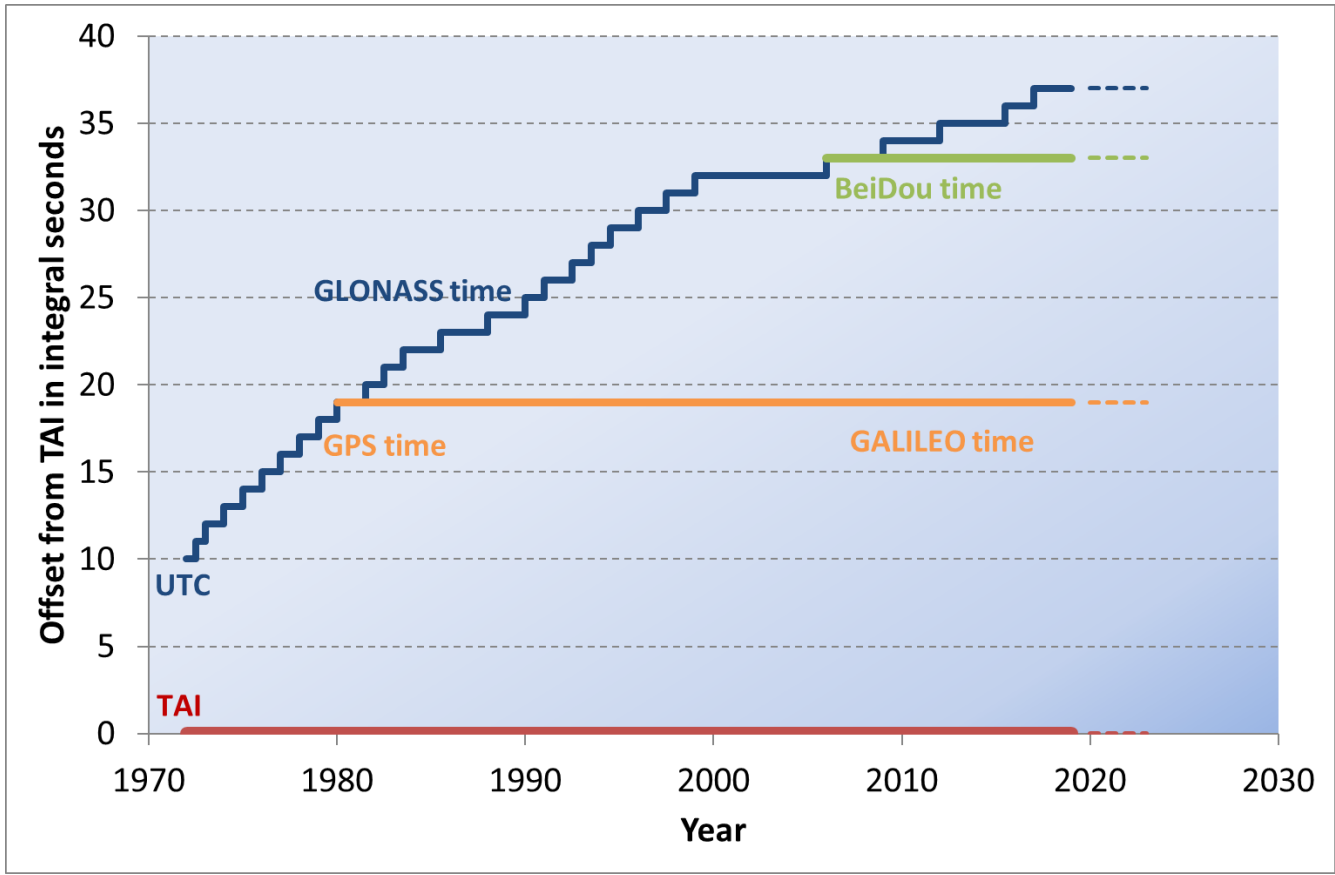


Different “methods” have been adopted

- Ignore leap seconds after an initial synchronization
  - GPS, Galileo, BeiDou system times.
  - Most current versions of Windows
    - Error persists until next calibration
- Stop clock for 2 seconds at 23:59:59 or 00:00:00
  - Network Time Protocol, Posix time on many computers
  - Two seconds have same name
  - Problems with causality, time ordering, time intervals
  - Leap second has no indicator
- Reduce frequency of clock over some interval
  - Google (24 h before), Microsoft, Facebook (18 h after), Alibaba (12 h before – 12 h after) …

All of these methods are not in agreement with UTC on the leap second day, and many disagree with each other

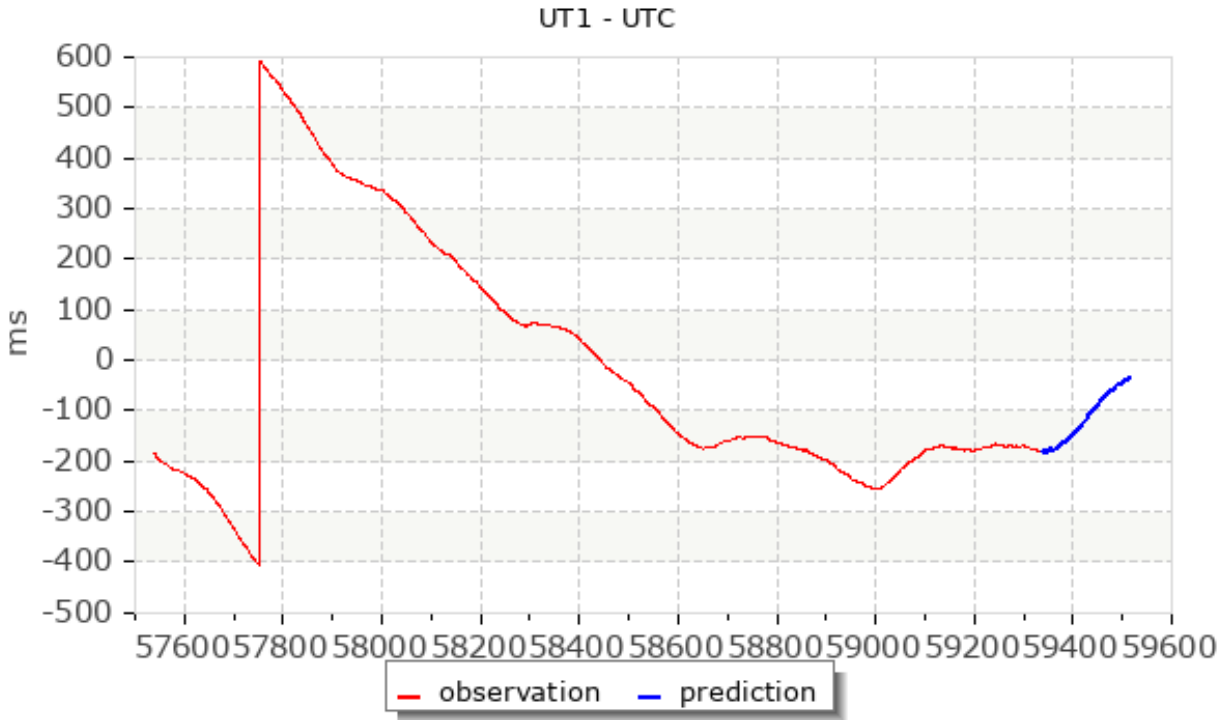
Users cannot tell which method is used by a time source, especially a posteriori

Leap second and the alternative methods threatens the resilience of the synchronization that underpin critical national infrastructures

The outcome

- UTC with leap seconds does not satisfy requirements of many applications
- Several different methods have been implemented and are proposed as international standards
- Solutions are not universal and different methods are not compatible with UTC or with each other
- UTC is becoming less relevant and less useful
- Risk of large-scale problems due to incorrect synchronization of systems

The recent acceleration of the Earth rotation may lead to a negative leap second, for the first time, never happened, never tested



https://eoc.obspm.fr/index.php?index=realtime&lang=en

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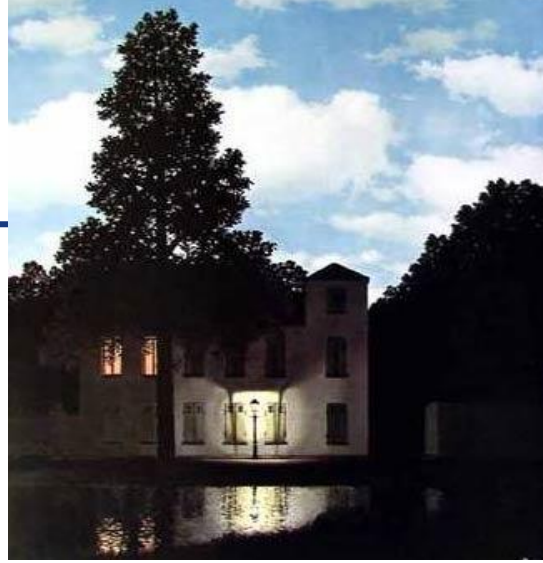
A Possible Solution discussed at CCTF



Increase tolerance of |UT1 - UTC|

- If limit of |UT1 - UTC| < 100 or XXX (indefinite) seconds
  - No leap seconds for a century or more at current rate of increase
  - Tolerance could be one hour (change of time zone)
- UTC remains linked to UT1, the Earth's rotation angle, the origin is the reference meridian of Greenwich
- UTC is approximately UT1 within the 15 min of seasonal day variation for centuries. For the general public this is a "no event"
- UTC supports the digital systems and the operations of complex systems as GNSS

- Limit the risk of incidents due to discontinuities or multiple time scales

Users of UT1 (Earth rotation angle) need precise information

- IERS and NASA web sites publish UT1-UTC with microsecond uncertainty
- GNSSs, possibly with some update, will still disseminate UT1-UTC

From first survey it seems that in the navigation messages:

- Most of the GNSS and RNSS have bits for |UT1-UTC|< 64 seconds
- GLONASS process of modernization includes |UT1-UTC|< 256 seconds

- Is UTC ~ UT1 needed in same GNSS operations?

CCTF is proposing to apply the new limit in 2035 and to find an agreement on the new limit (finite or infinite) by 2026 in collaboration with all the impacted Organizations

The ITU World Radio Conference meets in 2023 and a report on the UTC to better serving the users is expected

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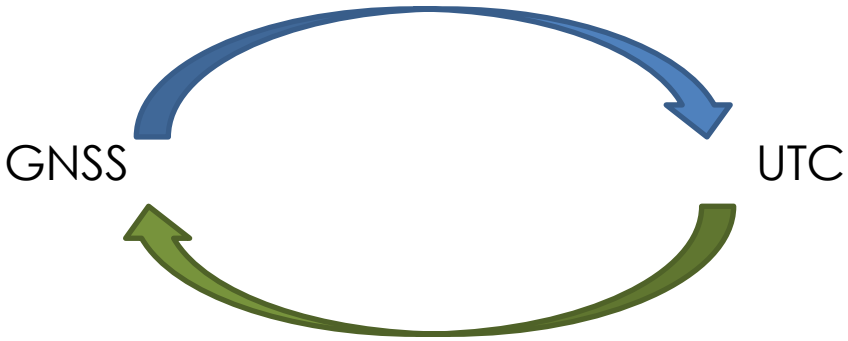
Promoting the mutual benefit of UTC and GNSS

1. Current use of GNSS for UTC
2. Calibration for GNSS hardware delays



1. UTC is disseminated by GNSS with the contribution of national metrological laboratories
2. Users may need traceability to UTC from GNSS measurements
3. UTC can help Interoperability (discussion at the ICG)

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GNSS **Interoperability**

From GNSS1 : ($t_{receiver} - t_{GNSS1}$)

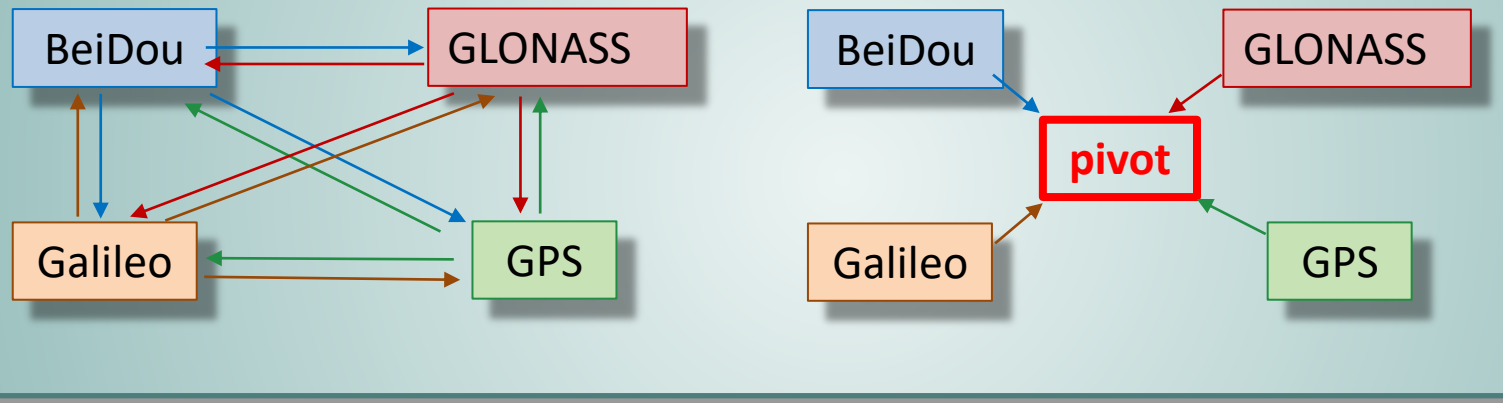
From GNSS2 : ($t_{receiver} - t_{GNSS2}$)

for combination : the user needs ($t_{GNSS1} - t_{GNSS2}$)

Inter-system bias

The intersystem bias, GNSS-to -GNSS Time offset can be:

1. Estimated by the user with an additional observation
2. Broadcast by the GNSS



<u>Discussion at the International Committee on GNSS</u>:
Each system can provide all GNSS-to-GNSS Time Offsets.
For simplicity, an intermediate pivot time scale could be used and each GNSS broadcasts only GNSS-pivot

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This Pivot could be
- one of the GNSST
- a new time scale devoted to this aim
- the broadcast_UTC_{GNSS} (each systems already provides its GNSST- Broadcast_UTC_{GNSS})

Recent research show that, for a ground user:

-*Performances of using Broadcast_UTC_{GNSS} as pivot*: Max 20 ns error on inter-system bias so-obtained, because of differences in Broadcast_UTC_{GNSS} (can be improved

-*Impact of an error on the inter-system bias from broadcast information*: For mass-market receiver, an error of 20 ns has no impact on positioning/timing

Sesia *et al. GPS Solut* **25,** 61 (2021)
Defraigne *et al. GPS Solut* **25,** 2 (2021)

See presentation on Wednesday
Joint WG S + D

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The need of deep space users may lead to different requirements

CCFT in 2021

recommends that
GNSS providers consider the benefit of using the predictions of (UTC-GNSStime) as reference for broadcasting the inter-system biases, which avoids the need to create an ad-hoc common reference time scale,
GNSS providers continue their efforts to improve the prediction of (UTC-GNSStime) with the help of time laboratories,
and further recommends that
Multi-GNSS receiver manufacturers explore the possibility to obtain the GNSS inter-system biases from these predictions of (UTC-GNSStime),
The International Committee on GNSS of United Nations supports this recommendation.

Thank you

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